Maryland Department of the Environment

OCTOBER 2025

ADVANCED CLEAN TRUCKS ACT

NEEDS ASSESSMENT AND DEPLOYMENT PLAN

EV ADVISORS ATLAS PUBLIC POLICY EVNOIRE UNIVERSITY OF MARYLAND CENTER FOR GLOBAL SUSTAINABILITY

October 2025

This report was developed through a collaboration between EV Advisors, LLC, Atlas Public Policy, EVNoire, and the Center for Global Sustainability (CGS) at the University of Maryland. A complete author list by report section is provided below.

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Suggested Citation

Krauthamer, M. I.; Sharpe, B.; Washburn, L.; Blomqvist, A.; Kennedy, K. M.; Lou, J.; Baad, A.; Brunell, C.; Buddi, B.; Di Filippo, J.; Foster, M.; Francis, S.; Hayes, M.; Kuna, J.; Kumar, H.; Leser, K.; Lu, K.; McKenzie, L.; O'Keefe, K.; Stein, S.; Vo, S.; Wilkins, D.; Zhao, A. Advanced Clean Trucks: Needs Assessment and Deployment Plan for Maryland; EV Advisors, LLC; Atlas Public Policy; EVNoire; Center for Global Sustainability, University of Maryland, 2025; p 202.

Acknowledgements

The author team would like to thank the several stakeholders and state agencies that provided insights for this report. Any conclusions stated in the report are those of the author team and do not necessarily reflect those of any interviewed stakeholder or state agency. Funding for this report was provided by the Maryland Department of the Environment. Cover photo provided courtesy of Volvo Trucks North America.

Acronyms

AC	Alternating Current
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
AFDC	Alternative Fuels Data Center
AFIP	Alternative Fuel Infrastructure Program
AFIR	Alternative Fuels Infrastructure Regulation
AHJ	Authority Having Jurisdiction
ATB	Annual Technology Baseline
B20	20% Biodiesel Blend
BEV	Battery Electric Vehicle
BGE	Baltimore Gas & Electric Company
BOACs	Billing Office Address Codes
C3	Clean Corridor Coalition
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CALeVIP	California Electric Vehicle Infrastructure Project
CARB	California Air Resources Board
CBE	Cab Behind Engine
CEVA	Corporate Electric Vehicle Alliance
CFI	Charging and Fueling Infrastructure Discretionary Grant Program
CFO	Chief Financial Officers
CGS	Center for Global Sustainability
CI	Carbon Intensity
CMAQ	Congestion Mitigation and Air Quality
CNG	Compressed Natural Gas
COE	Cab Over Engine
CONUS	Continental United States
CPCFA	California Pollution Control Financing Authority
CPRG	Climate Pollution Reduction Grant

CPUC	California Public Utilities Commission
CSNA	Climate Solutions Now Act of 2022
CRA	Congressional Review Act
DBM	Department of Budget and Management
DC	Direct Current
DCFC	Direct Current Fast Charging
DEEP	Decarbonization, Electrification, and Economic Planning
DGS	Department of General Services
DNR	Department of Natural Resources
DOT	Department of Transportation
DSM	Demand Side Management
E85	85% Ethanol Blend
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAST	Federal Automotive Statistical Tool
FEMP	Federal Energy Management Program
FCEV	Fuel Cell Electric Vehicle
GCAM-USA	Global Change Analysis Model - USA
GHG	Greenhouse Gas
GSA	General Services Administration
GVWR	Gross Vehicle Weight Rating
GWh	Gigawatt-hour
HEV	Hybrid Electric Vehicle
HOV	High-Occupancy Vehicle
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
ICCT	International Council on Clean Transportation
iMHZEV	Incentives for Medium- and Heavy-Duty Zero-Emission
INSITE	Investment Needs of State Infrastructure for Transp. Electrification
kVA	Kilovolt-amperes
kW	Kilowatts
LADOT	The Los Angeles Department of Transportation
LCFS	Low Carbon Fuel Standard
LD	Light- Duty
LDVs	Light- Duty Vehicles
LNG	Liquified Natural Gas
LPG	Propane
MCDOT	Montgomery County Department of Transportation
MCPS	Montgomery County Public Schools

MDE	Maryland Department of the Environment
MDOT	Maryland Department of Transportation
MEA	Maryland Energy Administration
MHD	Medium- and Heavy-Duty
MHDV	Medium- and Heavy-Duty Vehicle
MSEC	Maryland Smart Energy Communities
MTA	Maryland Transit Administration
MVA	Maryland Motor Vehicles Administration
MW	Megawatt
NEVI	National Electric Vehicle Infrastructure Program
NHTSA	National Highway Traffic Safety Administration
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
NYSDEC	New York State Department of Environmental Conservation
NWS	Non-wires Solutions
OEM	Original Equipment Manufacturer
PACT	Powering America's Commercial Transportation
PBOT	Portland Bureau of Transportation
PHEV	Plug-in Hybrid Electric Vehicle
PSC	Public Service Commission
R20	Renewable Diesel
RGGI	Regional Greenhouse Gas Initiative
ROW	Right-of-Way
SCADA	Supervisory Control and Data Acquisition
SEIF	Strategic Energy Investment Fund
SHA	State Highway Administration
SIN	Special Item Number
SMECO	Southern Maryland Electric Cooperative
SoC	State-of-Charge
TCO	Total Cost of Ownership
V2G	Vehicle-to-Grid
VIN	Vehicle Identification Number
VMT	Vehicle Miles Traveled
VW	Volkswagen
ZEDZ	Zero-Emission Delivery Zone
ZPAC	Zero-Emission Vehicle Planning and Charging
ZEV	Zero-Emission Vehicle

Foreword by Secretary Serena McIlwain

I am proud to present to the Maryland General Assembly the *Needs Assessment and Deployment Plan for the Clean Trucks Act of* 2023. This report represents more than a technical analysis—it is a strategic blueprint for a key part of Maryland's clean transportation future. It is grounded in data, shaped by stakeholder engagement, and driven by our commitment to economic growth, environmental justice, and public health.

Maryland has long led with pragmatism and purpose on climate action. Indeed, this fall the U.S. Energy Information Administration declared that Maryland was first among all U.S. states in reducing greenhouse gas emissions by nearly 50% over the last 18 years. The Clean Trucks Act of 2023 reflects that leadership and continued commitment by requiring a growing share of medium- and heavy-duty vehicle (MHDV) sales to be low- and zero-emission. In doing so, it positions our state to reduce harmful diesel pollution, protect vulnerable communities, and accelerate the transition to a clean energy economy.

We acknowledge, however, that national policy and economic shifts have an impact on Maryland's implementation of the clean trucks program. Earlier this year, the Federal government revoked the Clean Air Act waiver that enabled Maryland and other states to set these ambitious targets, creating profound legal uncertainty around state implementation of advanced vehicle regulations. Recent federal legislation canceled billions of dollars in incentives for consumers, states, automakers, battery manufacturers, and infrastructure developers that were accelerating this transition. Those factors, alongside real implementation questions, created uncertainty, which is why Governor Moore issued an executive order this April, pausing enforcement of the Clean Truck Act for the next two years, and until after the publication of this assessment.

Maryland's direction and determination are unchanged. Maryland remains firmly committed to reducing emissions from the transportation sector—the largest contributor to air and climate pollution in our state. Governor Moore continues to invest in this transition, devoting millions of dollars per year from Maryland's Strategic Energy Investment Fund. This report was developed using the original targets and timelines of the Clean Trucks Act as a foundation. While that schedule and targets of implementation remain uncertain, it still provides an essential, durable resource—regardless of how specific policies evolve. It identifies the infrastructure, policy, and investment priorities that can guide both public and private decision-making, helping us target resources where they will deliver the greatest impact.

The benefits of electrifying MHDVs are clear. Businesses stand to gain from lower fuel and maintenance costs, improved fleet performance, and leadership in a growing clean vehicle market. Marylanders stand to gain much, too: cleaner air, healthier communities, and reduced climate pollution. Electrifying state and private fleets—especially vehicles with fixed routes and regular downtimes, such as school buses, trash trucks, and delivery vans—offers immediate opportunities for progress.

Most importantly, this plan is a call to action. Achieving a clean transportation future will require coordination, innovation, and resolve. The Maryland Department of the Environment is committed to working with our partners across government, industry, and communities to seize this moment—and ensure a cleaner, healthier, and more equitable future for all Marylanders.

Sincerely,

Serena McIlwain
Secretary, Maryland Department of the Environment

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Executive Summary and Key Findings

The Clean Trucks Act of 2023 requires the Maryland Department of the Environment (MDE) to adopt regulations implementing the California Advanced Clean Trucks (ACT) regulation.[a] Maryland took this step as part of its efforts to reduce greenhouse gas (GHG) emissions and air pollutants from the transportation sector, which is the largest source of emissions in the state.

This report quantifies charging infrastructure needs and electrical grid impacts associated with implementing the ACT regulation as written through 2035 and also shows an illustrative pathway to reach 100% ZEV sales for new medium- and heavy-duty vehicles (MHDVs) by 2050. It identifies incentive pathways and sources of funding, analyzes the feasibility of transitioning the state fleet, and determines actors and use cases that are most likely to lead the transition to zero-emission vehicles (ZEVs) in the near-term.

The medium- and heavy-duty ZEV market today is in its infancy, with relatively few vehicles on the market. We expect demand to increase as manufacturers bring more vehicles to the market, and as technological advances reduce vehicle prices and improve ZEV capabilities. At present the ACT only regulates the supply of vehicles, leaving Maryland without a complementary requirement for customers to buy ZEVs.

Key findings

Chapter 1
Zero-Emission Vehicle Fueling Infrastructure Needs

- Maryland's MHDV fleet is dominated by Class 2b-3 vehicles, which account for nearly 70% of the total population (approximately 134,000 out of 195,000 vehicles).
- Class 2b-3 vehicles will transition most rapidly, reflecting their large baseline population, relatively mature electric technology, and charging infrastructure availability.
- Nearly all Class 2b-3 vehicles can charge using relatively inexpensive alternating current (AC) (commonly referred to as "Level 2") charging at a depot or home. The most expensive

[a] Federal action rescinding the waiver granting regulatory authority to the states has caused significant uncertainty about the future of this policy. Therefore, this report also provides many recommendations that could be pursued even without the ACT in place. These actions enable Maryland to continue making progress toward adoption of zero-emission medium- and heavy-duty vehicles (MHDVs) and its greenhouse gas reduction goals.

charging infrastructure, 150 kW direct current (DC) and higher, is needed primarily by Class 7 and 8 vehicles with shorter dwell times.

- Class 2b-3 vehicles will need a cumulative 23,600 Level 2 charging ports at homes and depots by 2035. For reference, the majority of Maryland's over 120,000 existing light-duty EVs are charged primarily at a Level 2 home charger.

- Class 4-8 straight trucks will require a cumulative 15,800 charging ports at depots by 2035 to meet ACT requirements: 12,800 Level 2 ports, plus 3,000 DC fast charging ports.

- Long-haul trucks will rely on enroute charging, and other vehicle segments will also require enroute charging support. We model roughly 900 cumulative enroute charging ports (exclusively high-power DC fast charging) needed by 2035 to support ACT implementation. This represents a nameplate charger capacity of approximately 370 MW in 2035. For comparison, public fast chargers built in Maryland to date (primarily for light-duty vehicles) total 230 MW, 69% of which opened in the last three years (2022 or later). Importantly, these charger nameplate capacities measure the sum of individual charger maximum power ratings but do not reflect the equipment's actual peak combined usage or grid impacts (investigated in Chapter 2).

Chapter 2
Electrical Grid Impacts

- Multiple studies emphasize that electric distribution network constraints, particularly along freight corridors and at depot locations, represent the primary grid infrastructure challenge from electric vehicles, rather than generation or transmission capacity.

- Longer term, PJM Interconnection is forecasting potential transmission and generation constraints if large data center loads materialize. However, we estimate that electric MHDVs' contributions to these bulk power system constraints will be relatively small. Also, MHDV electrification represents "beneficial electrification" that reduces particulate and greenhouse gas emissions from Maryland's transportation system as electric vehicles replace internal combustion vehicles.

- Implementing the ACT regulation is estimated to result in a roughly 2.6% increase in total statewide electricity consumption by 2035. The increase in peak electricity load due to commercial vehicle charging would be between 1.1% and 1.5% in 2035 (with the range depending on fleets' ability to manage their charging away from system peak). This represents an average increase of 0.1% per year in peak load, compared with the Maryland Public Service Commission's forecast of 1.3% annual growth in the state's summer peak load through 2033.

- Depot charging is expected to dominate medium- and heavy-duty EVs' load profile, consistent with data from the Federal Highway Administration's Vehicle in Use Survey that indicates most vehicles (excluding long-haul) return to a home base on a daily basis. Long-haul Class 7-8 tractors also see significant needs as they ramp up later in the ACT regulation, reflecting their long-distance routes and high energy demands.

- Maryland could consider a number of solutions to reduce delays in energizing MHDV sites and overcome distribution system constraints, including long-term distribution infrastructure planning, streamlined processes at utilities, flexible interconnection solutions, and hosting capacity maps.

- The cumulative investment needed for charging equipment, installation, and utility make-ready in our Base ACT Scenario is $805 million (in 2025 dollars) by 2035. Depot charging sees the biggest investment need ($402 million cumulative investment by 2035), followed closely by enroute charging ($349 million). Home charging requires the least investment ($54 million). This represents total investment across all parties: private sector, utilities, and government, and should be balanced against the significant benefits brought by the transition to zero-emission transportation.

- We model hydrogen vehicle uptake limited to the long-haul tractor truck segment and starting in 2036 (after ACT) as one option to meet 100% ZEV sales by 2050. Under these assumptions, there would be roughly 2,000 hydrogen trucks that require roughly 15,000 metric tons of fuel annually by 2050. This would require cumulative investment of $160 million across private and public sectors to support a network of 11 hydrogen stations located along highway corridors in the state. Policymakers and planners should continue to monitor battery electric and hydrogen vehicle technologies and costs as this timeframe approaches.

Chapter 3
Current Incentives and Funding Pathways

- A combination of financial incentives and policy mechanisms is necessary to accelerate electric MHD vehicle purchases and charging infrastructure installation (infrastructure being a prerequisite to purchasing battery electric vehicles, or BEVs).

- Sufficient and stable funding is critical to sending the signal that MHDV electrification is a priority, and to providing the private sector with the reliability and consistency it needs to make multi-year commercial decisions. Programs which run out of funds and result in waiting lists are not an effective long-term solution.

- Point-of-sale or otherwise guaranteed financial incentives for vehicles and infrastructure that are available on a continual and open-ended basis are more impactful and more likely to lead to greater and consistent vehicle and infrastructure adoption compared to post-purchase and tax incentives. Incentives should focus on covering the cost difference between internal combustion vehicles and ZEVs.

- Additional outreach, educational, and training programs should be created to help showcase the benefits of transitioning to electric vehicles; highlight successes and recognize early adopters; and help get agencies and staff ready for the transition to electric vehicles.
- Even sophisticated entities experience surprises in adopting EVs, particularly MHD EVs. A portfolio of fleet advisory services would ease the learning curve and mitigate mistakes.

Chapter 4
Transitioning State-Owned Vehicles to Zero Emissions

- Thirty percent (1,679 vehicles) of Maryland's state-owned vehicle fleet have an identical BEV replacement (primarily transit buses, which are not covered by the ACT), while 34% (1,891 vehicles) have a similar BEV replacement. Vehicles without a clear replacement will need to be reassessed in future years as the MHD market develops.
- It would cost the state an additional $18 million to replace all exact BEV-replaceable ACT compliant vehicles between 2027 and 2035 (BEV-replaceable refers to a vehicle's technical specifications and not necessarily the duty cycle requirements which could prevent a BEV from being adopted). This number includes a total of 242 vehicles; 191 Class 2b-3 trucks, 9 Class 4-8 trucks, and 42 Class 7-8 tractors. Eighty-eight of these vehicles will be eligible for BEV replacement in 2027, the first year of the program.
- The state can enhance its efforts to electrify its MHD fleet by expanding the process that the Department of Budget and Management (DBM) currently performs with light-duty vehicles to include MHD vehicles. Under this process, every new light-duty vehicle request is reviewed to determine whether a suitable zero-emission version is available. Including MHD vehicles would provide the market knowledge to individual agencies and require a justification for when a zero-emission vehicle is not selected.
- Electrification of the entire state fleet represented in the data set would lead to a reduction of 1.27 million tons of CO_2 emissions annually. The total emissions reduction of all BEV-identical replacement vehicles is 131,000 tons of CO_2, including 7,000 tons for ACT-compliant BEV-identical vehicles.

Chapter 5
Early Adopters and Industry Trends

- Vehicles that run short, fixed, and predictable routes that have regular downtimes are the best fit for early electrification, including Class 8 trash trucks, Class 7 school buses, Class 3-8 straight trucks for regional line-haul, and Class 2b-3 vans for local delivery.
- Potential first movers that could act as early adopters for certain types of BEVs include utility services, large logistics companies, local governments, certain state agencies, school systems, and regional line-haul trucking.

Recommendations

Maryland can take several steps to support achievement of the ACT's requirements, including the following:

- Designate a stable funding source for vehicle purchase incentives and charging infrastructure deployment. This funding source could take the form of a Clean Fuels Standard, such as those adopted in New Mexico, California, Oregon, and Washington, or other dedicated funding pathways previously proposed in the state's Climate Pollution Reduction Plan.
- Coordinate with surrounding states and the District of Columbia to mitigate buyers circumventing the ACT requirements by buying vehicles out-of-state, and to enable integrated charging networks that can support interstate travel.
- Lead by example through electrification of government-owned vehicles.
- Convene complementary industry stakeholders along the supply chain from manufacturers and dealers to logistics companies and corporate shipping clients to maximize utilization of BEVs and charging infrastructure.
- Offer fleet advisory services, potentially through or in conjunction with electric utilities with the approval of the Public Service Commission, or via a state agency. Examples of such services include a charging needs assessment and site evaluation, vehicle replacement analysis, total cost of ownership analysis, and workforce training.

Background and Introduction

Maryland has some of the most ambitious state-level greenhouse gas (GHG) reduction goals in the nation, established in the Climate Solutions Now Act of 2022 (CSNA).[1] The CSNA sets a target of reducing gross GHG emissions by 60% by 2031 relative to a 2006 baseline, and reaching net-zero GHG emissions by 2045. A critical part of meeting these goals will be reducing emissions from the transportation sector, which is currently the largest contributor to Maryland's emissions. To promote a reduction of these emissions, Maryland passed the Clean Trucks Act of 2023,[2] which requires the state to adopt the California Advanced Clean Trucks (ACT) regulations and to produce a study assessing the readiness of vehicles and charging infrastructure within the state.

Under the ACT regulation, manufacturers of medium- and heavy-duty vehicles (i.e., those vehicles with a gross vehicle weight of 8,501 or more, also known as Class 2b through 8 vehicles) must meet zero-emission vehicle (ZEV) sales requirements beginning with the 2027 model year. Because manufacturers generally do not sell directly to customers, the practical burden of compliance falls primarily on truck dealers located in Maryland. These requirements gradually increase through the 2035 model year and vary by vehicle weight class. There is no corresponding requirement on buyers to purchase ZEVs.

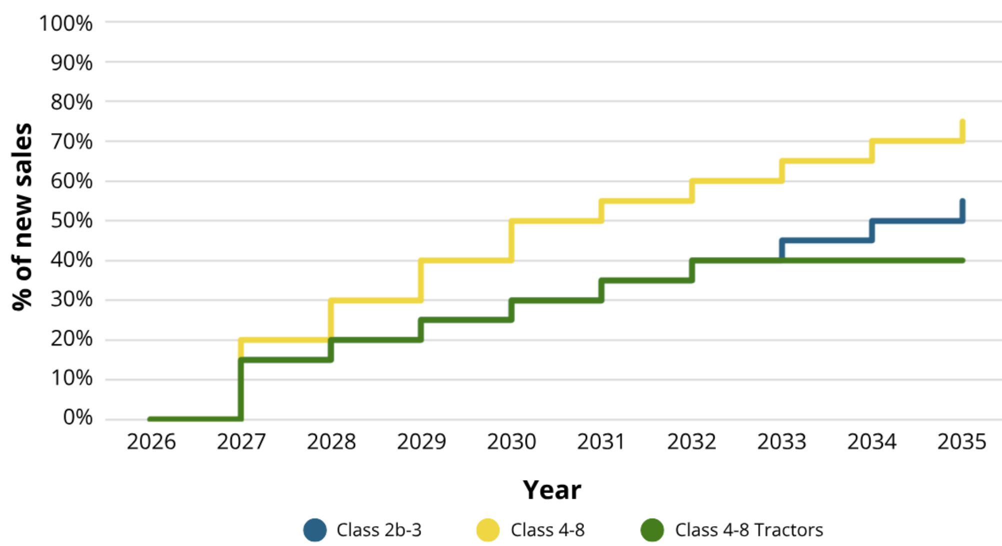

Figure 1. Zero-emissions vehicles sales requirements by vehicle category under the ACT.

California derives its authority to enforce certain air quality regulations which are more restrictive than federal standards, including the ACT rule, through a waiver process established in the Clean Air Act.[3] Other states are permitted, in accordance with Section 177 of the Clean Air Act, to adopt California's standards by reference; these are referred to as "Section 177 states." In June 2025, the federal government used the Congressional Review Act (CRA) to revoke waivers previously granted to California by the U.S. Environmental

Protection Agency (EPA).[4] Without a waiver from the EPA for the ACT in place, California and Section 177 states are prohibited under the Clean Air Act's preemption clause from adopting or enforcing their own emission standards for MHD motor vehicles.[3]

California and 10 other states are challenging the federal government's actions, arguing that the CRA was improperly used to invalidate the waivers, which they contend are "orders" and not "rules" subject to the CRA.[5] The U.S. Department of Justice, in turn, has filed two complaints against the California Air Resources Board (CARB), arguing that the state is attempting to illegally enforce preempted emissions standards.[6]

Separately, Governor Wes Moore has issued an executive order instructing the Maryland Department of the Environment (MDE) to exercise enforcement discretion to decline to pursue penalties under the ACT for model year 2027, and further for model year 2028 unless a Needs Assessment and Deployment Plan is published by December 1, 2025.[7]

This report provides the required needs assessment and deployment plan, with analysis of the readiness of vehicles and charging infrastructure to ensure the successful achievement of the ACT targets in Maryland. Each chapter analyzes key aspects of what is needed to attain these goals, as directed by the Clean Trucks Act:

> **Chapter 1**: The number of zero-emission medium- and heavy-duty vehicle recharging and refueling stations recommended for implementation of the ACT regulation, and the associated costs and timelines for installing those stations.
>
> **Chapter 2**: The projected electrical grid impacts from ACT implementation, including modest increases in statewide electricity consumption and peak loads, as well as stakeholder perspectives on infrastructure deployment challenges and timelines.
>
> **Chapter 3**: The purchase incentives and other mechanisms recommended for successful implementation of the ACT regulation, including incentives for recharging and refueling stations and related infrastructure, and the existing and potential sources of funding for those incentives and mechanisms.
>
> **Chapter 4**: The timeline, economic feasibility, and models available for transitioning MHD vehicles in the state vehicle fleet, including state-contracted MHD vehicles, to ZEVs.
>
> **Chapter 5**: The industries in the state that have MHD fleets which are likely to transition to ZEVs earliest, and the potential costs incurred by those fleets.

The report concludes with a set of recommendations on actions Maryland can take to support achievement of the ACT regulation targets. Importantly, many of these actions could be taken to support MHD ZEV deployment even if the ACT regulations are not able to be enforced.

Chapter 1: Zero-Emission Vehicle Fueling Infrastructure Needs

Authors: Ben Sharpe, James Di Filippo, Himangshu Kumar, Lucy McKenzie, John Kuna

Chapter at a Glance:

- Maryland's MHDV fleet is dominated by Class 2b-3 vehicles, which account for nearly 70% of the total registered vehicle population (approximately 134,000 out of 195,000 vehicles).
- Class 2b-3 vehicles will need a cumulative of nearly 23,600 Level 2 charging ports at homes and depots by 2035 to meet ACT. For reference, the majority of Maryland's over 120,000 existing light-duty EVs are charged primarily at a Level 2 home charger.
- Class 4-8 straight trucks will require a cumulative 15,800 charging ports at depots by 2035 to meet ACT: 12,800 Level 2 ports, plus 3,000 DC fast charging ports.
- Long-haul trucks will rely on enroute charging, and other vehicle segments will also require enroute charging support. We model roughly 900 cumulative enroute charging ports needed by 2035 to support ACT implementation. This represents nameplate charger capacity of approximately 370 MW in 2035. For reference, public fast chargers built in Maryland to date (which have primarily been built for light-duty vehicles) total 240 MW in nameplate capacity. Note that these charger nameplate capacities measure the sum of individual equipment's power ratings but do not reflect the equipment's actual peak combined usage or grid impacts

Introduction

In this chapter, we estimate the number of zero-emission medium- and heavy-duty vehicles (MHDVs) required to comply with Maryland's ACT regulation between 2027 and 2035, as well as a continued adoption trajectory that achieves 100% zero-emission sales by 2050. We then assess the charging and hydrogen refueling infrastructure needed to support this transition.

As shown in Figure 1.1, our analysis employs a six-step methodology that integrates baseline fleet inventory development, vehicle categorization, stock turnover modeling, charging needs analysis, long-haul infrastructure assessment, and deployment timeline estimation.

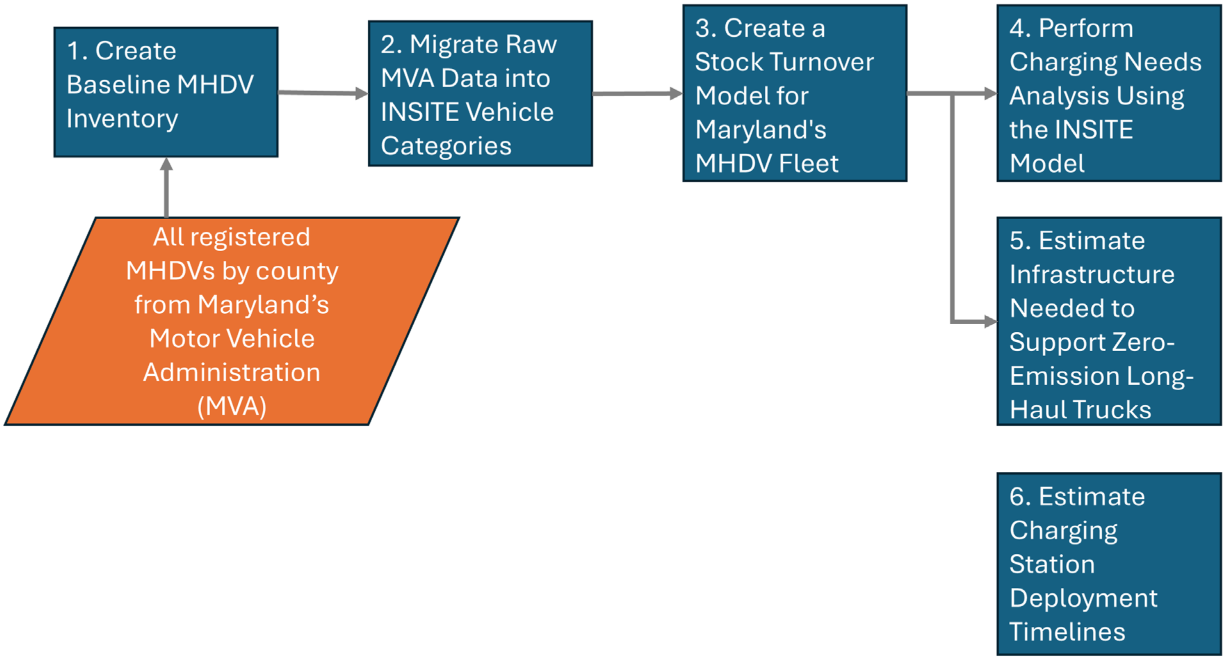

Figure 1.1. Overview of Fleet and Charging Infrastructure Needs Modeling Methodology

The methodology begins with creating a comprehensive baseline MHDV inventory using data from the Maryland Motor Vehicle Administration, followed by categorization according to Atlas Public Policy’s INSITE tool vehicle types. A stock turnover model projects fleet evolution over time under different ACT compliance scenarios. The INSITE tool then performs detailed charging needs analysis to estimate required charger quantities, types, and associated costs. For long-haul trucks, a separate spatial analysis estimates infrastructure needs for both battery-electric and hydrogen fuel cell vehicles. Finally, a literature review and stakeholder interviews provided insights into charging station deployment timelines, permitting processes, and construction requirements for MHDV charging infrastructure.

1.1 Methods: Vehicle Fleet Modeling

1.1.1 Tallying Medium- and Heavy-Duty Vehicles Registered in Maryland Today

To create a database of the existing operational MHDV fleet in Maryland, we begin with a full vehicle registration snapshot from the Maryland Motor Vehicle Administration (MVA) dated April 2025. It contains all vehicles registered as of that date, including Vehicle Identification Numbers (VINs) and basic vehicle and registration attributes.

VINs are decoded using Atlas's modified NHTSA decoder to classify vehicle types, drivetrain systems, and weights.[8] We also use outputs from the MOVES4 model for Maryland to estimate refuse truck populations in each county.[9]

Filtering and Cleaning Process

We filter the dataset to include only vehicles with a gross vehicle weight rating (GVWR) of 8,501 pounds or more, according to the definition of MHDV. Vehicles are removed if their MVA registration type indicates they are not in the active stock, such as historic registrations. Additionally, vehicle records like construction equipment and trailers are also excluded.

Decoding and Data Imputation

Because the VIN decoder does not produce a complete record for all vehicles, missing or ambiguous data is backfilled using MVA records. Key fields filled using MVA information include:

- Model year, where missing from VIN but present in MVA
- GVWR class, inferred from recorded maximum gross weight
- Vehicle type and subtype, inferred from body type
- Drivetrain classification, inferred from fuel type

In some cases, MVA registration classes offer more precise information than the VIN decoder. We use these fields to improve assignment of vehicle purpose and weight class where relevant.

- Cutaway vans are split into trucks and passenger bus conversions
- School buses are identified using common registration codes
- Cargo vans spanning Class 2b-3 are reassigned based on MVA weight data

Refuse trucks are not explicitly labeled in VIN decoder data and cannot be reliably identified by registration class. To address this, we use EPA MOVES4 model estimates of county-level refuse truck counts and probabilistically assign a matching number of vehicles from the pool of Class 8 straight trucks.

Geographic Assignment and Aggregation

We employed a multi-method approach combining ZIP code pattern matching with geographic proximity analysis. First, we used Maryland-specific ZIP code patterns (e.g., 208xx for Montgomery County → Pepco) to assign utilities based on known regional distributions. For cases where pattern matching was insufficient, we implemented coordinate-based assignment using free APIs (zippopotam.us) to obtain latitude/longitude coordinates, then calculated distances to known utility service areas using the Haversine formula. This system weighted nearby utilities by coverage percentage and distance to determine the most appropriate assignment.

To map vehicles to counties, we used a similar methodology, combining specific ZIP code-to-county mappings with API lookups for verification.

As described in the following chapter, this study focuses on Maryland's five largest electric utilities by electricity delivered, representing approximately 95% of total state electricity consumption[10]:

- Potomac Electric Power Company (Pepco): Washington, DC metropolitan area
- Baltimore Gas & Electric Company (BGE): Baltimore region
- Potomac Edison Company (Potomac Edison): Western Maryland
- Delmarva Power & Light Company (Delmarva): Eastern Shore
- Southern Maryland Electric Cooperative, Inc. (SMECO): Southern Maryland

Estimated Vehicle Population Subject to Advanced Clean Trucks Regulation

The baseline vehicle fleet represents the foundation for Maryland's Advanced Clean Trucks regulation implementation, encompassing approximately 195,000 medium- and heavy-duty vehicles subject to ACT requirements as of 2025. This population excludes transit buses, emergency vehicles, and other specialized fleets that fall outside the ACT regulation's scope.

As shown in Figure 1.2, the fleet composition is dominated by Class 2b-3 vehicles, which account for nearly 70% of the total population at approximately 134,000 vehicles. Class 4-8 straight trucks represent the second-largest segment with roughly 59,000 vehicles, while Class 7-8 tractor trucks comprise about 1,800 vehicles. The geographic concentration shows higher registered vehicle densities in the Baltimore-Washington corridor, reflecting the state's major population and economic centers.

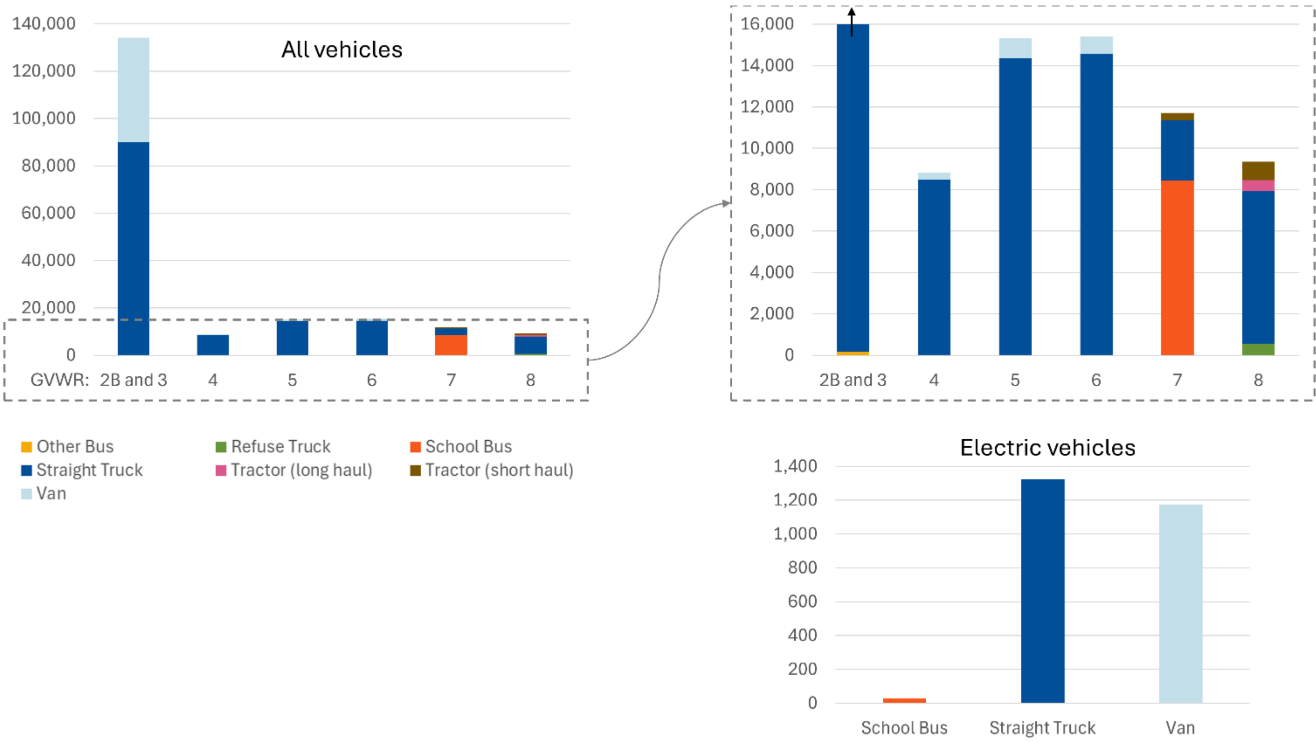

Figure 1.2. Estimated 2025 Population of Maryland-Registered Vehicles Subject to the Advanced Clean Trucks Regulation, by Gross Vehicle Weight Rating Class

1.1.2 Modeling the Future Vehicle Fleet

Atlas's vehicle turnover model simulates year-over-year transitions in vehicle stock by combining survival-based turnover dynamics with policy-driven zero-emission vehicle (ZEV) adoption. This fully deterministic model integrates bottom-up stock and flow modeling with top-down regulatory compliance constraints to model internal combustion engine, battery electric vehicle (BEV), and fuel cell electric vehicle (FCEV) populations consistent with the ACT regulation.

The model's primary output is net adoption of new ZEVs each year, which serves as the basis for estimating annual charging and fueling infrastructure deployment needs. Each vehicle retirement triggers the purchase of a new vehicle, and if electric, creates a charging infrastructure need. As BEV adoption grows, the turnover chain becomes more complex. As a necessary simplification, we assume that whenever an EV replaces an internal combustion engine vehicle in the vehicle stock, it generates the need for new charging infrastructure.

Vehicle attrition is modeled using Weibull survival functions that define scrappage probability based on vehicle age, with retirement parameters calibrated to average lifespan and curve shape for each vehicle type and class. Growth in the total vehicle fleet is derived from projected freight ton-mile demand, as reported in Maryland's Climate Pollution Reduction Plan.[11] That demand was forecast using GCAM model data scaled to GDP growth, assuming constant per-vehicle annual VMT over time.

ACT Compliance Solver

Advanced Clean Trucks (ACT) regulation compliance is modeled using a mathematical framework that solves for a set of segment-class-level BEV sales percentages that satisfy the ACT regulation requirement (total credits) within adoption dynamics-based constraints.

The model employs a multiaffine polynomial structure where total credits (a known value derived from ACT regulation) is a function of the sum of each vehicle segment's BEV sales percentage (unknown variables), multiplied by sales volumes and weighted by regulatory credit values assigned to each segment. The model uses a bisection-based numerical solver to solve for the BEV sales percentage for each segment that when combined satisfy total credit requirements while respecting the following two constraints: (1) Each vehicle segment has maximum BEV sales percentage saturation thresholds and (2) relative adoption propensities based on market readiness (e.g., a market-ready segment may have twice the adoption propensity of a less ready segment).

When compliance cannot be achieved under initial limits, the model incrementally relaxes constraints until a feasible solution is found. This approach ensures regulatory targets are met while maintaining realistic adoption patterns across vehicle segments, preventing unrealistic early over-adoption in segments with limited market readiness. The relative propensity and saturation parameters are specified using market data and expert opinion.

Hydrogen Vehicles

Hydrogen-powered vehicle development in the commercial sector has so far been limited to tractor trucks and transit buses, with no legacy manufacturers or startups announcing commercialization plans for hydrogen models in other vehicle segments. Based on this market reality, we assume for this analysis that hydrogen uptake is restricted to tractor trucks only. Working with MDE team guidance, we developed a hydrogen tractor truck sales scenario showing hydrogen's share of ZEV sales within this segment. Our assumptions introduce hydrogen-powered tractors commercially in 2036, capturing 1% of zero-emission tractor sales in that year while battery-electric vehicles comprise the remaining 99%. The hydrogen portion of the overall ZEV market share then grows progressively to 5% by 2040, 15% by 2045, and 25% by 2050.

Final Stock Accounting and Policy Validation

BEV, FCEV, and internal combustion engine vehicle additions are added to each year's vehicle stock. At the end of each simulated year, the model validates whether the updated stock composition satisfies ACT credit requirements. This compliance check ensures consistency between modeled outcomes and regulatory obligations.

The key output is each year's marginal BEV adoption, net of BEV retirements. This is saved and forms the basis of charging infrastructure needs in the INSITE model.

Long-Haul Truck Activity

The turnover model accounts for the electrification of long-haul trucks registered in Maryland, but it does not fully represent all long-haul truck activity in the state. Major freight corridors, including I-95, carry trucks that are not registered in Maryland but pass through as they move between origins and destinations. In addition, Maryland's port facilities and large population centers serve as significant origins and destinations for long-haul traffic. To reflect the interstate nature of this activity, long-haul truck adoption is modeled at the national level using a simplified approach. The adoption rate derived for Maryland is applied to the national market, and truck traffic is then allocated to Maryland based on the state's share of national truck parking spaces, which serves as a proxy for the share of stopping and refueling likely to occur in Maryland.

1.2 Methods: Modeling Charging

To estimate future charging needs associated with our modeled BEV adoption, we use Atlas's Investment Needs of State Infrastructure (INSITE) model. INSITE is an integrated technoeconomic modeling framework developed to produce high-level planning estimates of charging infrastructure needs and associated deployment costs for newly adopted electric medium- and heavy-duty vehicles. The model combines a physical model of charger energy delivery, an activity-based model of vehicle energy demand, and a simplified economic model for estimating infrastructure costs. More details of the INSITE model methodology can be found in Appendix A.

1.2.1 Charging Locations

Figure 1.3 illustrates the three charging locations for medium- and heavy-duty electric vehicles modeled by INSITE. Home/Private Residence charging is charging that occurs while vehicles are parked at residences. Depot charging, also known as "return-to-base" charging, is charging that occurs where the vehicle is stored, typically overnight. Depots are typically private industrial or commercial locations and can be owned by the vehicle owner or by a third party (e.g. shared depot, charging-as-a-service provider). Enroute charging occurs at charging stations away from home or depot locations, serving vehicles without established home bases where charging is possible and providing supplemental charging for depot and home-based fleets during longer trips or routes (including long-haul vehicles).

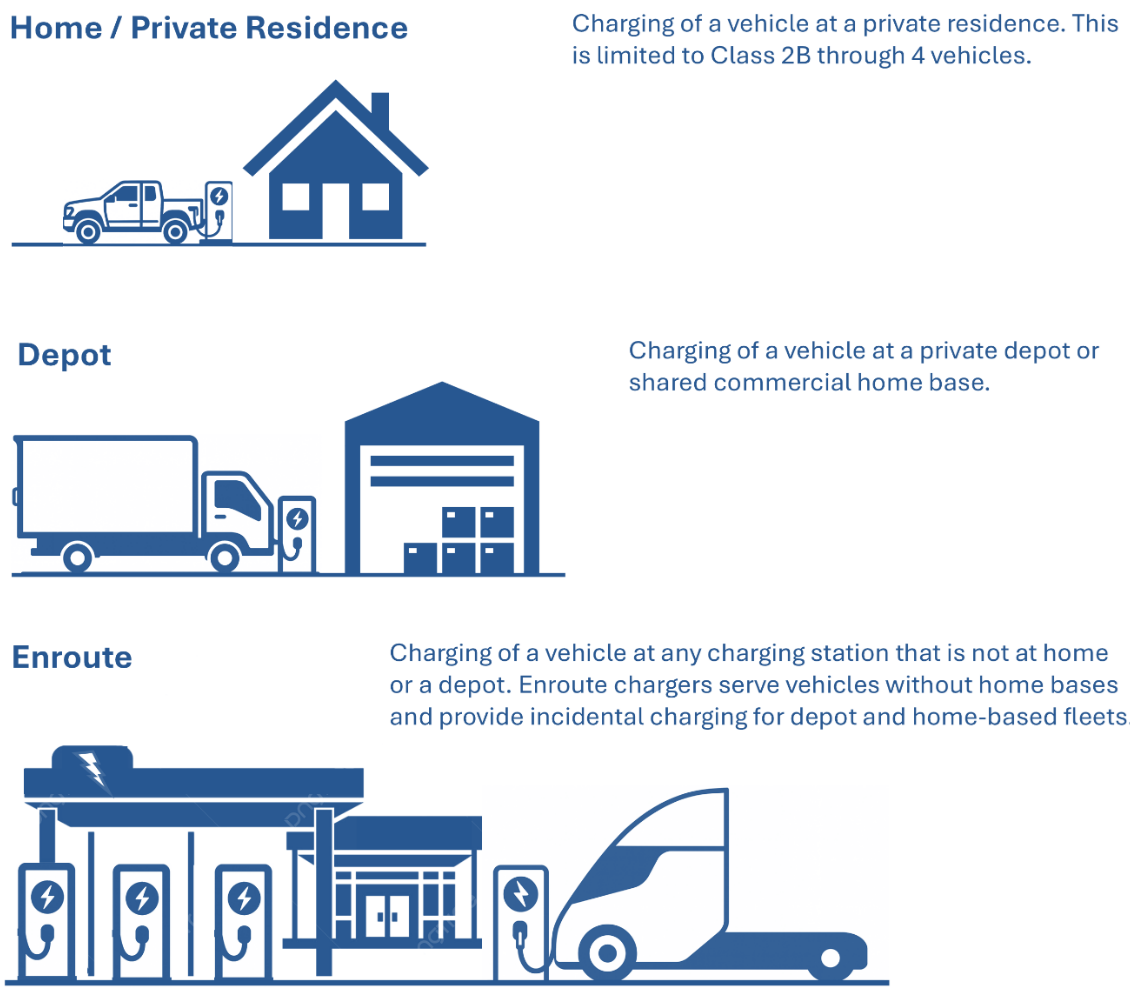

Figure 1.3. Three Modeled Charging Locations

Figure 1.4 displays the distribution of vehicles by their primary charging location, which was assessed using parking location data from the 2021 Federal Highway Administration Vehicle Inventory and Use Survey.[12] Many Class 2b-3 vehicles are modeled as being charged primarily at home, reflecting the large prevalence of drivers who park these vehicles at a residence overnight (note that many Class 2b vehicles are pickup trucks used as personal, non-commercial, vehicles). Most Class 4-8 vehicles are expected to charge primarily at depots. Vehicles relying primarily on enroute charging represent a smaller but notable share across most classes. Class 8 long-haul trucks are assumed to rely entirely on enroute chargers since they typically do not return to base on a daily basis. In addition to modeling enroute charging to serve the vehicles shown here as charging primarily enroute, we also model enroute charging sufficient to provide 5% of energy need for vehicles that charge primarily at home or depots, to reflect the fact that these vehicles may also need enroute charging support from time to time.

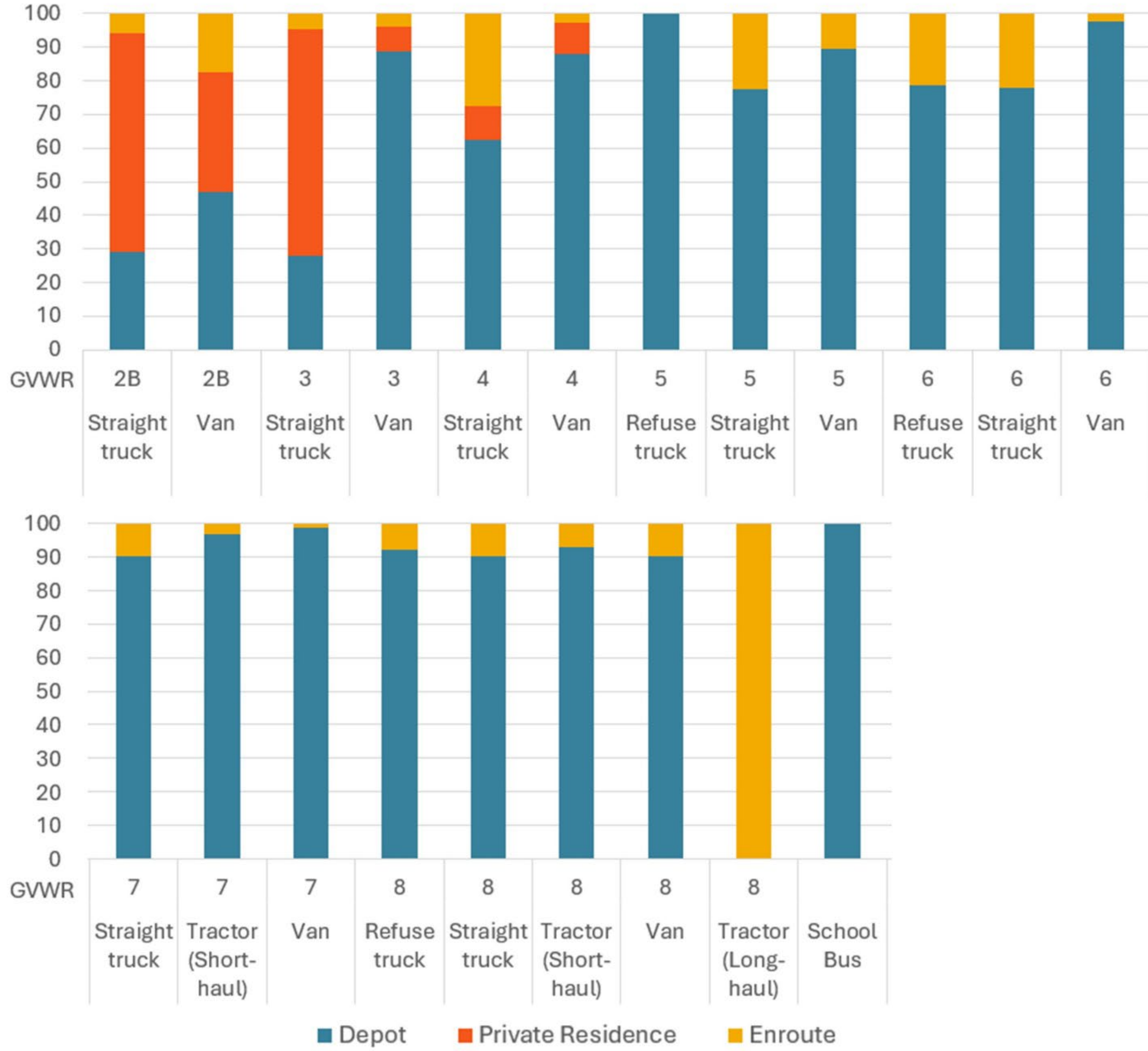

Figure 1.4. Percent of Vehicles Assigned to Each Primary Charging Location, by Gross Vehicle Weight Rating Class and Vehicle Segment

1.2.2 INSITE Model Design

As shown in Figure 1.5, one of the model's key inputs is projected annual counts of new BEVs, disaggregated by vehicle class and segment from the turnover model results. INSITE is configured using additional scenario inputs including vehicle operational patterns, efficiency projections, and environmental factors (i.e., average cold weather temperatures by county). It generates two primary outputs: the number of charging ports required by power level and installation context, and associated costs including for equipment, installation, and utility connections.

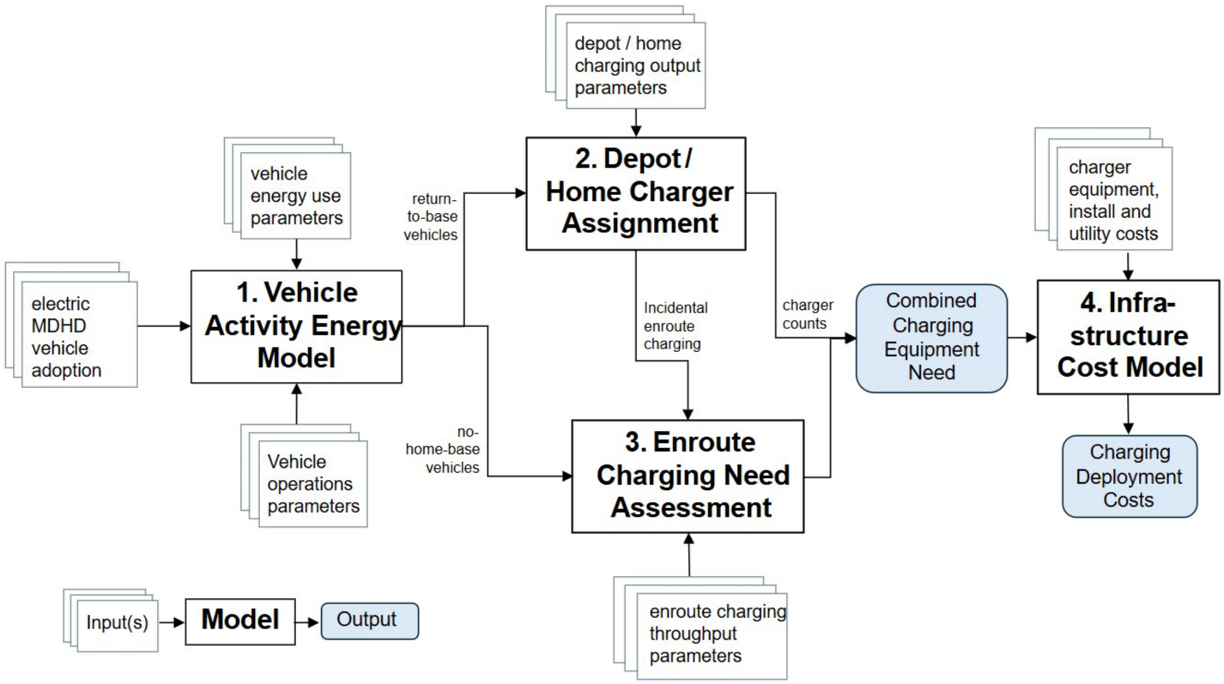

Figure 1.5. INSITE Model Methodology Process Diagram

Step 1: Vehicle Activity Energy Model

This step estimates peak day energy requirements for the projected BEV population. The calculations account for baseline electric vehicle efficiency (sourced from Argonne National Laboratory's Autonomie model),[13] distributions of vehicle miles traveled (sourced from the 2021 Federal Highway Administration Vehicle Inventory and Use Survey),[12] and adjust for cold weather impacts to provide peak energy demand estimates.[12,14] A 20% energy planning margin is then added to this peak day energy requirement to help ensure that modeled charging can meet fleets' real-world peak demand.

Step 2: Depot and Home Charging Assignment

This step estimates charging infrastructure quantities and power levels for vehicles that regularly recharge at depots or private residences. The model assigns charger power levels by matching vehicle energy recovery needed to the charger required to deliver that energy. The algorithm simulates operator behavior by selecting the lowest-powered charger capable of meeting peak cold day energy recovery needs within available charging windows, after adding a 20% energy planning margin, accounting for charging losses and simulating battery charging curves.

For depot charging, seven options of power levels are considered (7 kW to 1,000 kW), while home charging uses three AC power levels (7 kW, 11 kW, 19 kW). The model allows DC fast chargers to be shared between up to two vehicles when energy recovery needs cannot be satisfied by lower-powered options but don't require dedicated high-power chargers. AC chargers are assumed not to be shared.

Step 3: Enroute Charging Needs Assessment

This step estimates the number of shared high-power chargers required to meet enroute charging demand. Enroute charging is divided into three categories: Class 2b–3 vehicles, Class 4–8 non-long-haul vehicles, and long-haul tractors. The module calculates total energy demand and applies dispensing factors that account for charger power, efficiency, and expected utilization to determine daily energy delivery capacity. The number of chargers is then calculated as the ratio of total energy demand to the energy that can be supplied by a single charger.

Charging infrastructure needs are first calculated at the statewide level and then downscaled to counties and utility territories using two proxies. For non-long-haul trucks, the allocation is based on each area's share of Maryland's annual average daily traffic. For long-haul trucks, the allocation uses truck parking share, which reflects the locations where trucks are most likely to stop for breaks or overnight stays.

Step 4: Cost Calculation

The model applies a deterministic, bottom-up framework using modeled charger quantities and average per-port unit costs indexed by power level, vehicle class (as a proxy for footprint), and charging location. Three principal cost components are included: charging equipment costs, installation costs encompassing labor and site preparation, and utility-side infrastructure costs for distribution system upgrades. Total infrastructure costs are computed as the sum of charger-specific costs across all power levels and locations, expressed in real 2025 dollars.

1.3 ZEV Adoption Scenarios

Table 1.1 outlines three distinct compliance scenarios that examine how manufacturers might meet ACT requirements in Maryland through varying degrees of credit pooling flexibility. The Base ACT scenario represents strict in-state compliance, while the two pooling scenarios allow manufacturers to trade credits from other ACT states to offset local deficits. After the ACT regulation ends in sales year 2035, we assume a continued adoption trajectory that achieves 100% zero-emission sales by 2050.

Scenario	Description
Base ACT	The ACT rule as written, with the first regulated model year in Maryland being 2027 and the final model year being 2035. Beyond 2035, ZEV market share for all new vehicles reaches 100% by 2050.
ACT + 50% Pooled Credit Use	Same as Base ACT, but OEMs selling vehicles in Maryland meet compliance using 50% of the maximum allowable pooled credits (originating from other states).
ACT + 100% Pooled Credit Use	Same as Base ACT, but OEMs selling vehicles in Maryland meet compliance using 100% of the maximum allowable pooled credits (originating from other states).

Table 1.1. Scenario Descriptions

The pooling mechanism works by allowing manufacturers to transfer credits between states up to specific annual limits, as detailed in Table 1.2. These limits, which are a percentage of the total compliance requirement for each model year, decrease from 20% in 2027 to 10% by 2032 and beyond, ensuring that pooling provides transitional relief rather than permanent avoidance of in-state electrification.

For example, using a scenario developed by MDE for considering this mechanism, a manufacturer selling 100 Class 4 trucks, 100 Class 8 trucks, and 80 Class 7-8 tractors would generate total deficits of 85 credits:

$$(100 * 15\% * 1.0) + (100 * 20\% * 2.0) + (80 * 15\% * 2.5) = 15 + 40 + 30 = 85$$

Under the 20% pooling cap, they could transfer up to 17 credits ($85 * 20\% = 17$) from other states using any combination of tractor and non-tractor credits. This flexibility allows manufacturers to phase in Maryland ZEV sales while still driving overall market transformation across participating states.

Model Year	2027	2028	2029	2030	2031	2032+
Credit Transfer Allowance	20%	18%	16%	14%	12%	10%

Table 1.2. Credit Transfer Allowance Limits for Pooling Flexibility Mechanism

Figure 1.6 illustrates the substantial growth trajectory of ZEVs under the Base ACT scenario. The analysis shows modest initial deployment through 2030, with fewer than 17,000 total ZEVs, followed by rapid acceleration as ACT requirements increase and vehicle availability improves.

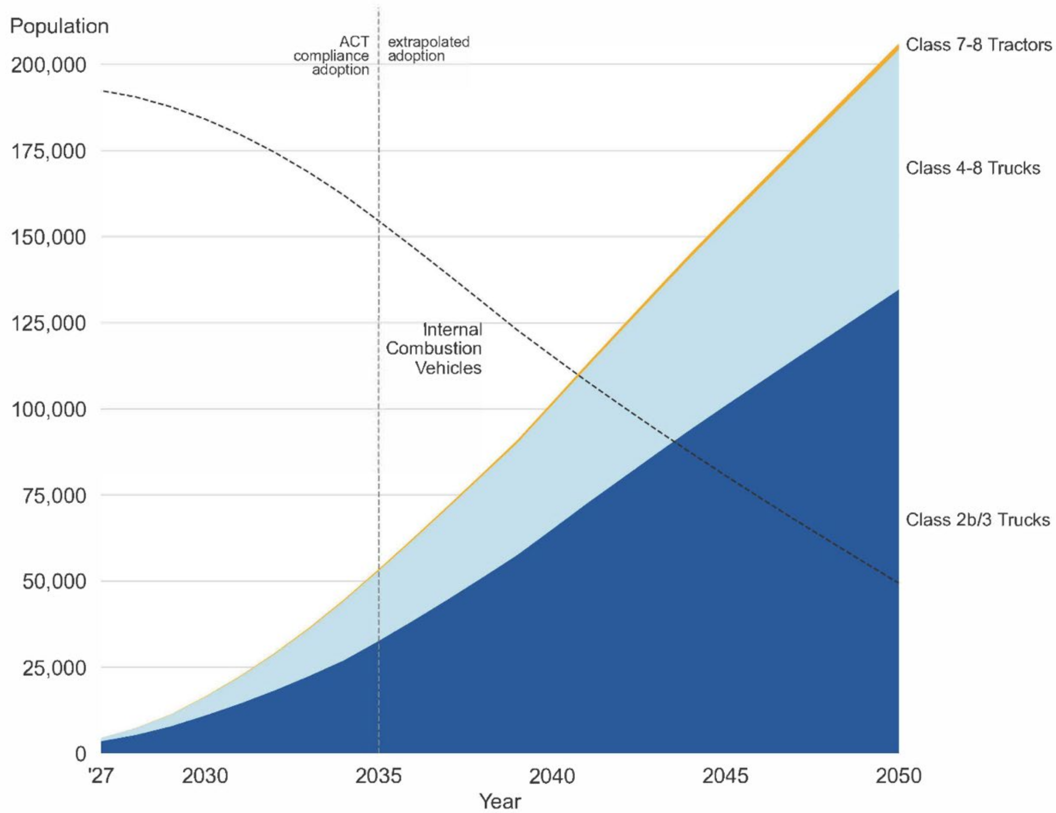

Figure 1.6. Total ZEV Populations, Base ACT Scenario

Class 2b-3 vehicles exhibit the steepest growth curve, reaching approximately 135,000 units by 2050, reflecting both their large baseline population and relatively mature electric technology. Class 4-8 straight trucks follow a similar but more moderate trajectory. Tractor electrification growth slows in the mid-2030s as ACT requirements level off under the current regulatory design, then accelerates again as ZEV adoption is modeled for this study to approach 100% of sales by 2050 for those vehicles.

Figure 1.7 presents ZEV populations. At the completion of the current ACT regulation in 2035, ZEV vehicles would represent:

- 23% of all registered Class 2b-3 trucks, vans and other vehicles
- 31% of all registered Class 4-8 straight trucks and buses
- 21% of all registered Class 7 and 8 tractor trucks

One important caveat regarding long-haul tractor trucks: the tractor truck numbers shown represent only vehicles registered in Maryland, which likely understates the actual population of long-haul trucks operating within the state. Long-haul operations typically involve interstate travel patterns where trucks registered in other states regularly traverse Maryland's highways and utilize in-state infrastructure. This distinction is crucial for infrastructure planning, as the actual demand for long-haul charging and hydrogen refueling stations could be substantially higher than suggested by registered vehicle counts alone. The interstate nature of long-haul trucking means that Maryland's infrastructure must serve the broader flow of commercial traffic through major freight corridors, particularly along I-95, I-70, and I-270. This reality necessitates regional coordination and infrastructure planning that extends beyond state-specific vehicle registration data.

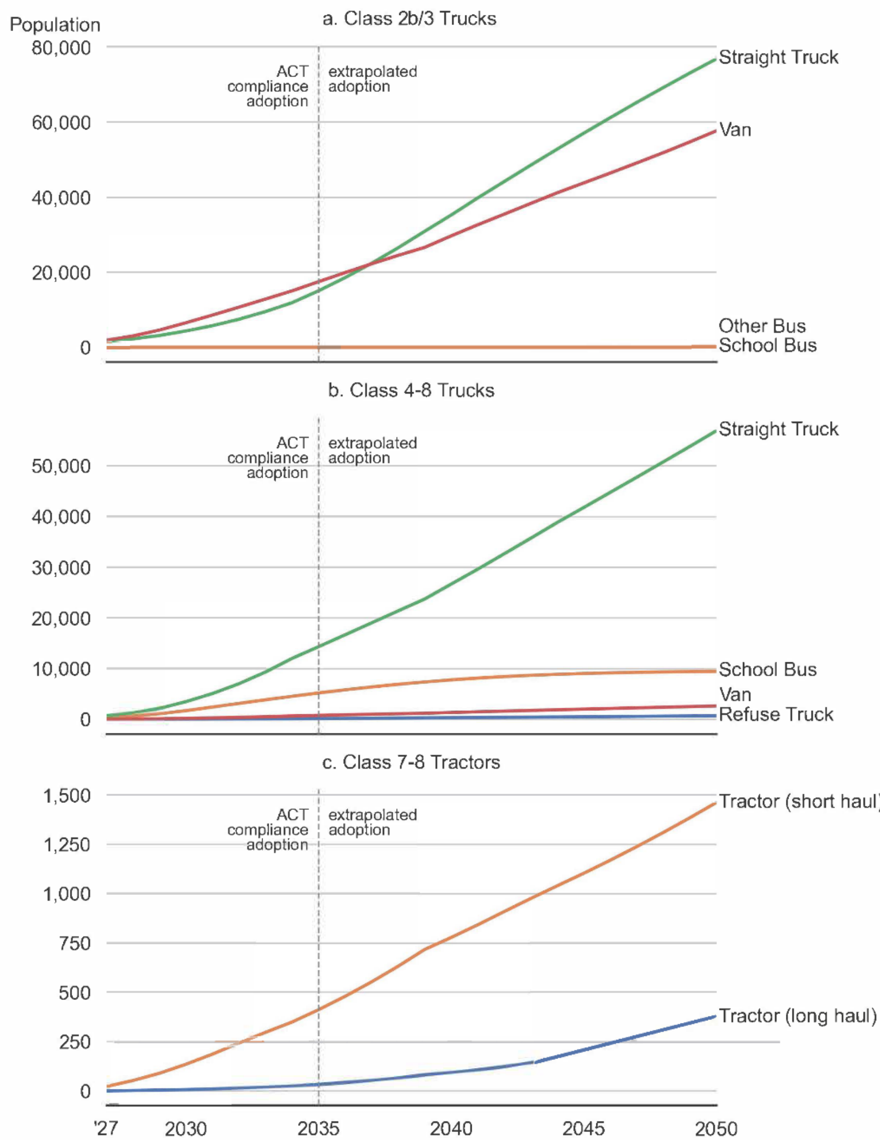

Figure 1.7. Total ZEV Populations for the Base ACT Scenario

1.4 Results: Charging Infrastructure Needs

The following infrastructure results focus on the Base ACT scenario, which represents the core ACT regulatory framework without credit pooling flexibility, plus an assumption that

ZEVs reach 100% of new vehicle sales by 2050. The analysis encompasses depot charging power level assignments, charging port counts across different charging categories, and geographic distribution patterns that can guide strategic deployment. Section 1.4.3 separately examines how the pooling scenarios modify baseline ACT requirements.

1.4.1 Depot Charging Power Level Assignment

Figure 1.7 demonstrates the results of the depot charger assignment process for 2035, revealing a diverse charging infrastructure mix that reflects the varied operational patterns of Maryland's commercial vehicle fleet. The analysis shows that the majority of depot-charging vehicles can be served by AC charging (≤11 kW and 19 kW) at the depot. Medium-power DC charging (50 kW and 150 kW) supports vehicles with moderate energy demands and/or shorter charging windows, while high-power charging (350 kW) addresses large battery vehicles with short dwell times, the most demanding applications.

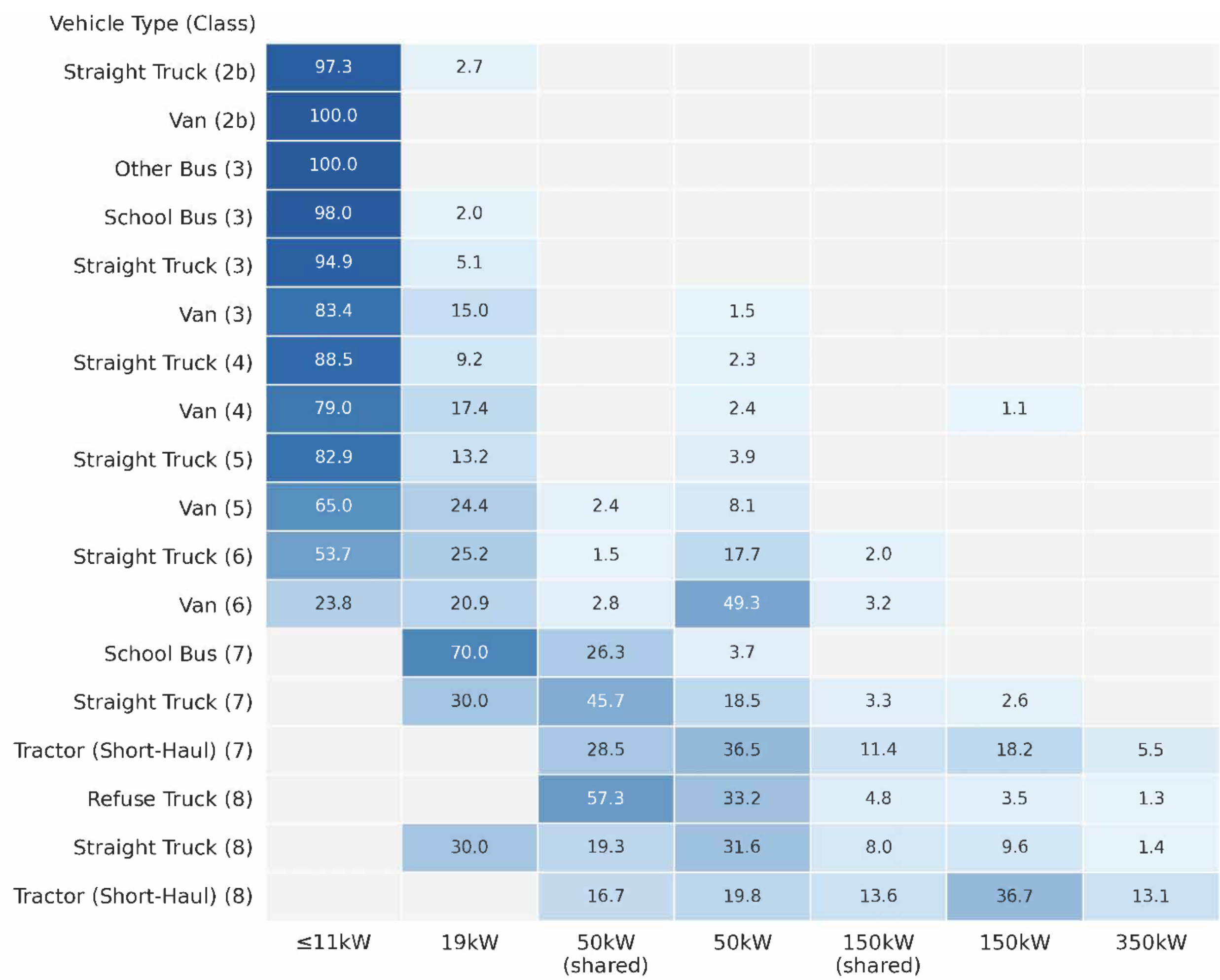

Figure 1.8. Percent of Vehicle Segment and GVWR Class Assigned to Each Depot Charger Power Level, 2035, Base ACT Scenario

1.4.2 Charging Infrastructure Results for the Base ACT Scenario

Table 1.3 and Figure 1.9 reveal the scale of charging infrastructure deployment required under the Base ACT scenario, with home and depot charging port counts growing to nearly 40,000 total by the end of the ACT regulation in 2035. The infrastructure mix at homes and depots heavily favors AC charging, with $\leq$ 11 kW ports representing the largest deployment category, reaching over 136,000 units by 2050.

Power	2030	2035	2040	2045	2050
≤11 kW (AC)	8,207	29,864	63,879	101,450	136,143
19 kW (AC)	2,058	6,716	10,962	14,730	17,834
50 kW (DC)	819	2,929	5,128	7,526	9,951
150 kW (DC)	125	394	735	1,133	1,550
350 kW (DC)	24	67	117	145	168

Table 1.3. Cumulative Port Counts for Depot and Home Charging

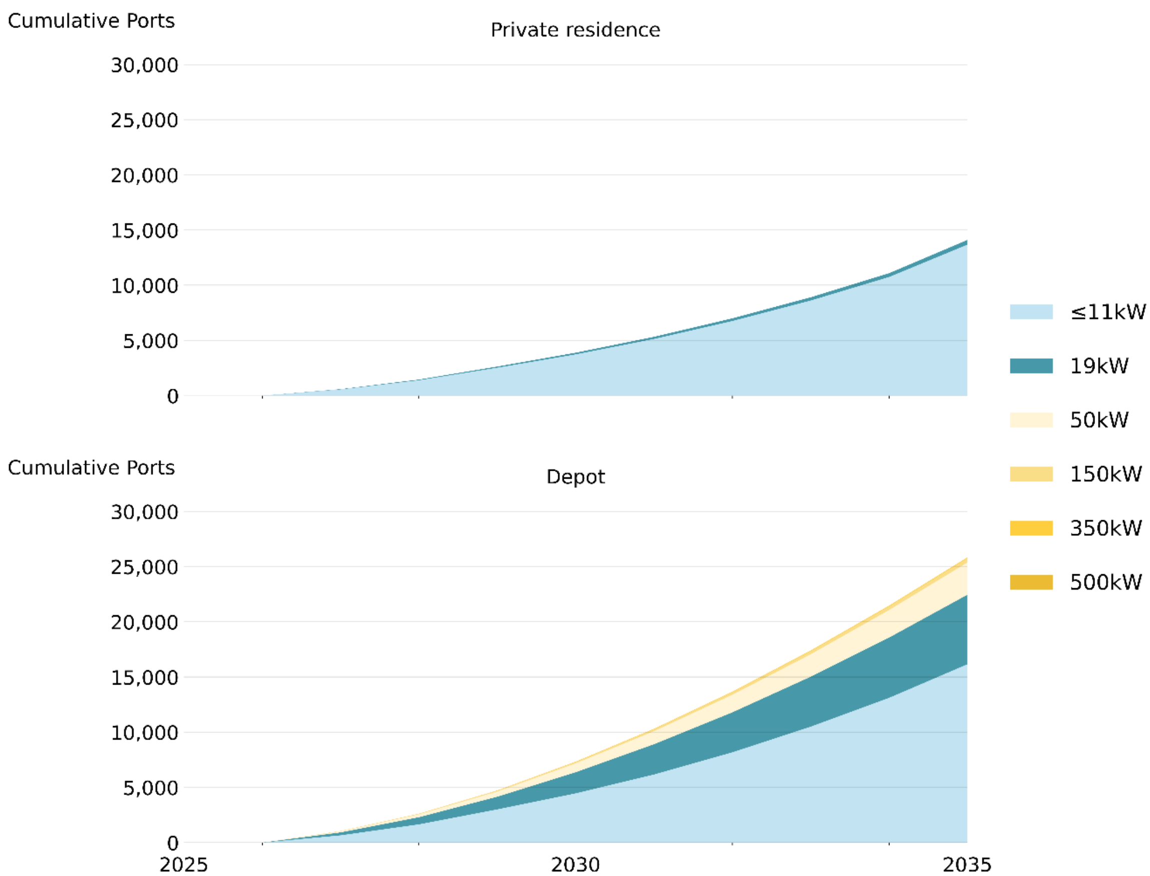

Figure 1.9. Cumulative Port Counts by Power Rating

This distribution reflects the predominance of Class 2b-3 vehicles in Maryland's fleet, many of which can meet their daily energy needs through overnight depot charging or residential charging at lower power levels. The progression shows steady growth in medium and high-power DC charging as heavier vehicle classes adopt electric powertrains, with 50 kW, 150 kW, and 350 kW depot charging ports growing to about 2,930, 390, and 70 units, respectively, by the end of the ACT regulation in 2035. The cumulative deployment pattern demonstrates how early infrastructure investments in lower-power charging establish the foundation for subsequent high-power installations as fleet electrification increases across all vehicle segments.

In later years, as presented in Table 1.4 and Table 1.5, and Figure 1.10, our modeling shows enroute infrastructure growing to 912 ports by the end of the ACT regulation in 2035. Based on the larger batteries of many MHD vehicles and the economic disincentive for MHDV drivers to stop for long periods of time for enroute charging, we model enroute charging as consisting of 350 kW to 1 MW per port nameplate capacities. Nameplate charger capacity is estimated to reach 371 MW by 2035.

Importantly, this installed nameplate capacity measures the sum of all individual equipment's power ratings but does not reflect the equipment's actual peak combined usage or contribution to coincident system peaks, which are substantially lower (see Chapter 2). These installed capacity values should therefore not be misconstrued as necessarily representing needed grid upgrades.

Ports	2030	2035	2040	2045	2050
350 kW (DC)	209	832	1,885	3,805	6,451
1,000 kW (DC)	19	80	199	436	782

Table 1.4. Cumulative Port Counts for Enroute Charging

Power	2030	2035	2040	2045	2050
350 kW (DC)	73	291	660	1,331	2,258
1,000 kW (DC)	19	80	199	436	782

Table 1.5. Cumulative Installed Capacity (MW) for Enroute Charging

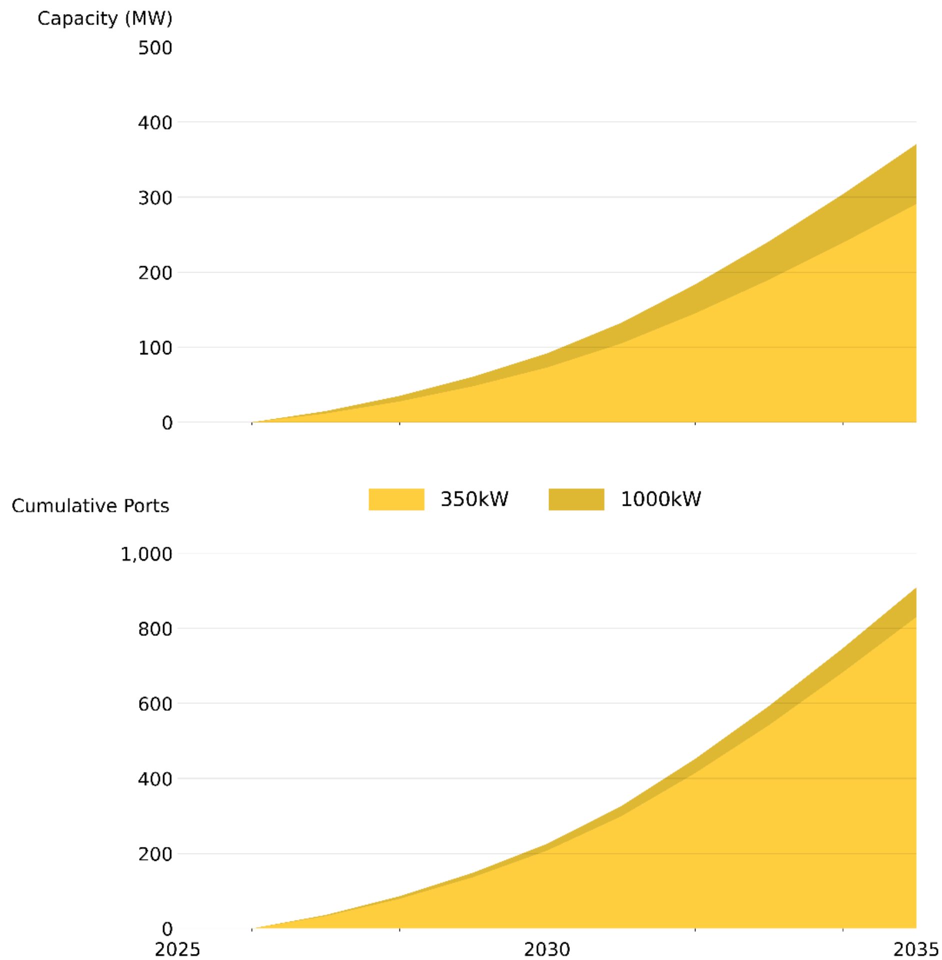

Figure 1.10. Enroute Charging: Cumulative Charging Port Counts and Installed Capacity by Power Rating, Base ACT Scenario

We model enroute charging deployment exclusively as high-power DC fast charging, reflecting the operational requirements for rapid energy recovery during commercial vehicle operations. 350 kW charging is modeled as being used for short dwell time charging for smaller MHDVs, as well as for long dwell time charging of long-haul vehicles during drivers' ten-hour mandated break. This 350-kW infrastructure dominates deployment numbers, growing to around 830 charging ports by 2035. Megawatt charging (1,000 kW) is modeled as being needed for short dwell time charging of tractor trailers, providing flexibility in the charging network for long-haul vehicles that are not able to charge during drivers' long breaks, and providing enroute charging support for short-haul tractors. Our modeling shows 80 charging ports of 1 MW each by 2035 when the ACT regulation currently ends. In total, we model 371 MW in enroute charger nameplate capacity needed by 2035 to meet ACT. For comparison, public fast chargers built in Maryland to date (which have primarily been built for light-duty vehicles) total 230 MW in nameplate capacity (69% of which started operating in 2022 or later).[15]

Figure 1.11 demonstrates the geographic distribution of installed capacity of charging infrastructure across Maryland's five primary electric utilities. BGE shows the highest infrastructure deployment, reaching nearly 400 MW in installed nameplate charger capacity by 2035, consistent with its service territory encompassing the Baltimore metropolitan area and central Maryland's major commercial corridors. Delmarva, serving the Eastern Shore, and Potomac Edison in Western Maryland each reach roughly 190 and 170 MW, respectively, by 2035. Pepco serves the DC metro area with growth to nearly 160 MW by 2035. SMECO shows steady growth to about 40 MW by 2035, demonstrating how even co-op utilities must prepare for charging infrastructure for commercial vehicles. Again, this installed nameplate capacity measures the sum of all individual equipment's power ratings but does not reflect the equipment's actual peak combined usage or contribution to coincident system peaks—which are substantially lower (see the following chapter). These installed capacity values should therefore not be misconstrued as representing the total amount of necessary grid upgrades.

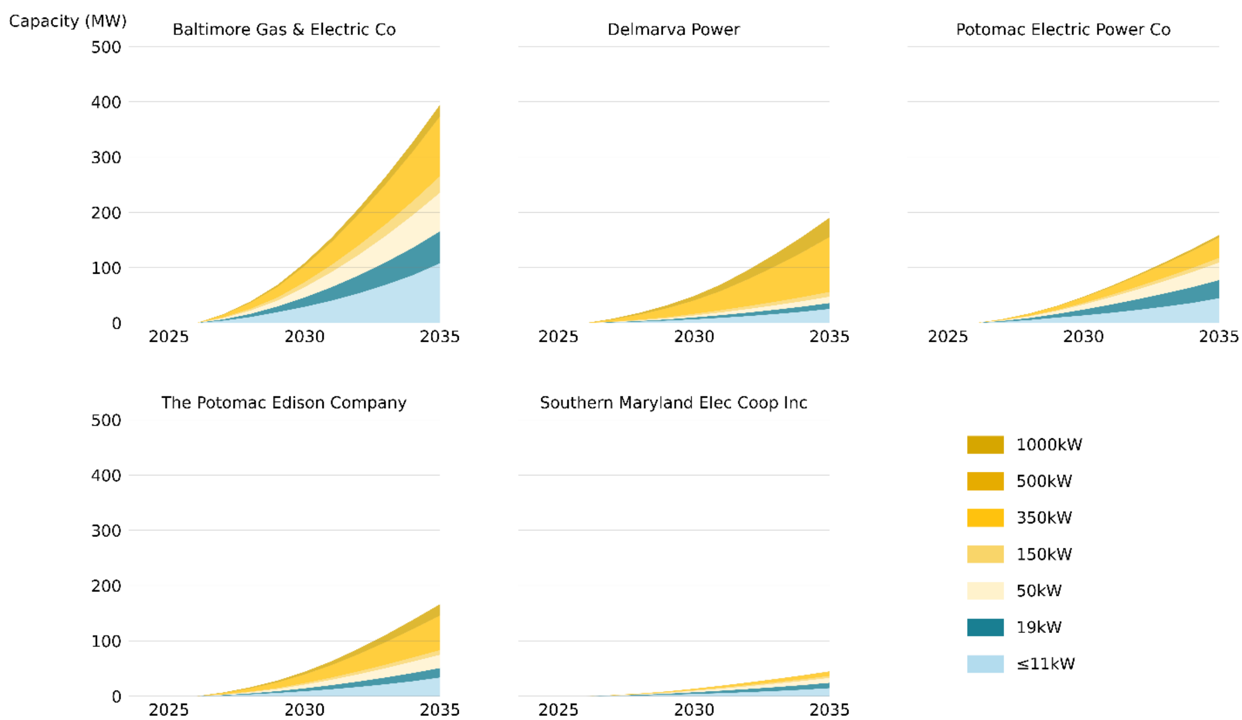

Figure 1.11. Total Installed Capacity by Charging Power Level and Utility

Table 1.6 and Figure 1.12 provide infrastructure requirements across the three primary ACT regulatory categories, revealing distinct deployment patterns. Class 2b-3 vehicles drive the largest infrastructure deployment in terms of the number of charging ports, with home charging representing a significant component due to the large prevalence of these vehicles being used for personal transportation

	2030		2035		2040		2045		2050	
	Ports	**MW**	**Ports**	**MW**	**Ports**	**MW**	**Ports**	**MW**	**Ports**	**MW**
-										
Home	3,834	30	13,927	107	31,505	239	50,388	254	67,596	506
Depot	3,040	24	9,649	74	20,989	162	33,279	379	44,615	340
Class 4-8 Straight Trucks										
Home	55	0	186	2	431	4	716	6	983	8
Depot	4,195	98	15,885	349	27,285	607	39,739	864	51,316	1,139
Class 7 and 8 Tractor Trucks										
Depot	105	16	318	46	611	84	860	115	1,133	146
Enroute (All Vehicle Classes and Types)										
	228	92	912	371	2,084	859	4,241	1,767	7,233	3,040

Table 1.6. Cumulative Ports and Installed Capacity by ACT Regulatory Category

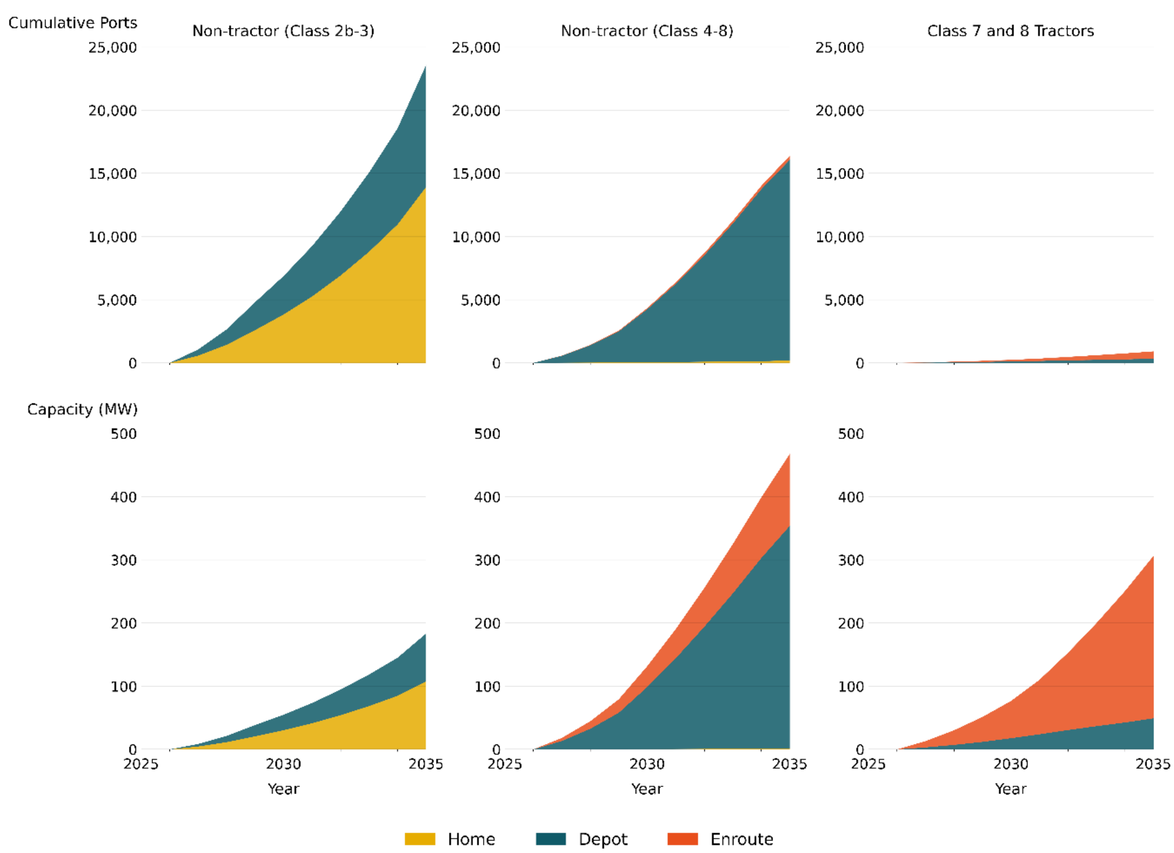

Figure 1.12. Cumulative Charging Ports and Installed Nameplate Capacity by ACT Regulatory Category, Base ACT Scenario

The analysis shows Class 2b-3 vehicles requiring about 112,000 combined home and depot ports by 2050, with installed capacity reaching nearly 850 MW. For comparison, the majority of Maryland's over 120,000 existing light-duty EVs are likely already charged at a Level 2 charger at home.[16, b] For Class 4-8 straight trucks, depot charging dominates charging infrastructure needs. The roughly 51,300 depot charging ports and 1,140 MW of installed nameplate capacity needed by 2050 for this segment reflect higher power requirements per vehicle.

Class 7-8 tractor trucks show the most power-intensive profile, with enroute charging playing a role alongside depot installations. Despite representing the smallest vehicle population, many tractors require substantial charging infrastructure capacity due to their high energy demands and long-distance or continuous-use operational patterns.

Figure 1.13 reveals the county-level distribution of total charging nameplate capacity, highlighting geographic concentration patterns across Maryland's diverse landscape. The map clearly shows the Baltimore-Washington corridor accounting for a large amount of charging infrastructure deployment, with Prince George's County, Frederick, Montgomery County, Anne Arundel, and Baltimore County all with cumulative installed nameplate capacity of over 300 MW by 2050. Again, this installed nameplate capacity measures the sum of all individual equipment's power ratings but does not reflect the equipment's actual peak combined usage or contribution to coincident system peaks, which are substantially lower (see the following chapter). These installed capacity values should therefore not be misconstrued as representing the magnitude of needed grid upgrades.

Table 1.7 shows the percentage of long-haul truck parking spaces by county in Maryland. These data are based on a 2019 survey conducted by the U.S. Department of Transportation.[18]

Corresponding to the values in Table 1.7, Cecil County receives 37% of Maryland's long-haul tractor charging allocation—more than double any other county. This allocation reflects actual truck traffic patterns, as long-haul vehicles naturally funnel through Cecil County when traveling between major northeastern ports and southeastern markets, making it a critical gateway for interstate freight movement.

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[b] A national study by JD Power found that 68% of EV owners in the U.S. use a Level 2 permanently mounted charger at home, with additional drivers using a portable Level 2 charger. A typical Level 2 charger is rated at 7.6 or 9.6 kW AC (240 volt), though this designation technically goes as high as 19.6 kW AC (240 volt). In addition, a majority (60%) of current Level 1 household outlet (1.8 kW AC (120 volt)) users say they are likely to upgrade their home charging station to Level 2.[17]

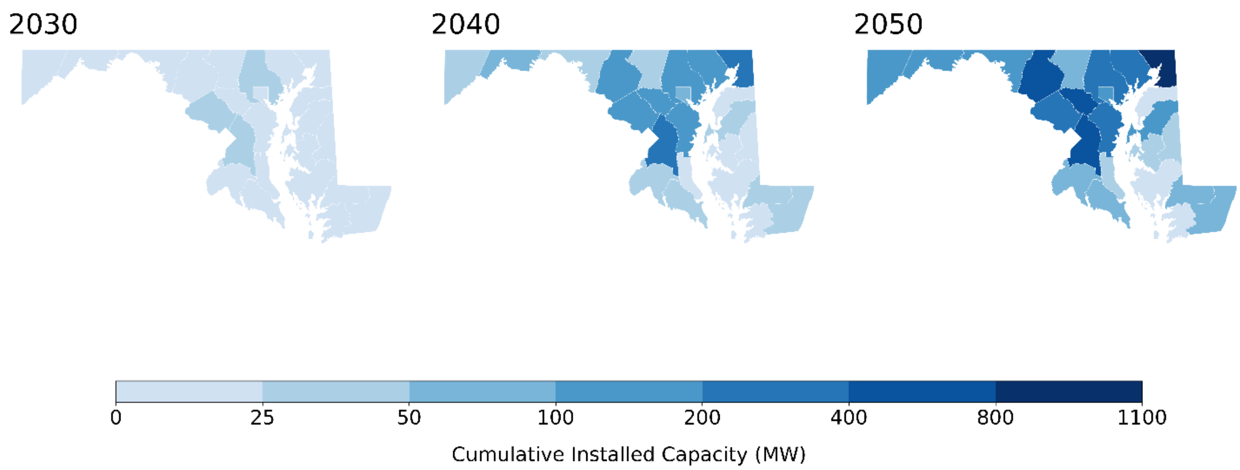

Figure 1.13. Total Installed Nameplate Charging Capacity by County

County	Percentage of Maryland's Truck Parking Spaces
Cecil	37%
Frederick	15%
Howard	14%
Harford	10%
Garrett	6%
Prince George's	5%
Queen Anne's	4%
Montgomery	4%
Worcester	2%
Dorchester	2%
Washington	1%

Table 1.7. Distribution of Maryland's Truck Parking Spaces by County

Returning to Figure 1.13, the Eastern Shore counties, served primarily by Delmarva Power, demonstrate more modest but distributed deployment patterns, with concentrations along major transportation corridors including US-50 and US-13. Western Maryland counties show lower overall deployment levels consistent with their rural character and lower commercial vehicle density, though strategic corridors like I-70, I-68, and I-81 drive local infrastructure concentrations. Southern Maryland counties exhibit moderate deployment patterns, with higher concentrations near the DC metro area boundary diminishing toward the rural southern regions.

1.4.3 Scenario Comparisons

Table 1.8 demonstrates how credit pooling mechanisms impact near-term charging infrastructure deployment while having minimal effect on long-term requirements. The 50% pooled credit scenario reduces 2030 charging port deployment by 6.2% compared to the Base ACT scenario, while 100% pooled credit use achieves a 14.5% reduction, providing meaningful flexibility during the initial implementation period.

Year	Base ACT	ACT + 50% Pooled Credit Use	Delta vs. Base ACT	ACT + 100% Pooled Credit Use	Delta vs. Base ACT
2030	11,462	10,747	-6.2%	9,795	-14.5%
2035	40,886	39,309	-3.9%	37,426	-8.5%
2040	82,908	81,582	-1.6%	79,726	-3.8%
2045	129,228	128,485	-0.6%	127,232	-1.5%
2050	172,883	172,804	-0.1%	172,186	-0.4%

Table 1.8. Cumulative Charging Port Deployment for the Three Scenarios

However, these differences diminish substantially over time as pooling allowances decrease and all scenarios converge toward similar long-term deployment levels. By 2035, the pooling scenarios show 3.9% to 8.5% reductions in total Maryland charging port counts. Assuming that the regulation's stringency is increased beyond 2035 to get to 100% ZEV sales by 2050, the differences in 2050 become negligible at 0.1% to 0.4%. This convergence pattern demonstrates that credit pooling provides transitional relief for early adopters while maintaining the regulation's long-term electrification objectives, allowing for more manageable infrastructure ramp-up without compromising ultimate policy goals.

1.4.4 Other Potential ACT Flexibility Mechanisms

Two additional regulatory flexibilities merit consideration for their potential impacts on ZEV deployment: fully interchangeable credits and proportional credits.

Fully Interchangeable Credits

Currently, the ACT regulation limits credit interchangeability between vehicle categories. While manufacturers can use excess tractor credits to meet non-tractor requirements, tractor deficits can only be satisfied with tractor credits. Fully interchangeable credits would allow unlimited credit trading across all three ACT categories (Class 2b-3 vehicles, Class 4-8 non-tractors, and Class 7-8 tractors).

This flexibility could provide manufacturers with greater compliance pathways and reduce overall costs by allowing focus on the most market-ready segments. However, it could slow tractor truck electrification as manufacturers may avoid introducing ZEVs into the tractor segment by over-producing credits in easier-to-electrify categories such as smaller trucks and vans. Beyond ACT implementation through 2035, the longer-term impacts would depend on whether policy mechanisms ensure eventual tractor development, as unlimited credit trading could indefinitely delay tractor electrification if not properly structured.

Proportional Credits

Proportional credits would allocate manufacturers credit balances based on their California sales proportions relative to state-specific sales. This mechanism provides early-year compliance relief, particularly benefiting manufacturers with existing California ZEV programs.

Proportional credits impacts would vary significantly by manufacturer, with the companies that have a significant market presence in California benefiting most. Through 2050, proportional credits would not likely fundamentally alter electrification outcomes but could provide a more manageable transition pathway during the early 2027 to 2035 implementation period across all vehicle categories.

1.5 Hydrogen Refueling Station Needs for Long-Haul Trucks

While battery-electric vehicles are expected to dominate most MHD ZEV segments, hydrogen fuel cell trucks may play a complementary role in specific applications where battery technology faces operational limitations. This analysis examines the infrastructure requirements for supporting hydrogen-powered long-haul trucks in Maryland, with our methodology and assumptions largely informed by the analysis conducted by the National Renewable Energy Laboratory.[19]

1.5.1 Hydrogen Modeling Methodology

Our hydrogen truck deployment scenario assumes a conservative commercialization timeline that reflects the current state of the technology and manufacturer announcements. As shown in Figure 1.14, we model hydrogen truck commercialization as beginning in 2036, gradually increasing to capture 25% of total zero-emission long-haul tractor truck sales by 2050. This timeline is based on the current proof-of-concept status of hydrogen vehicles and pilot project demonstrations, with products not expected to be widely available until the late 2020s or early 2030s.

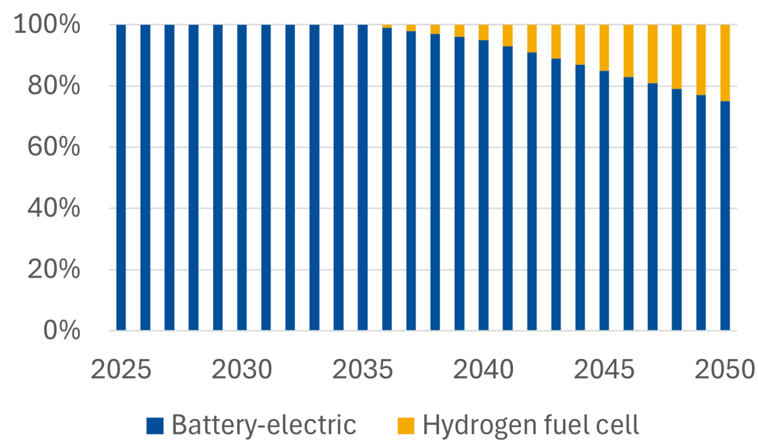

Figure 1.14. Assumed Sales Shares of Zero-Emission Long-haul Tractor Trucks

Several major manufacturers are actively developing hydrogen-powered trucks, though primarily targeting the European market initially. Daimler Trucks and Volvo Trucks are leading hydrogen truck development efforts and are expected to deploy products in the U.S. market when hydrogen fuel economics become more favorable and fleet demand increases.[20,21] Additionally, Cummins, Honda, and Toyota are making significant investments in Class 8 hydrogen-powered tractor trucks.[22–24]

Our analysis focuses exclusively on long-haul trucking as the primary market segment for hydrogen adoption among medium- and heavy-duty vehicles. This assumption reflects our assessment that hydrogen trucks will only be economically viable in situations where heavy loads, long travel distances, and operational constraints—such as unavailable charging infrastructure or inability to park for extended charging periods—make battery-electric trucks infeasible. Current manufacturer development efforts align with this assessment, as they are almost exclusively targeting the long-haul tractor segment.

For fuel consumption modeling, we utilized estimates from Argonne National Laboratory's Techscape portal,[14] which provides "Low" and "High" technology progress scenarios for per-vehicle fuel consumption (kilograms of hydrogen consumed per mile) values for hydrogen fuel cell long-haul tractor trucks in 2025, 2030, 2035, and 2050. In 2050, Argonne National Laboratory's Low and High scenarios represent a 25% and 32% reduction, respectively, in diesel-equivalent fuel consumption for the hydrogen fuel cell long-haul tractor truck compared to a conventional diesel vehicle. We averaged the Low and High hydrogen fuel cell fuel efficiency values and used linear interpolation to calculate consumption for intervening years. Our analysis assumes all hydrogen-powered trucks use fuel cell technology rather than hydrogen combustion engines.

Infrastructure modeling assumptions, based on Bracci et al.,[19] include hydrogen stations with a maximum daily throughput of eight metric tons per day, assuming liquid hydrogen delivery via tank trucks and 700-bar dispensing. All modeled stations are identical in capacity and costs. We assume a 50% utilization rate triggers deployment of additional stations—representing the midpoint of utilization scenarios ranging from 30% to 80%. Each station carries a capital cost of $14.5 million, with operational costs excluded from our analysis. Average vehicle miles traveled data comes from the 2021 Vehicle Inventory and Use Survey.[12]

1.5.2 Hydrogen Results

Figure 1.15 presents our hydrogen modeling results for the Base ACT scenario across four key metrics. The top left panel shows the projected number of long-haul hydrogen trucks in Maryland, demonstrating minimal adoption through 2035 followed by rapid growth beginning in 2036, reaching approximately 2,100 vehicles by 2050. This growth pattern reflects our assumption that commercial hydrogen truck availability will be limited until the mid-2030s, and that beyond the ACT regulation ending in 2035, ZEV adoption continues, reaching 100% of new vehicle sales in 2050.

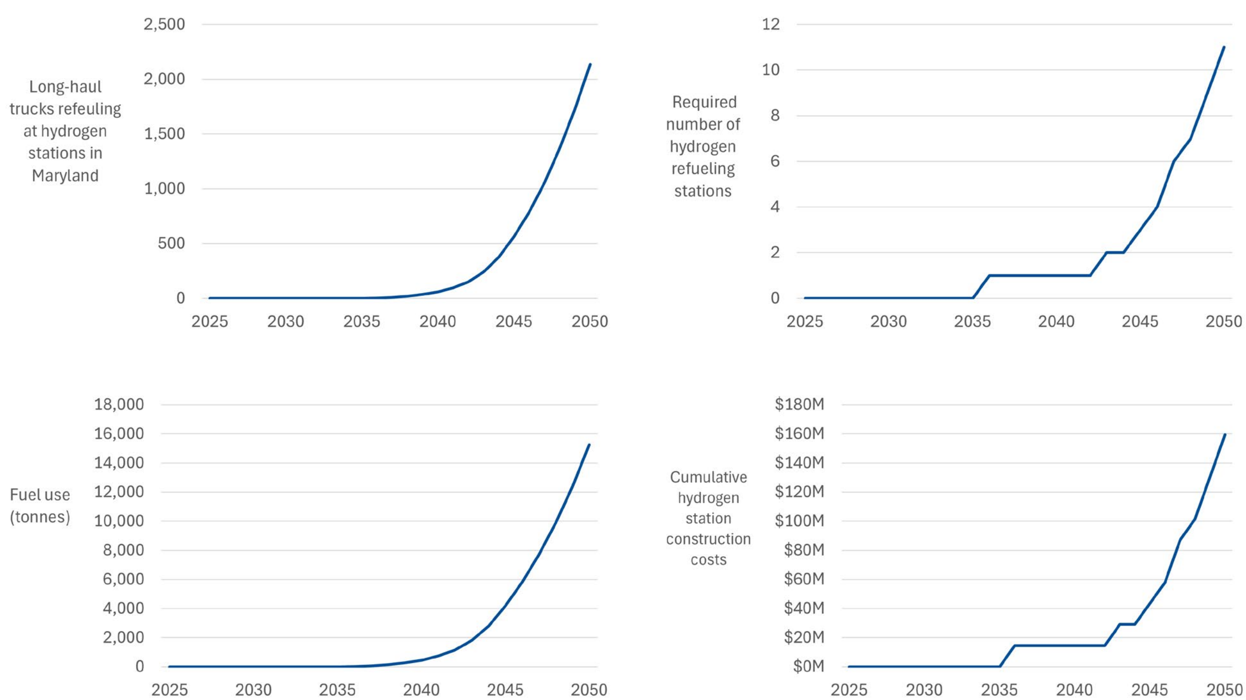

Figure 1.15. Hydrogen Modeling Results for the Base ACT Scenario

The bottom left panel illustrates total hydrogen fuel consumption, measured in metric tons, showing exponential growth from near-zero consumption through 2035 to approximately 15,000 metric tons annually by 2050. The top right panel displays the required number of hydrogen refueling stations to meet this fuel demand, showing a corresponding infrastructure deployment pattern that begins around 2040 and grows to 11 stations by 2050.

Finally, the bottom right panel presents cumulative capital investment requirements for hydrogen refueling infrastructure, reaching approximately $160 million by 2050. This substantial investment requirement underscores the significant financial commitment needed to support even limited hydrogen truck adoption, highlighting the importance of coordinated planning and potentially public-private partnerships to develop this infrastructure efficiently if it indeed becomes needed after 2035.

These results suggest that while hydrogen trucks may serve as a complementary technology for specific long-haul applications, the infrastructure investment requirements are considerable relative to the projected vehicle population, emphasizing the need for strategic deployment focused on high-utilization corridors and coordinated regional planning efforts. We note also that this investment begins in our modeling ten years from today: it will be prudent to investigate the need for these vehicles and fueling infrastructure in the future as BEV ranges and operations improve.

1.6 Charging Station Deployment Timelines

Current charging deployment timelines vary significantly based on project complexity, stakeholder coordination, and local utility processes, with installations ranging from less than a year for simple Level 2 systems to three years or more for complex high-power installations requiring substantial electrical upgrades. Experience among the individual(s) responsible for installing infrastructure may also affect overall project duration.

The experience from light-duty vehicle charging deployment provides important context but also highlights the additional complexities inherent in MHDV charging. Commercial fleets can create concentrated charging demand during specific time windows, requiring additional systems for load management and more complex utility coordination.

1.6.1 Review of Existing Real-World Timelines for Medium and Heavy-Duty Vehicle Charging Deployments

The California Public Utilities Commission's evaluation of utility make-ready programs provides the most comprehensive real-world data on MDHV charging infrastructure deployment timelines publicly available.[25] While California-specific, these findings from the evaluation of nearly 140 MHDV charging infrastructure projects provide initial examples of the kinds of deployment challenges that other states could encounter.

Data from California's utility programs spanning 2021 to 2023 reveal median start-to-finish deployment timelines of 600 to 862 days. The design and permitting phase represents the longest bottleneck, requiring a median of 252 to 344 days, followed by construction at 84 to 133 days. Significant variation exists across vehicle market sectors, with transit bus deployments averaging 956 days compared to 664 days for school buses.[25]

Critical findings include procurement lead-times for equipment such as custom switchgear may extend to nearly a year—consistent with national supply chain constraints during the 2021 to 2023 timeframe which continue to persist in certain instances—and the revelation that original utility estimates of 11 to 19 months significantly underestimated actual deployment durations.

1.6.2 Utility Side Upgrades

Compared to charging infrastructure to support passenger vehicles, MHDV charging can have higher power requirements that can make interconnection more costly and time consuming. MHDV charging may require the following key utility equipment and system upgrades.

1. Distribution transformers (customer and substation)
2. Distribution lines
3. Switchgear and protection equipment

1.6.2.1 Distribution Transformers

Transformers are essential components in any electrical service. The types typically required for larger EV charging installations are often in high demand, necessitating early ordering to mitigate the risk of a delay to the project. Transformers convert electricity from the grid to a usable voltage by stepping voltage down (or up) from one level to another. Transformers are rated in kilovolt-amperes (kVA), which for practical purposes can be considered roughly equivalent to kilowatts (kW) of power delivery (i.e., 1 kVA ≈ 1 kW). Energy is transmitted to substations at what is referred to as transmission or subtransmission voltage level; the voltage of a specific line is determined by factors such as distance and quantity of power to be transmitted, and generally ranges from 110 to 765 kV for transmission and 34.5 to 69 kV for subtransmission. Once a transmission or subtransmission line enters a substation, the power is stepped down to a distribution level voltage, typically 1 kV to 35 kV. Nomenclature as well as voltages vary between utilities, and most customers connect to the distribution system at what is typically referred to as low voltage (1 kV to 35 kV), while some customers take service at medium voltage (typically 69 kV, 115 kV, or 138 kV). Depending on the utility's tariff and the customer's rate, a transformer may be on the utility or the customer side of the meter.

While the framework of customer and substation transformers is useful for explaining most MHDV charging installations, there could be limited cases where it does not fully apply. For example, when a site requires very large amounts of power but is not located near a distribution substation with sufficient capacity, the charging facility could connect directly to transmission or subtransmission lines. This is not common today. In such situations, the "customer transformer" effectively serves as a substation transformer as well, and the site operates with its own dedicated mini-substation.

Customer Transformers

MHD electric vehicle charging infrastructure will require a new or upgraded transformer unless an existing electrical panel or transformer is nearby and has sufficient spare capacity. New or upgraded transformers are typically needed in the following scenarios:

1. **Site upgrade**: At existing facilities, the existing transformer may not have sufficient capacity to handle the additional charging load. In these cases, the utility or customer must install a larger-capacity transformer or add an additional unit to serve the site's needs.

2. **New site or service**: For newly-developed charging sites or where charging equipment is installed far from an existing transformer, a new transformer will be required to connect to a feeder.

Most MHDV charging sites will use pad-mounted transformers rather than pole-mounted units because higher kVA ratings cannot be provided by pole-mounted transformers. Standard (catalog) pad-mounted transformers are typically available in ratings up to a few thousand kVA. For significantly larger capacities or nonstandard voltage classes, custom transformer designs are more common, though these are often associated with transmission or subtransmission connections rather than standard distribution service.

The reported lead time for standard 500 to 1,000 kVA pad-mounted transformers is currently less than six months, which would not typically be a limiting constraint due to fitting in with the typical charging station development process. This period could lengthen, however, due to changes in the market. Moreover, because both finished transformers and key components are often imported, trade policies and Build America Buy America requirements can further increase costs and create acquisition bottlenecks.

Substation Transformers

Substation transformers (also called primary transformers) step down power from the transmission network to medium-voltage feeders that serve end users. These transformers are much larger than typical customer transformers (can exceed 200,000 kVA), though sizes vary by region and demand. A single substation transformer supplies many customers, meaning MHDV charging deployments usually only require new substation capacity when the load they add to the system pushes the existing transformers beyond their limits. When that occurs, utilities typically pursue one of two approaches:

1. **Substation Upgrade:** In most cases, the utility can accommodate new load by adding a new transformer or upgrading an existing one at the serving substation.
2. **Substation Development:** If nearby substations cannot be expanded or upgraded (and if the aggregated charging demand is high enough) the utility may need to

construct an entirely new substation. This is a major investment that requires substantial justification.

Technically, any additional load can be enough to necessitate a substation upgrade if the existing transformers are already operating near their limits. The likelihood that a charging project will trigger an upgrade increases with the site's power demand and the coincidence of the charging site's load profile with local peak. In practice, smaller projects deploying Level 2 chargers (and especially where charging happens outside of peak hours) are unlikely to require substation upgrades. One positive indicator: our modeling suggests that the majority of chargers needed to meet the ACT regulation are Level 2 chargers (though often higher-powered Level 2 chargers than passenger vehicles require).

When they are required, smaller substation transformer lead times range from 45 to 80 weeks, while larger transformer lead times may range from two to five years. However, the other work associated with upgrading a substation may also take a significant period of time, therefore the delay may not necessarily be attributed solely to the transformer. In such cases, the timeline needed for a substation upgrade may render a charging project infeasible.

Both the National Renewable Energy Laboratory and the National Infrastructure Advisory Council note that, while most substation transformers are manufactured domestically, U.S. production capacity is insufficient to scale rapidly in response to rising demand. Demand for new and replacement transformers is expected to grow by as much as 260% by 2050.[26,27] Compounding this challenge, transformers rely on specialized materials (such as electrical steel and other key components) that are primarily sourced from overseas.

1.6.2.2 Distribution Lines

Distribution line (medium-voltage feeder) extensions, upgrades or additions are a necessary component of many MHDV charging projects and a common source of utility delays. Typical interventions include:

1. **Line Extension**: If the site does not yet have electric service, a new branch is constructed from a nearby feeder and extended to the charging site.
2. **Line Upgrade**: If the existing feeder cannot provide sufficient capacity or voltage for the added load, the utility may need to upgrade the feeder, either by reconductoring it for higher capacity or converting it to a higher voltage class.
3. **Feeder Addition**: For very high-power sites, the utility may construct a new (in some cases, dedicated) feeder to reliably serve the charging load.

As with transformers, the need for any given intervention depends on both the project's load and the existing system capacity. Line extensions are common when charging is added at facilities with limited prior electrical demand, while feeder upgrades or additions respond to system constraints and are more typical for larger projects. The resulting impact on deployment timelines varies widely based on site-specific and local factors.

Supplies of conductor materials and components such as utility poles are not typically the primary source of delay for distribution line work. Instead, timelines are more often driven by project complexity and labor availability. Lead times for new or upgraded power lines vary widely and are shaped by local conditions. For example, labor shortages are a common constraint,[28] and in some areas there are few companies with the expertise to perform live line work, which is dangerous but often necessary to avoid service disruptions for other customers.

Local permitting and ordinances can also extend timelines, especially when line extensions cross multiple municipalities or jurisdictions. In some areas, power lines must be placed underground. While this improves safety and resilience, it is significantly more costly and time-consuming than overhead installation.[29]

Finally, site characteristics and surrounding geography can further complicate routing. Remote or rural sites, as well as those in mountainous terrain, can be difficult to reach with new power lines if supporting infrastructure does not already exist.

1.6.2.3 Switchgear and Protection Equipment

Like power lines, switchgear and protection equipment are essential components of utility projects. This equipment allows utilities to divert or shut off power in an emergency. Through systems such as supervisory control and data acquisition (SCADA), utilities can monitor the health of the distribution network through sensors and automation. For EV charging projects, such equipment is needed less frequently than transformers, typically only when existing nodes lack sufficient protection or when new nodes (e.g., feeders, substations) are added to serve a site.

The price of raw materials used in protection equipment has nearly doubled since 2020.[30] Lead times for switchgear have also increased, from an average of 14 weeks pre-COVID to 26–32 weeks today, with the heaviest-duty equipment sometimes requiring up to 80 weeks.[31]

SCADA systems, when used, similarly do not typically cause substantial delays, though future changes in cybersecurity or supply chain regulations could add new requirements. As with line work, labor shortages remain the most common source of delay, with many U.S. regions facing shortages of qualified electricians.[28] On the supply side, manufacturers are expanding production capacity and optimizing supply chains, with some projecting average switchgear lead times could decline to around 24 weeks in the near term.[30] Much of this effort is driven by global demand growth, particularly from the renewable energy sector.

1.6.3 Permitting Complexity

Permitting complexity varies significantly across authorities having jurisdiction (AHJ), with no national standards for EV charging infrastructure permitting. Each AHJ requires unique processes, creating what researchers term "balkanized permitting" that complicates the process for developers operating in multiple jurisdictions.

The permitting challenge is compounded by the lack of established standards for commercial vehicle charging facilities. Fire codes, zoning requirements, and electrical permits often require interpretation and negotiation for each project, as many jurisdictions lack specific provisions for or experience with high-power charging installations. This uncertainty creates risk for developers and can lead to project delays or redesigns late in the development process.

Certain states and cities have implemented or introduced policies to streamline permitting and zoning processes for EV charging infrastructure. For example:

- Colorado's HB 1173 established an expedited permitting process for the approval of EV charging stations for counties and municipalities, and instructed the Colorado Energy Office to develop a model code regarding the approval of charger permits and provide counties and municipalities technical assistance
- Delaware's Administrative Code (Title 22, Ch. 1, Sec. 119) and SB 187 (2022) jointly established that municipalities with populations over 30,000 must have an ordinance that requires the municipality to approve or deny a permit within 90 days of receiving a permit application
- New Jersey's S3223 established a model statewide EV ordinance which considers applications for installation of EVSE or make-ready parking as a permitted accessory use within a given municipality
- California's AB 1236 requires all cities and counties to develop an expedited, streamlined permitting process for EV charging stations by creating an ordinance and official checklist. AB 970 works in tandem by setting specific and binding timelines to the permit review period based on the size of the project

1.6.4 Best Practices for Timeline Optimization

Despite potential energization delays at some sites, utilities, charging providers, and fleets are rapidly and successfully installing charging in Maryland and across the country. Through October 2024, over 1,000 public fast charging ports have opened in Maryland with a nameplate capacity of 246 MW.[15,16] Across the U.S., over 200,000 electric MHDVs are already operating.[32] Helping matters, as shown in our modeling, is that the large majority (90%) of charging ports needed to meet the ACT regulation through its 2035 timeline are Level 2.

Several best practices can help reduce delays and support Maryland's fleets as they electrify.

Early Stakeholder Engagement

Almost universally, the interviewees held the view that early stakeholder engagement represents the most critical success factor across all deployment categories. Successful projects involve utilities, permitting authorities, and electrical contractors during initial site selection rather than after site commitment. This proactive approach allows for identification and resolution of potential issues before they become project delays. ACT regulation sales requirements increase over time, allowing for this kind of forward planning and process improvement over time.

Additionally, proactively engaging with large fleet customers provides utilities with valuable information regarding the anticipated timing of fleet electrification and the addition of new load centers to their distribution networks. This insight enables utilities to effectively plan and allocate resources to meet future demand.

Utility Strategies

Proven effective utility strategies include establishing single points of utility contact for each project, providing hosting capacity transparency through grid mapping tools,[33] and coordinated planning where multiple projects share infrastructure upgrades. Leading utilities maintain transformer and switchgear inventory to reduce procurement delays, recognizing that equipment availability is often the critical path for project completion.

When utilities treat BEV charging as a distinct service category with specialized teams and procedures, deployment timelines can be meaningfully reduced compared to standard commercial interconnection processes.

Process Standardization and Energization Timeline Reductions

Process standardization reduces deployment timelines through model ordinances for municipal permitting, pre-approved equipment lists, and standardized interconnection studies. For example, California's AB 1236 streamlining efforts reduced design revisions through progressive detailed checklists and clearer regulatory requirements.[34] These standardization efforts create predictability for developers and reduce the administrative burden on permitting authorities.

The development of standard design templates and pre-approved equipment configurations can significantly reduce engineering and permitting time. When jurisdictions establish clear requirements and pre-approved solutions, developers can move more quickly through the approval process while maintaining safety and reliability standards.

Beyond municipal-level standardization, legislators and utility regulators play a critical role in improving timelines by developing requirements for simplified, standardized, and prioritized design and installation processes at utilities. Regulatory interventions can employ rules governing maximum wait times for responding to charger project requests, reducing delays that often extend project timelines. Utility regulators can also explore the feasibility of incorporating grid connection timelines into utility cost recovery calculations, require utilities to establish dedicated transportation electrification teams, and mandate utilities to maintain stocks of key equipment to avoid procurement delays.

Recent legislative examples demonstrate these approaches. California's Senate Bill 410, passed in 2023, requires the California Public Utilities Commission (CPUC) to establish reasonable average and maximum target grid connection time periods.[35] Similarly, Colorado's Senate Bill 218, passed in 2024, holds utilities to transparent grid connection deadlines and establishes these timelines as a performance metric in utility cost recovery, creating accountability for meeting established targets.[36]

Interim and Non-Wires Solutions

On-site electricity generation and storage solutions can offer significant timeline advantages over traditional grid-tied installations. Mobile and off-grid charging systems can often be deployed in a matter of weeks compared to the 12 to 36 months typically required for permanent grid-tied infrastructure. These approaches provide valuable interim solutions that allow fleet operators to begin electrification programs without waiting for full grid upgrades to be completed.

Beyond their role as temporary bridges, non-wires solutions (NWS) can also reduce or defer the need for traditional utility investments. Battery-based charging systems can serve fleets directly while also providing grid services such as peak shaving, load shifting, and demand management. These capabilities can improve the value proposition for both customers and utility partners. In some cases, on-site renewable generation such as solar PV can further offset grid demand, while hybrid systems that combine storage, generation, and smart charging strategies can increase resiliency and flexibility.

Charging station operators should also discuss expectations of peak load with their utilities. This can be useful in situations where the cumulative nameplate load of chargers exceeds the readily available capacity, resulting in a costly or long upgrade. However, sometimes the utility will agree to provide the total requested capacity sooner or at lower cost on the condition that the customer reduce their load periodically, for example on peak days or when a grid emergency is declared.

In practice, these solutions are most effective as complements to long-term infrastructure development. For smaller or early-stage deployments, interim and non-wires approaches can enable electrification to move forward quickly.

Utility Advance Preparation for New Loads

Distribution system-level constraints, such as near-capacity distribution lines and substation transformers, can derail projects when utilities must respond to requests for new or expanded service that exceed available capacity. In many cases, this triggers lengthy upgrade projects that delay or defer deployment.

One way to shorten these timelines is for utilities to proactively reinforce grid assets in areas where capacity is already constrained or expected to become strained by MHDV charging. By building ahead of projected demand, fewer MHDV facilities would face capacity limits at the time they are ready to invest in electric vehicles and their associated charging infrastructure.

Maryland is currently finalizing an electric system planning regulation that requires utilities to develop distribution plans anticipating EV charging loads, along with other new sources of demand. These plans will help identify potential system constraints that can then be addressed through investments approved in future rate cases.[37] While this is a step forward, there may be opportunities for further innovation.

For example, New York recently approved a long-term proactive planning framework that goes beyond traditional planning. It combines load projections with a dedicated process, separate from normal rate cases, where utilities can propose and gain approval for eligible projects. This approach aims to shorten the gap between identifying constraints and authorizing projects.[38] Maryland could consider this model as a natural evolution from a planning-focused process toward one that links planning more directly with investment. Such a shift could enable more timely proactive investment and reduce the number of projects stalled by system-level limits.

Proactive investment, however, carries risks. If projected demand does not materialize, the result may be overbuilt infrastructure that increases costs without delivering benefits, referred to in the industry as a stranded asset. For that reason, proactive investment should be undertaken with caution, ensuring that it improves service while preserving affordability.

It is also important to note that while proactive planning can address distribution system-level constraints, utilities do not have the data to reliably predict exactly when individual customer sites will choose to electrify. Thus, while proactive planning can shorten timelines by removing system constraints, individual sites will still need to wait for line extensions and customer transformers when they choose to electrify. Proactive communication as early as possible between sites and utilities can help reduce these wait times.

Chapter 2: Electrical Grid Impacts

Authors: Ben Sharpe, James Di Filippo, Himangshu Kumar, Lucy McKenzie, Dan Wilkins, Alicia Zhao, Kowan O'Keefe

Chapter at a Glance:

- The cumulative investment needed for charging equipment, installation, and utility-side make-ready in our Base ACT Scenario is $805 million (in 2025 dollars) by 2035. This represents total investment across all parties: private sector, utilities, and government, and should be balanced against the significant benefits brought by the transition to zero-emission transportation.
- Maryland would need a steady but manageable increase in electricity generation to meet the demands imposed by additional electric commercial vehicles. Implementing the ACT regulation is estimated to result in a roughly 2.5% increase in total statewide electricity consumption by 2035, and 5% by 2050 to support 100% ZEV sales. The increase in peak electricity loads due to commercial vehicle charging would be between 1.1% and 1.5% in 2035 (with the range depending on fleets' ability to manage their charging away from system peak). This represents an average increase of 0.1% per year in peak load, compared with the Maryland Public Service Commission's forecast of 1.3% annual growth in summer peak load through 2033.
- We model hydrogen vehicle uptake limited to the long-haul tractor truck segment and starting in 2036 as one option to meet 100% ZEV sales by 2050. Under these assumptions there would be roughly 2,000 hydrogen trucks that require roughly 15,000 metric tons of fuel annually by 2050. This would require cumulative investment of $160 million across private and public sectors to support a network of 11 hydrogen stations located along highway corridors in the state. Policymakers and planners should continue to monitor battery electric and hydrogen vehicle technologies and costs as this timeline approaches.

Introduction

In this chapter, we analyze the impacts to Maryland's electrical grid resulting from implementation of the Advanced Clean Trucks (ACT) regulation. This comprehensive assessment builds upon extensive modeling by the University of Maryland's Center for Global Sustainability and leverages real-world operations data to project growth in energy and power demand across Maryland's utility service territories. As shown in Figure 2.1, the analysis employs a six-step methodology that integrates a literature review, grid projections, county-level charging infrastructure needs distribution, hourly load modeling, and peak demand assessment.

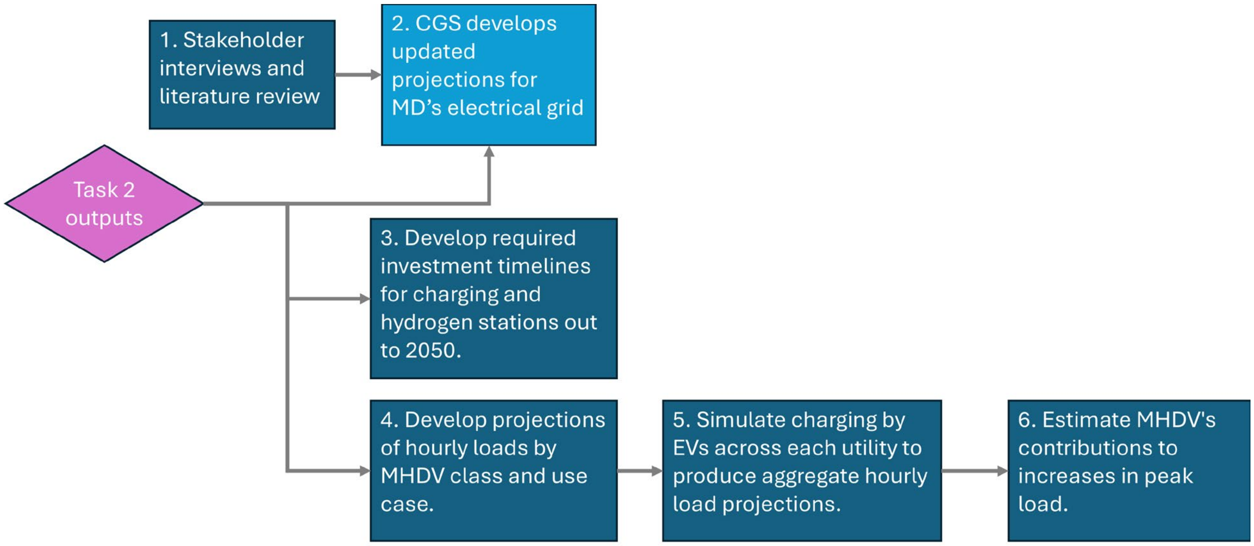

Figure 2.1. Overview of methodology

By examining how MHDV electrification will affect each utility's operations and capacity requirements, this work provides critical insights for infrastructure planning and investment strategies. The findings inform the estimated timing, location, and magnitude of grid upgrades needed to support Maryland's transition to zero-emission commercial transportation under scenarios where the ACT regulation is implemented as originally codified in the Clean Trucks Act of 2023.

2.1 Literature Review of Maryland's Electrical Grid

The electrification of Maryland's medium- and heavy-duty vehicle fleet under the ACT regulation represents a challenge that must be understood within the broader context of the state's evolving electrical infrastructure. This literature review examines recent studies and reports that provide essential insights into Maryland's current grid capacity, projected energy demands, and the anticipated impacts of transportation electrification. The analysis synthesizes findings from utility-specific studies, statewide assessments, and policy documents to establish a comprehensive foundation for understanding how MHDV electrification will interact with Maryland's electrical system.

2.1.1 Overview of Maryland's Electrical Grid

Maryland is home to 11,924 MW of installed generation capacity, dominated by natural gas and nuclear generation.[10] The state imports approximately 43% of its consumed electricity and faces accelerating demand growth driven by data centers, electrification initiatives, and steady population expansion. Maryland's population is currently 6.3 million and is forecasted to reach roughly 6.7 million residents by 2040.[39]

Grid Infrastructure and Electricity Imports

Maryland's generating assets produce about 36,000 GWh annually. The state is a founding member of PJM Interconnection since 1956, functioning within a regional wholesale electricity market serving 65 million customers across 13 states and the District of Columbia. Maryland imports roughly 26,000 GWh annually, making it heavily dependent on electricity from Pennsylvania, Virginia, and West Virginia through the PJM network. This import dependency has ranged from 33% to 45% annually over the past decade.[10]

Population Trends and Growth Projections

Maryland's population reached 6.26 million in 2024, representing 17.9% growth since 2000.[40] Official projections from the Maryland Department of Planning indicate annual growth rates of 0.5 to 0.7% through 2035, concentrated primarily in the Baltimore-Washington corridor.[39] Regional population distribution heavily influences electricity demand patterns, with Montgomery County leading at 1.1 million residents and Southern Maryland showing the fastest projected growth between 0.9 and 1.1% annually through 2035.[39]

Generation Mix Transformation

Maryland experienced a historic milestone in 2023 when natural gas generation exceeded nuclear for the first time, marking a fundamental shift in electricity supply.[41] Natural gas now provides 41.0 to 42.5% of in-state generation (approximately 15,000 GWh), narrowly surpassing nuclear at 40.0 to 41.6%. Solar generation has expanded dramatically, increasing 575% since 2014 to reach nearly 2,400 GWh, while coal generation has decreased to below 5% of the generation mix.[41]

Peak Load Growth

Maryland's peak electricity demand showed modest growth of 0.1 to 0.3% annually from 2014 to 2019, followed by COVID-19 impacts and subsequent recovery acceleration.[42] PJM's 2025 Long-Term Forecast projects robust demand acceleration, reflecting multiple convergent factors including data center development, building sector electrification, and electric vehicle adoption.[42] Combined state peak load reached approximately 16 GW in 2024.[43] In their most recent 10-year plan for electric utilities in Maryland from December 2024, the Public Service Commission forecasts 1.3% annual growth in summer peak load through 2033, bringing peak load to 17.9 GW.

Electric Utility Rankings and Market Structure

Figure 2.2 shows electric utility service territories.[44] Table 2.1 shows the approximate number of electricity customers and energy delivered for the five largest utilities in the state.[41]

Baltimore Gas & Electric (BGE) dominates Maryland's utility landscape with approximately 29,000 GWh of annual electricity delivery, serving 1.3 million customers across northern and central Maryland. Potomac Electric Power Company (Pepco) ranks second with 13,000 GWh delivered to 603,000 Maryland customers in Montgomery and Prince George's Counties. Potomac Edison serves 291,000 customers in Western Maryland with 7,000 GWh annually. Delmarva Power delivers 4,000 GWh to 215,000 customers on the Eastern Shore, while Southern Maryland Electric Cooperative (SMECO) provides 3,000 GWh to 177,000 cooperative members in Southern Maryland.

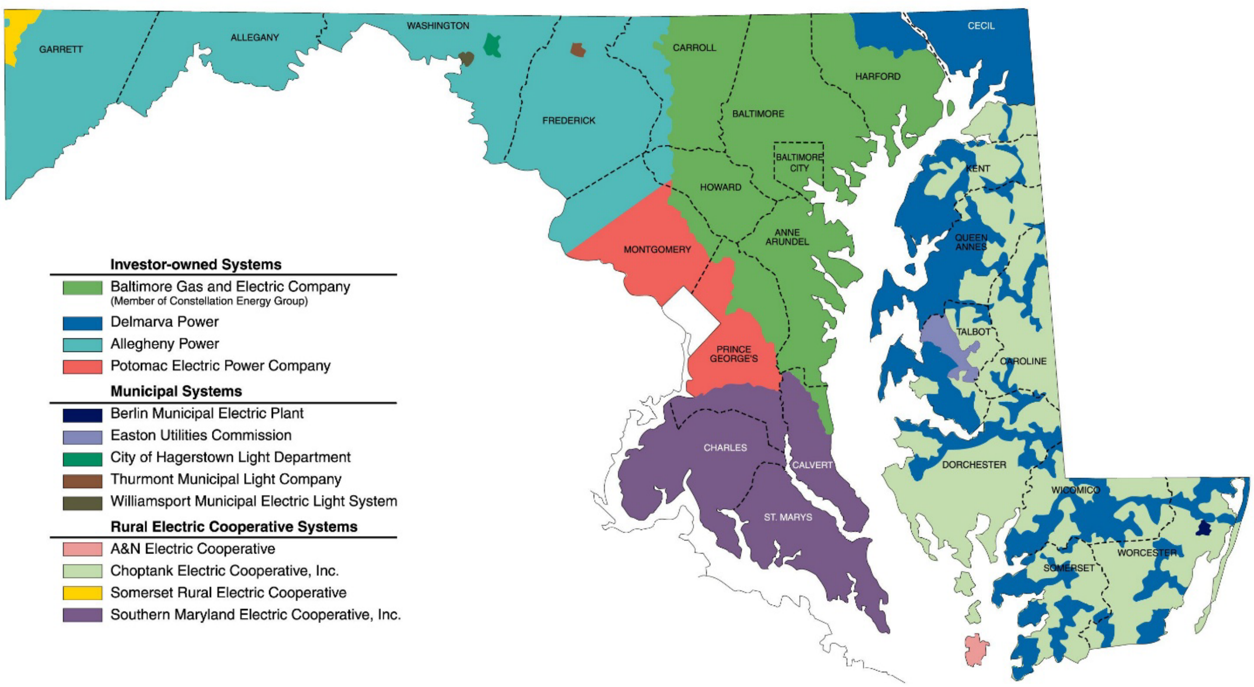

Figure 2.2. Electric Utility Service Territories in Maryland

Utility	Total Customers	Annual Energy Delivered (GWh)
Baltimore Gas & Electric	1,343,000	29,000
Potomac Electric Power Company	603,000	13,000
Potomac Edison	291,000	7,000
Delmarva Power & Light	215,000	4,000
Southern Maryland Electric Cooperative	177,000	3,000

Table 2.1. Number of Customers and Energy Delivered by Maryland's Five Largest Utilities

Modeling Simplification for This Study

As shown in Figure 2.3, this study focuses on Maryland's five largest electric utilities by electricity delivered, representing approximately 95% of total state electricity consumption.[10] This modeling simplification enables detailed analysis while maintaining analytical precision for the large majority of Maryland's electrical demand. The excluded smaller utilities - including Choptank Electric Cooperative and municipal systems in Hagerstown, Easton, Berlin, Thurmont, and Williamsport - collectively serve less than 5% of state electricity demand. This approach allows for comprehensive assessment of ACT regulation impacts on Maryland's electric grid while focusing analytical resources on the utilities serving the majority of commercial and industrial customers most likely to be affected by ACT requirements.

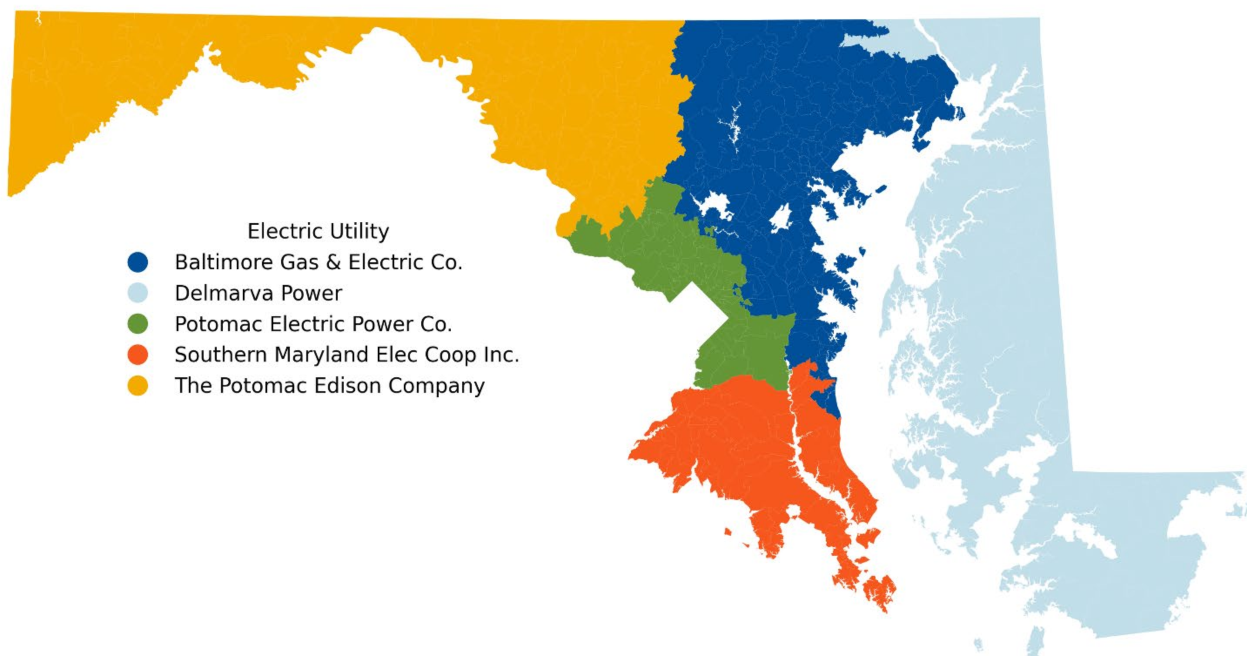

Figure 2.3. Simplified Electric Utility Service Territories

2.1.2 Brattle (2021): An Assessment of Electrification Impacts on the Pepco DC System

The Brattle Group's 2021 assessment of electrification impacts on the Pepco DC system provides valuable insights into grid capacity and demand projections for the greater Washington metropolitan area, encompasses significant portions of Maryland's electric utility infrastructure.[45] This study examined how widespread electrification of transportation and buildings would affect system operations, peak demand patterns, and infrastructure requirements.

The analysis projected substantial growth in electricity demand driven by vehicle electrification, with particular attention to the timing and magnitude of peak load increases. The study assumes 100% of light-duty vehicles, over 75% of medium-duty vehicles, and over 50% of heavy-duty vehicles are electrified by 2050. A key finding was that transportation electrification could add approximately 500 MW to peak demand by 2050 in the Pepco service territory. However, the study emphasized that energy efficiency measures and load flexibility programs could significantly mitigate these impacts, potentially reducing 2050 peak demand by 14% to 2,740 MW compared to the 3,180 MW of peak load in 2050 in the electrification scenario.

The study highlighted critical timing considerations, noting that unmanaged electrification could shift system peak demand to winter mornings when solar generation is limited. This potential seasonal shift has important implications for resource planning and grid reliability, particularly as Maryland pursues its clean energy mandates. The analysis demonstrated that coordinated demand response and managed charging programs could reduce winter morning peaks by 5% to 10%, providing valuable time for new clean capacity deployment.

While the Brattle study focused primarily on the District of Columbia system and did not specifically address the ACT regulation's impacts, its methodological approach and findings regarding electrification timing challenges provide important context for Maryland's broader grid planning efforts. The study's emphasis on managed charging and demand response as critical tools for managing electrification impacts directly informs approaches for MHDV charging infrastructure deployment.

2.1.3 Energy and Environmental Economics (E3) (2022): BGE Integrated Decarbonization Strategy

Baltimore Gas and Electric's Integrated Decarbonization Strategy, developed by E3, is a utility-specific analysis of electrification impacts in Maryland.[46] As BGE serves approximately half of Maryland's electricity customers, this study provides critical insights into how the state's largest utility anticipates managing the transition to widespread electrification.

The analysis projected growth in BGE's electrical load, with total consumption increasing 30% to 51% between 2020 and 2045 across different decarbonization scenarios. More significantly for grid planning, peak demand was projected to increase 66% to 150% over the same period, driven primarily by electrification of transportation and building heating.

The study employed E3's comprehensive modeling framework, which integrated economy-wide energy demand projections with detailed utility system analysis. The methodology considered multiple decarbonization pathways, including scenarios with varying levels of electrification adoption and alternative energy delivery systems. This approach allowed for assessment of how different policy choices and technology deployment patterns could affect overall system costs and infrastructure requirements.

The research quantified the investments required to accommodate increased electrical loads, providing essential data for understanding the financial implications of rapid electrification. The study found that transmission and distribution capacity costs could range from $203 to $258 per kW-year.

The BGE analysis also examined the transition from summer to winter peak demand patterns, projecting that winter morning peaks would become the system constraint around 2026-2027. This shift aligns poorly with solar generation patterns and emphasizes the importance of energy storage, demand response, and other flexible resources for maintaining grid reliability during the electrification transition.

2.1.4 Maryland Public Service Commission (2024): Ten-Year Plan (2024-2033) of Electric Companies in Maryland

The Maryland Public Service Commission's Ten-Year Plan provides a comprehensive statewide perspective on Maryland's electrical infrastructure development through 2033.[47] This annual compilation integrates information from all Maryland electric utilities and offers essential baseline data for understanding current system capacity and planned improvements.

The plan established that statewide summer peak demand was 13.7 GW in 2024 net of demand side management programs (DSM), with projections indicating growth to 15.2 GW by 2033 net of DSM. However, this aggregate figure masks significant variation among utility service territories. Pepco's Maryland service area anticipates approximately 6.9% growth in summer peak demand between 2024 and 2033, while BGE projects a summer peak demand growth of approximately 5.5%.

The document provides detailed forecasts of summer and winter peak demand growth across all Maryland utilities, offering critical insights into system-wide capacity requirements. These projections incorporate various factors including economic growth, energy efficiency programs, and initial stages of transportation and building electrification. The granular utility-specific data enables analysis of regional variations in demand growth and infrastructure needs.

Energy delivery projections in the Ten-Year Plan help gauge overall electricity consumption trends and system expansion requirements. The plan documents proposed generation additions and transmission upgrades across Maryland's utilities, providing insight into the substantial infrastructure investments already planned to meet baseline growth.

The plan's documentation of proposed infrastructure projects demonstrates that utilities and system planners have identified critical capacity constraints and are working to address them proactively.

2.1.5 Brattle (2023): An Assessment of Electrification Impacts on the Maryland Electric Grid

The Brattle Group's 2023 statewide assessment represents the most recent and comprehensive analysis of electrification impacts across Maryland's electrical grid.[48] This study expanded the methodological approach from the earlier Pepco-focused analysis to examine electrification effects on all Maryland utilities.

The analysis employed Brattle's Decarbonization, Electrification, and Economic Planning (DEEP) model to project electric load based on detailed scenarios for heat pump adoption, electric vehicle deployment, distributed energy resources, energy efficiency, and load flexibility. The modeling framework was calibrated to each Maryland utility system, enabling utility-specific projections while maintaining consistency in analytical approach.

A key finding was that statewide peak demand could remain within historical growth patterns if two key conditions are met: fleets shift most depot charging to off-peak hours, and utilities complete necessary local feeder upgrades where MHDV charging clusters develop.

The study incorporated ACT regulation compliance timelines, projecting that Class 2b-3 vehicle and Class 7 and 8 tractor sales would reach 35% zero-emission by 2031, while Class 4 through 8 non-tractor truck and school bus sales would achieve 55% zero-emission by the same year. Under these adoption scenarios, the analysis estimated that, by 2031, 8% of Class 2b-3 vehicles and Class 7-8 tractors on the road would be zero-emission, along with 13% of Class 4-8 non-tractors and school buses.

This study found that the distribution system could likely accommodate projected electrification growth through 2031. However, the study emphasized that localized distribution network upgrades would be necessary in specific areas experiencing concentrated demand. Importantly, the analysis did not extend beyond 2031 nor did it assess potential impacts to the bulk power system or transmission infrastructure. The distribution network constraints identified as the primary challenge for MHDV electrification include feeders serving freight corridors, urban depots connected to aging secondary networks, and transit bus yards where multiple vehicles converge simultaneously. The study's key finding was that bulk system capacity would not be the limiting factor for electrification; rather, targeted distribution upgrades at these localized high-demand sites represent the critical infrastructure requirement for successful implementation.

2.1.6 Maryland Department of the Environment (2023): Climate Pollution Reduction Plan

Maryland's Climate Pollution Reduction Plan describes the policy framework within which ACT implementation must occur, identifying specific strategies for achieving economy-wide decarbonization and interim greenhouse gas reduction targets established in the CSNA.[11]

The plan projects significant contributions to Maryland's overall emission reduction goals from the ACT regulation. The transportation sector analysis estimated that projected electric vehicle projections under Advanced Clean Cars II and ACT could deliver 6.6 million metric tons of CO_2 equivalent reductions in annual emissions by 2045, representing a substantial portion of the state's climate commitments. The plan's modeling incorporated federal policies including the Inflation Reduction Act, Clean Air Act regulations, and various clean energy tax credits.

Particularly relevant for grid planning is the plan's proposed requirement that 100% of Maryland's retail electricity sales come from "clean" sources by 2035. Planned additions include 8.5 GW of offshore wind by 2031 and 3 GW of storage by 2033.

The plan also addressed infrastructure timing challenges, noting that lead times for high-capacity transformers and other critical equipment can extend 18 to 24 months. This timing constraint means that equipment orders must be placed well in advance of actual deployment needs.

2.1.7 Maryland Department of Transportation (2023): Climate Pollution Reduction Plan

MDOT's Climate Pollution Reduction Plan provides perspective on ACT implementation, offering detailed analysis of vehicle adoption scenarios, fleet turnover patterns, and charging infrastructure deployment requirements.[49] This plan translates the ACT regulation's sales percentage requirements into specific vehicle retirement and replacement projections for Maryland. The plan's vehicle adoption modeling projected that ACT compliance would result in retirement of approximately 5,800 medium-duty and 3,200 heavy-duty diesel vehicles by the mid-2030s. These projections provide the foundation for estimating charging infrastructure needs and associated electrical demand growth. The analysis incorporated realistic fleet turnover patterns and acknowledged the complexity of coordinating private fleet decisions with regulatory requirements.

MDOT's analysis emphasized the importance of corridor charging infrastructure for supporting long-haul trucking operations that pass through Maryland but may not be registered in the state. The plan identified this as a critical gap in charging infrastructure planning, as traditional approaches based on vehicle registration data may underestimate corridor charging needs.

The plan documented substantial needed investment in ZEV adoption, as well as a wide range of other technological, behavioral, and operational interventions for the transportation sector. Altogether, MDOT estimated costs of $21.7 billion to $33.9 billion for comprehensive transportation sector strategies through 2031.

Particularly important for grid planning is the plan's recognition that hydrogen fuel cell vehicles may play a role in specific applications, particularly long-haul freight operations.

While the plan projected that battery electric technology would provide the majority of ACT compliance, it acknowledged that hydrogen infrastructure development could create additional electricity demand through electrolysis requirements.

2.1.8 Synthesis of Literature

The literature review reveals several themes that will shape ACT implementation and its impacts on Maryland's electrical grid. First, the timing and location of MHDV charging infrastructure deployment emerges as important. Multiple studies emphasize that distribution network constraints, particularly along freight corridors and at depot locations, represent the primary grid infrastructure challenge, rather than generation capacity.

Load Outlook and Growth Projections

Maryland's electric system faces substantial growth in demand across all scenarios examined in the literature. University of Maryland modeling anticipates statewide electricity sales climbing over 50% between 2020 and 2045. The Public Service Commission's official Ten-Year Plan projects statewide summer peak demand growth from 13.7 GW in 2024 to 15.2 GW by 2033, but longer-term studies project more substantial increases. BGE's analysis shows potential peak demand growth of 66% to 150% by 2045 compared to 2020.

These projections reveal a pattern of modest growth through the current decade followed by steeper increases beginning in the early 2030s. The coincidence of MHDV adoption with broader electrification trends emphasizes the importance of integrated planning.

Seasonal Peak Transitions and Generation Resource Planning

A consistent finding across multiple studies is the anticipated transition from summer to winter peak demand patterns, with the crossover expected in the 2026 to 2027 timeframe. This shift results from increased adoption of electric heating technologies and EV charging patterns that align poorly with solar generation availability. The transition highlights the particular value of storage and load shifting solutions if the state pursues 100% of electricity consumption being served by clean electricity by 2035.

Distribution Network Constraints and Infrastructure Requirements

The literature consistently identifies distribution system upgrades as the critical grid infrastructure requirement for successful ACT implementation. Three studies specifically highlight common problem areas: feeders serving freight corridors, urban depots connected to aging secondary networks, and transit bus yards serving multiple vehicles simultaneously. Johns Hopkins University research documenting Baltimore-area feeders operating within 10% of thermal limits on winter mornings provides specific evidence of some existing capacity constraints.

The Public Service Commission's documentation of new transmission lines and substations in development demonstrates proactive planning but also highlights the need to further plan ahead for long lead times required for major infrastructure projects.

Managed Charging and Demand Response Critical Success Factors

Multiple studies emphasize that managed charging programs and demand response capabilities are essential for keeping ACT-related electricity demand within manageable bounds. Brattle's finding that coordinated programs could flatten winter morning peaks by 5% to 10% demonstrates the substantial value of these approaches. The literature suggests that unmanaged charging could contribute to system reliability challenges, while well-designed programs could help optimize infrastructure utilization.

Evidence Gaps and Analysis Limitations

Despite the comprehensive scope of available studies, several critical gaps remain. None of the reviewed reports provides feeder-level or substation-level forecasting of MHDV charging loads, limiting precision in infrastructure planning. Cost estimates for megawatt-scale depot interconnections, corridor charging facilities, and hydrogen electrolysis equipment are either embedded in broader categories or excluded entirely.

Additionally, the potential interaction between ACT implementation and emerging high-demand uses such as data centers and artificial intelligence applications has not been systematically analyzed.

2.1.9 Contributions of this Study

This analysis will address several gaps in the existing literature.

While existing studies provide valuable statewide and utility-level projections, this analysis will deliver county-level and utility-specific assessments of charging infrastructure needs and associated electricity demands.

Our methodology will produce hourly load projections aggregated over all MHDV classes and types, providing utilities with an important input for operational planning and capacity assessment.

Our analysis provides estimates of the level of investment needed for charging infrastructure, by power level, charging location, and infrastructure type.

This study will provide the largest Maryland utilities with projections of how ACT implementation will affect their specific peak demands and infrastructure requirements.

Addressing Infrastructure Timing and Lead-Time Challenges

This study will provide specific timelines for infrastructure deployment requirements, incorporating realistic lead times for equipment procurement, permitting, and construction. By aligning these timelines with projected fleet adoption schedules, we will identify potential timing mismatches that could create implementation challenges and recommend strategies for avoiding or mitigating these issues.

Our analysis will also examine the implications of potential delays in either fleet adoption or infrastructure deployment, providing contingency planning information for managing implementation risks. This forward-looking approach addresses the literature's noted concern about timing challenges and provides actionable guidance for maintaining implementation momentum.

Framework for Ongoing Monitoring and Adaptive Management

Finally, this study will establish a framework for ongoing monitoring of ACT implementation progress and adaptive management of infrastructure deployment strategies. By providing baseline projections and identifying key performance indicators, we will enable Maryland to track implementation progress and adjust strategies as needed based on actual adoption patterns and infrastructure performance.

This adaptive framework acknowledges the uncertainty inherent in large-scale technology transitions and provides Maryland with the tools needed to maintain implementation effectiveness as conditions change over time. The framework will support evidence-based decision-making and help ensure that ACT implementation achieves its intended objectives while maintaining grid reliability and managing costs effectively.

2.2 Impacts to the Electrical Grid from Electric Medium- and Heavy-Duty Vehicle Adoption

For this part of the analysis, we partnered with the University of Maryland's Center for Global Sustainability (CGS). In this section, we first provide a short overview of CGS' Global Change Analysis Model for the United States (GCAM-USA) tool. A more in-depth description of GCAM-USA can be found in the Modeling Appendix of Maryland's Climate Pollution Reduction Plan.[50] Then, we describe the results of the GCAM-USA modeling. Note that these results are associated with the Base ACT scenario developed by Atlas Public Policy (see Chapter 1 for a discussion of the scenarios developed for this study), and the "Current Policies" scenario developed by CGS for Climate Pollution Reduction Plan.

2.2.1 GCAM-USA Model Description

The University of Maryland's Center for Global Sustainability utilized the GCAM-USA model to assess statewide electrical grid impacts from ACT regulation implementation. GCAM-USA is an integrated assessment model that disaggregates the U.S. energy system into 50 states and the District of Columbia while maintaining detailed global representations for other regions.

For electric grid modeling, GCAM-USA represents the complete electricity value chain from primary energy resources through final consumption. The model includes detailed representations of generation technologies spanning fossil fuels (coal, natural gas, oil), renewables (solar, wind, hydropower), nuclear, and bioenergy sources. It represents regional electricity markets and state-specific grid characteristics, enabling analysis of electricity import dynamics. The model operates as a market equilibrium system, solving for electricity supply and demand balance across five-year time increments while accounting for technology vintaging, where aging equipment is retired and replaced with new capacity to meet evolving demand patterns. This framework enables assessment of how transportation electrification policies influence electricity generation mix, capacity requirements, and interstate power flows.

2.2.2 Electricity Consumption and Generation Impacts

GCAM-USA modeling reveals modest electricity consumption increases from ACT implementation across Maryland. Figure 2.4 shows the estimated electricity consumption in Maryland both with and without ACT implementation. Statewide electricity consumption is projected to reach roughly 74,600 GWh by 2030 with ACT versus nearly 74,000 GWh without ACT, representing a 600 GWh (0.8%) increase. This difference grows over time, with consumption reaching about 108,900 GWh with ACT by 2050 compared to 103,700 GWh without ACT, indicating a 5,200 GWh (5.1%) increase attributable to the implementation of the ACT regulation.

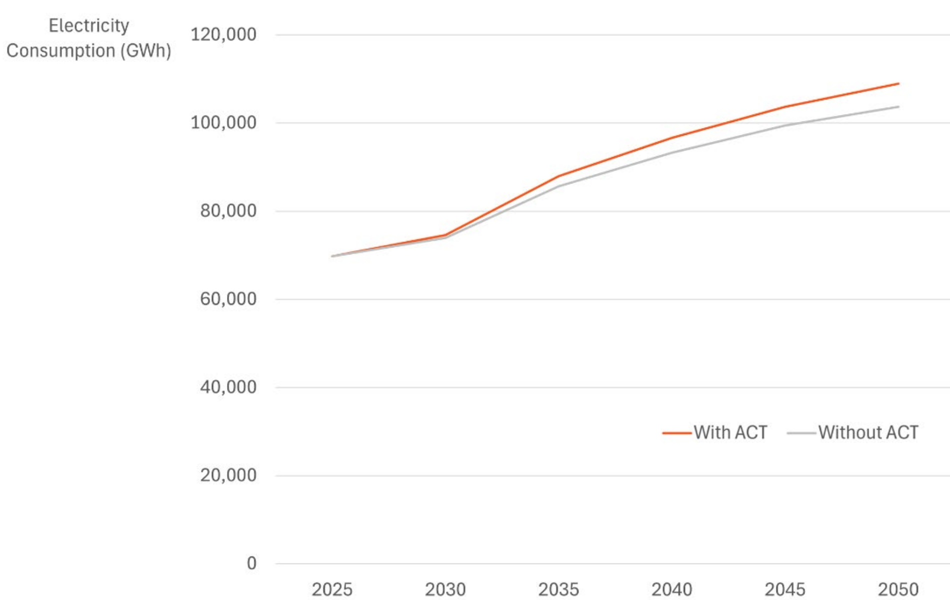

Figure 2.4. Statewide electricity consumption impacts, ACT Base Case (ACT through 2035, then to 100% electric MHDV sales by 2050) vs no ACT regulation

Maryland would need a steady increase in electricity generation to meet the demands imposed by additional electric commercial vehicles. In Figure 2.5, the stacked area chart represents the additional electricity generation contribution from imports, renewables, and natural gas, and the orange line is the annual percent increase in electricity generation from implementing the ACT, as well as continued ZEV adoption to 100% of new sales by 2050. As shown with the orange line in the figure, by 2050 electricity generation would be about 5% greater due to compliance with the ACT regulation. By 2050, the additional generation requirement reaches approximately 5,200 GWh annually. If we assume that MHDVs are the marginal load added to the system, imports are projected to provide roughly 4,800 GWh, renewables 300 GWh, and natural gas 200 GWh.

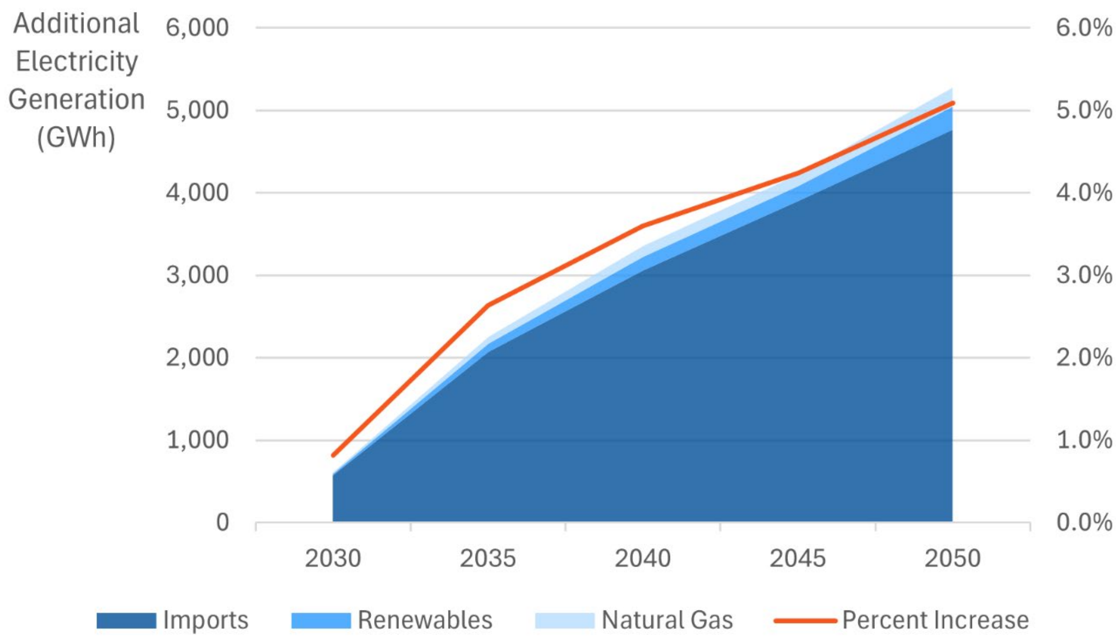

Figure 2.5. Additional sources of electricity generation resulting from the implementation of the ACT regulation, assuming ACT vehicles are the marginal load

2.3 Charging Energy Consumption and Costs

This section examines the financial requirements for deploying charging infrastructure across different power levels and installation contexts, while analyzing projected electricity consumption patterns from medium- and heavy-duty electric vehicles. The modeling and analysis in the remainder of this chapter was performed by Atlas Public Policy.

2.3.1 Electricity Consumption from Battery-Electric Vehicles

Figure 2.6 illustrates the projected annual energy consumption by Maryland's zero-emission MHDV fleet, growing from roughly 1,000 GWh in 2035 to approximately 5,000 GWh by 2050. Class 7-8 tractors dominate energy consumption despite representing the smallest vehicle population, reflecting their long-distance routes, high energy demands and intensive operational patterns. By 2050, tractors account for 2,560 GWh or about 51% of total MDHV energy consumption, while Class 4-8 trucks contribute 1,552 GWh and Class 2b-3 vehicles 847 GWh.

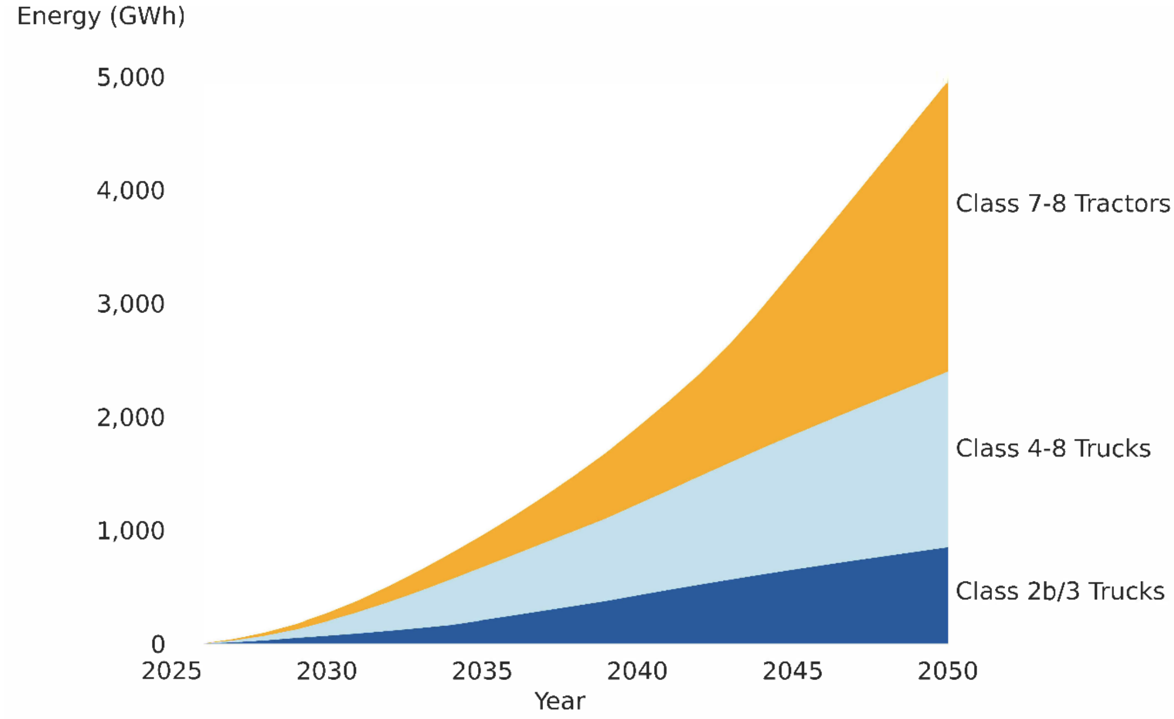

Figure 2.6. Annual Electricity Consumption by ACT Vehicle Category for the Base ACT Scenario

2.3.2 Charging Infrastructure Costs

The per-port charging infrastructure costs presented in Table 2.2 reflect an analysis of equipment, installation, and utility-side infrastructure requirements across different power levels and deployment contexts. These cost estimates are derived from a literature review and real-world data from state agencies and industry stakeholders, with the Maine Department of Transportation's Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles serving as a particularly important reference for our analysis.[51]

The table reveals significant variation in costs across the power levels, with per-port costs ranging from about $5,500 for basic 7 kW installations to $887,500 for megawatt-powered enroute chargers. Utility-side infrastructure represents the largest cost component for higher-power installations, reflecting the substantial grid upgrades required. Installation costs also increase dramatically with power level, particularly for enroute applications where site preparation and electrical infrastructure requirements may be more challenging.

Location	Charger Power (kW)	Per port Equipment Cost	Per port Installation Cost	Per port Utility Make Ready Cost	Total Cost
Depot	7	$1,197	$2,950	$1,400	$5,547
	11	$1,835	$2,950	$2,200	$6,985
	19	$2,602	$2,950	$3,800	$9,352
	50	$28,401	$10,000	$11,650	$50,051
	150	$75,000	$18,750	$34,950	$128,700
	350	$140,000	$48,000	$105,000	$293,000
	500	$200,000	$68,571	$150,000	$418,571
Enroute	350	$140,000	$57,000	$140,000	$337,000
	1,000	$350,000	$87,500	$450,000	$887,500
Private Residence	7	$1,197	$900	$1,400	$3,497
	11	$1,835	$1,270	$2,200	$5,305
	19	$2,602	$2,010	$3,800	$8,412

Table 2.2. Per-port charging infrastructure costs (2025 dollars)

Table 2.3 and Figure 2.7 illustrate the investment requirements for Maryland's charging infrastructure under the Base ACT scenario, with cumulative costs derived from multiplying the per-port costs in Table 2.1 by the port deployment totals presented in Section 1.4.2. Total investment needs grow from $212 million in 2030 to $4.5 billion by 2050, reflecting the accelerating pace of ZEV adoption and infrastructure deployment.

Charging Location	2030	2035	2040	2045	2050
Depot	113	402	728	1,066	1,385
Enroute	83	349	810	1,667	2,866
Residence	15	54	120	190	252
Total	**212**	**805**	**1,658**	**2,924**	**4,503**

Table 2.3. Cumulative charging infrastructure investment need for the Base ACT scenario ($ million, 2025 dollars)

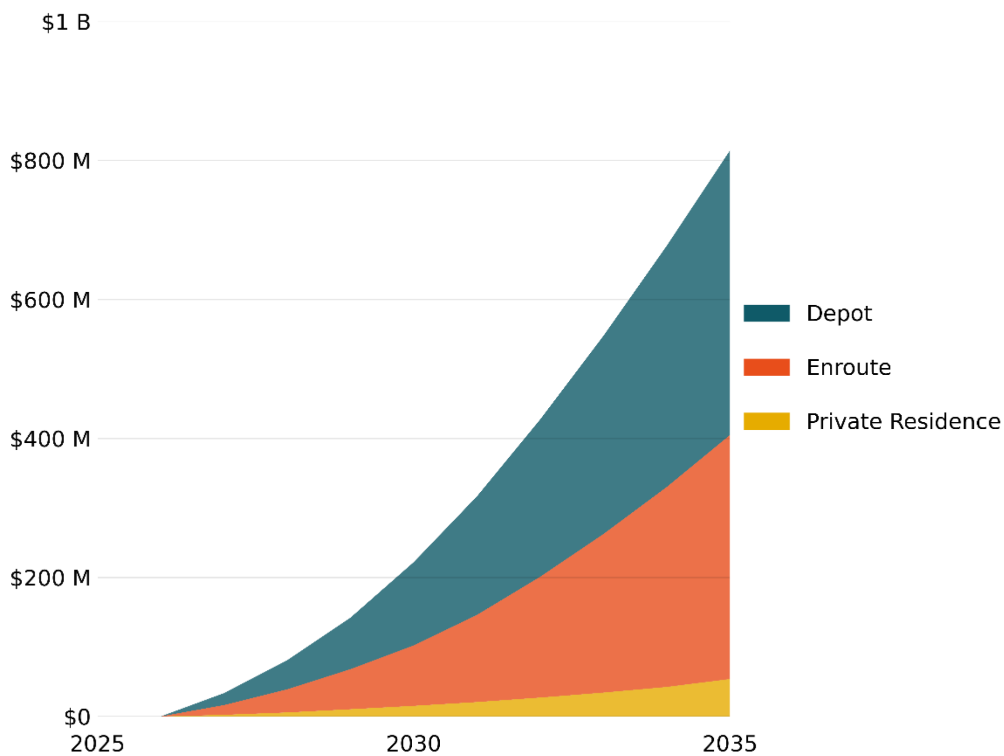

Figure 2.7. Cumulative charging investment need for the Base ACT scenario (2025 dollars)

Enroute charging shows the steepest cost trajectory, growing from $83 million in 2030 to $2.9 billion in 2050, reflecting the deployment of high-power charging infrastructure. Depot charging represents the second largest cost component, reaching $1.4 billion by 2050, driven by the high volume of lower-power installations and utility-side infrastructure requirements for higher-power charging. Residential charging remains the smallest component at $252 million by 2050, consistent with the more modest power requirements and installation costs for modeled home charging of smaller vehicles.

While these infrastructure investments are substantial, a comprehensive cost-benefit analysis was beyond this study's scope but represents a critical analytical step. Previous analysis on ACT implementation in Maryland estimated approximately $875 million in health benefits and nearly $500 million in annual fleet cost savings from ACT by 2050, providing important context for the returns on these infrastructure investments.[52] This includes avoiding 39,000 cases of acute bronchitis, exacerbated asthma, other respiratory symptoms, and reduced restricted activity days and lost workdays. In addition, in a report developed for the Union of Concerned Scientists, the firm ERM finds that ACT could potentially decrease average residential and commercial electricity rates in Maryland by as much as 3.7% by 2050 thanks to improved utilization of utility assets from EVs, saving the average Maryland household $51 per year and the average commercial customer $184 per year on their electricity bills.[52] This accounting also does not include reductions in greenhouse gas emissions attributable to the regulation.

2.4 Load Curves and Contribution to Peak Demand

Understanding when and where MHD electric vehicles are likely to charge allows utilities and policymakers to anticipate grid infrastructure needs and potential strain on existing infrastructure. This analysis examines projected charging patterns across three primary locations—depot facilities, home charging for smaller vehicles, and enroute public charging stations—while comparing unmanaged charging scenarios with optimized managed charging strategies.

2.4.1 Home and Depot Charging Methodology

We built per-utility electric load profiles for MHDV charging at homes and depots. We simulate two operating modes: unmanaged charging (vehicles begin charging as soon as they park) and peak-shaved managed charging (charging is shaped to the flattest feasible profile).

To estimate unmanaged charging load shapes, we simulate 24-hour load profiles (power draw by time of day) by approximating charger power draw behavior from charge start to charge end (wrapping around midnight to accommodate overnight charging). We simulate these profiles for each pairing of vehicle energy demand and charger type and then aggregate them into a single overall load curve by utility territory.

- DC fast charging (DCFC): Modeled power starts near the charger's nominal rating, then we apply a modeled battery management system (BMS) taper across the second half of the state-of-charge (SoC) window; after 80% SoC the model enters a constant-voltage phase with additional falloff.
- Level 2: Modeled power follows a near-constant-current segment that ends with modest falloff as SoC enters a constant-voltage phase past 80% SoC.

We assume vehicles return at 30% SoC and charge to 90% SoC, which is a middle-of-the-road charging pattern that allows us to simulate the impact of charging curves while keeping the modeling tractable.

For the peak-shaved managed charging case, we reallocate charging within the vehicle's available dwell window to minimize peaks while guaranteeing energy recovery by the required driving start time and respecting charger power limits. This produces the flattest feasible load shape given energy needed, charger rating, and time available.

Charging start-time patterns are derived from depot-based MHDV summary statistics published by the National Renewable Energy Laboratory.[53] Synthetic charging sessions are generated from the hourly parked-vehicle share using an optimization algorithm. The algorithm produces a set of sessions defined by start time and duration. When these sessions are distributed across hours (wrapping past midnight as needed) and then reaggregated, the resulting pattern closely reproduces the original parking share curve.

To estimate utility-wide charging curves, we map the charging-start values to the corresponding simulated load for each energy demand and charger type, and scale by vehicle population. We then aggregate load across vehicles in each utility service territory to produce weekday load profiles. The input total energy is calibrated to a typical coldest-weather day, so the resulting curves represent a winter annual peak.

Key assumptions include the 30%-to-90% SoC window, representative dwell windows, simulated start times, and service territory-level aggregation. These simplify the wide range of real-world behaviors while preserving the main dynamics that drive broad system peaks.

2.4.2 Enroute Charging Methodology

We developed statewide hourly electric load profiles for MHDV charging at enroute stations in Maryland using a Monte Carlo simulation approach. The analysis incorporated two vehicle categories: long haul tractors and non-long-haul trucks (regional tractors, delivery trucks, box trucks, vans etc.), each with distinct charging patterns and infrastructure requirements.

Long Haul Enroute Long-Dwell Charging

Long-haul charging is done either at 350 kW stations during off-duty hours at truck stops, or at 1,000 kW stations during breaks or shift changes. 350 kW charging accounts for 70% of long-haul energy recovery needs, and the remaining 30% from 1,000 kW fast-charging. The 1,000-kW case is modeled similarly to other enroute charging methods.

Because 350 kW long-dwell charging closely resembles depot-type charging, we applied a similar approach to that outlined for home and depot charging. To capture usage patterns based on truck parking sessions, we created synthetic parking start and end times using truck parking occupancy data,[54] conditioned on hours-of-service regulations, and then simulated charging loads using the same processes described in Section 1.4.1.

Enroute Short-Dwell Charging

For short-dwell enroute charging of tractors (including 30% of long-haul tractor charging and all other tractors), straight trucks, and vans, charging patterns were modeled using hourly traffic data from the Federal Highway Administration.[55] For tractors, we assumed one charging scenario: 1000-kW fast charging events (20-minute duration) following daytime traffic patterns for quick fill-ups. Non-tractor vehicles utilized 350-kW chargers with 20-minute durations following daytime traffic patterns.

The simulation employed 15-minute time intervals across 30-day periods, with results averaged to represent typical daily patterns. For each year (2025 to 2050), we conducted 10 Monte Carlo simulations and used iterative calibration to match annual energy consumption targets within one percent tolerance for each vehicle-charger combination. Charging events were randomly distributed across the simulation period according to hourly probability distributions, with event durations following normal distributions around specified mean values.

2.4.3 Results

Figure 2.8 illustrates the projected statewide electric load curves across Maryland's utility service territories if vehicle charging loads are not managed. The analysis shows relatively modest charging loads in 2030, with statewide peaks reaching approximately 70 MW under unmanaged charging scenarios. If ZEV MHDVs make up 100% of MHDV sales by 2050 and vehicles do not manage their charging load, peak loads from charging are modeled to reach 516 MW in 2040 and 1,352 MW in 2050. This represents a 0.4% addition to statewide peak demand in 2030, 2.6% by 2040, and 6.1% by 2050. This growth to 100% zero-emission MHDV sales in 2050 represents an increase of 0.3% per year in peak load, well under the Maryland Public Service Commission forecasts of 1.3% annual growth in summer peak load through 2033.

Managed charging strategies show significant potential for peak load reduction, particularly visible in the comparison between unmanaged and managed statewide curves. Managed charging limits peak demand increases to 56 MW (0.3%) in 2030, 395 MW (2.0%) in 2040, and 985 MW (4.4%) in 2050. These results demonstrate that while medium- and heavy-duty vehicle electrification will create new electrical demand, strategic charging management can help mitigate grid impacts during peak periods while maintaining fleet operational requirements.

The utility-specific breakdown in Figure 2.8 demonstrates that BGE and Delmarva Power territories bear the largest charging loads, reflecting their service areas' higher concentrations of commercial and industrial activity.

Figure 2.9 provides insights into charging location patterns, revealing that depot charging is expected to dominate the load profile. Depot charging peaks occur during nighttime hours (around 9 PM), reflecting vehicles returning after daytime operations. Enroute charging follows expected daytime traffic patterns, peaking at 4 PM when commercial vehicle activity is highest. Long-haul overnight charging shows evening peaks around 8 PM, aligned with truck drivers' mandatory rest periods and overnight parking occupation patterns at truck stops and travel plazas.

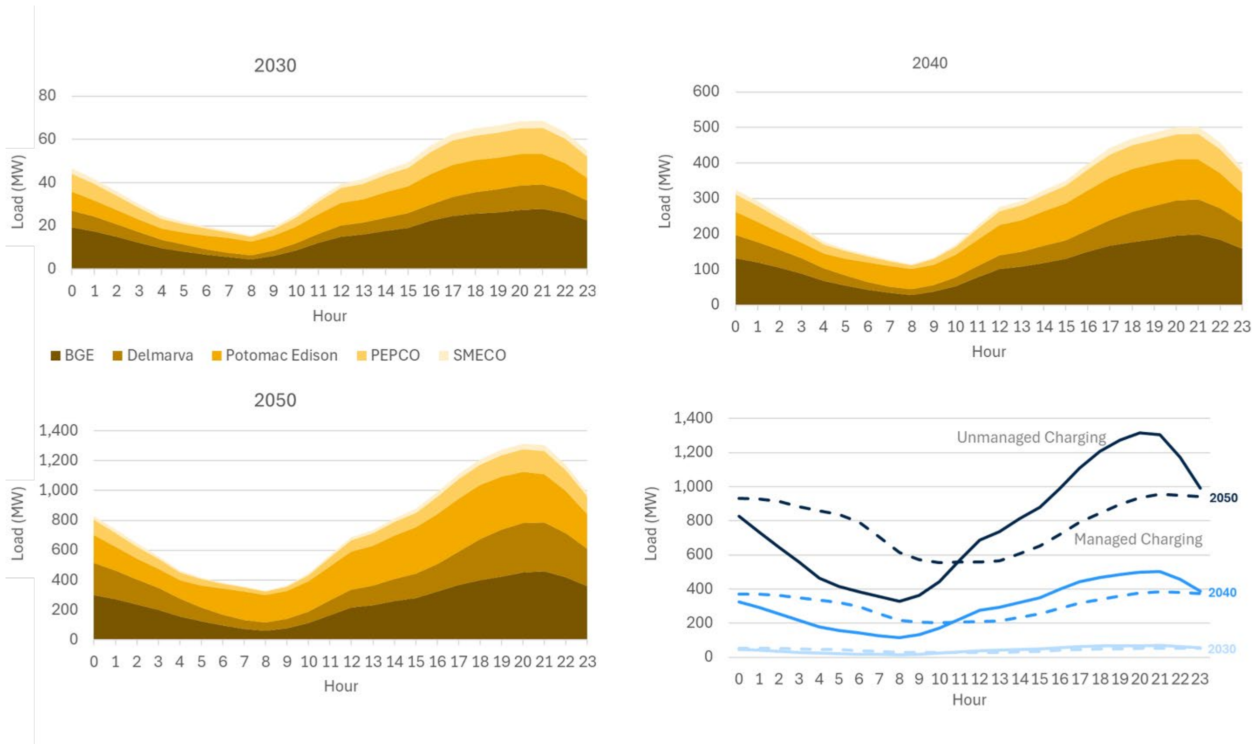

Figure 2.8. Estimated statewide load curves by utility, assuming unmanaged charging except where noted.

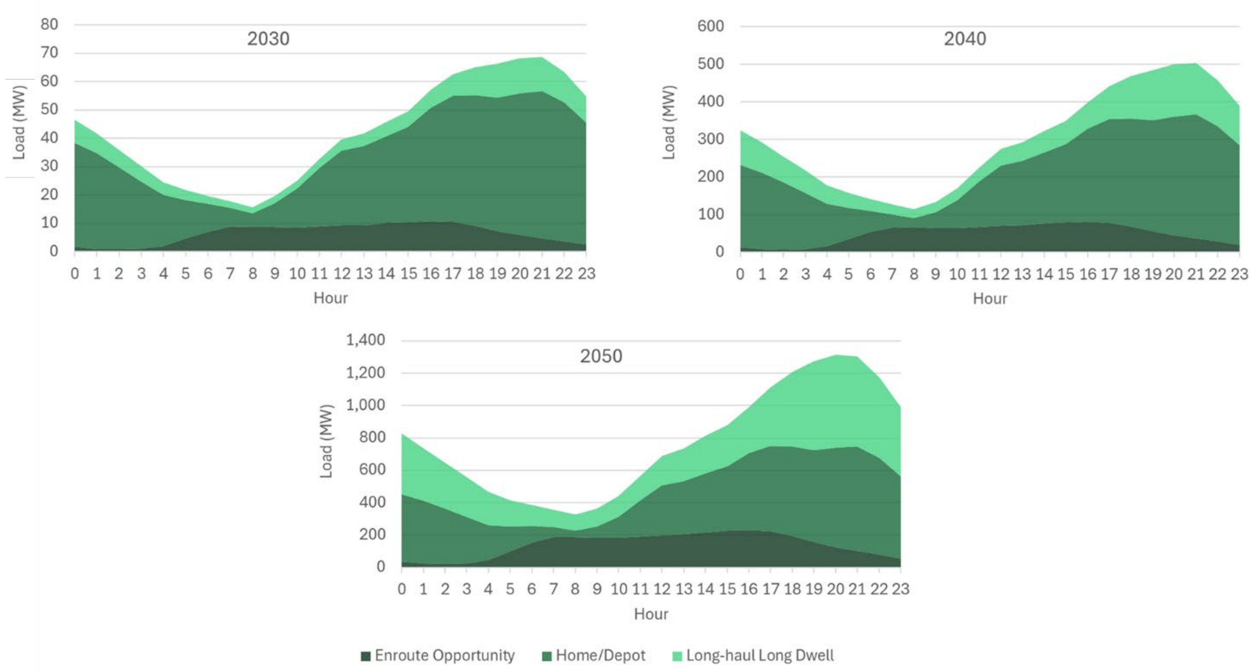

Figure 2.9. Estimated Statewide Load Curves by Charging Location

	Projected Statewide Peak Load without ACT Implementation (MW)	Additional Peak Load (MW) with ACT + 100% ZEV sales by 2050 Implementation			
		Unmanaged Charging	% Increase	Managed Charging	% Increase
2030	17,489	70	0.4%	56	0.3%
2040	19,603	516	2.6%	395	2.0%
2050	22,259	1352	6.1%	985	4.4%

Table 2.4. Projected statewide peak loads and impacts of ACT implementation

2.5 Stakeholder Perspectives on Electrical Infrastructure and Utilities

The implementation of the ACT regulation in Maryland presents significant electrical infrastructure challenges that emerged as a central concern across stakeholder interviews. From utility representatives to fleet operators, engineering firms to government agencies, a complex picture emerges of both systemic challenges and promising opportunities in preparing Maryland's electrical grid for MHDV electrification.

2.5.1 Utility Planning and Capacity Constraints

Utility representatives emphasized that Maryland's electrical infrastructure faces varying capacity constraints across different regions. Urban substations typically handle 200 MW capacity, while suburban installations range from 50-100 MW, and rural substations operate at approximately 25 MW. These capacity limitations create geographic disparities in electrification readiness, with rural areas facing particular challenges due to smaller infrastructure and greater distances between facilities.

The planning horizon for electrical infrastructure emerged as a critical timeline consideration. Utility representatives noted that major infrastructure upgrades, particularly new substations, require eight- to 10-year lead times, with large transformer procurement alone taking up to three years. This extended planning cycle means utilities must begin making investment decisions based on forecasts that carry significant uncertainty about where and when electrification demand will materialize.

Distribution planning processes are evolving to accommodate electric vehicle loads, and utilities are currently treating these requests similarly to traditional new business connections rather than implementing proactive electrification strategies. The challenge lies in balancing prudent infrastructure investments with the need to be ready when demand materializes, particularly given the variability in electrification forecasts and long lead times.

2.5.2 Infrastructure Upgrade Requirements and Timelines

Fleet operators and government agencies consistently reported lengthy timelines for electrical service upgrades. Commercial charging installations for medium and heavy-duty electric vehicles can require 12 to 18 months for completion, with some projects extending to three years or more depending on complexity. The timeline breakdown typically includes one-third engineering, design, and permitting, one-third utility construction, and one-third customer site preparation although these factors may vary considerably from project to project.

For larger installations such as (but not limited to) transit facilities, which may require dedicated feeders—electrical lines serving a single customer—the process becomes even more complex. These dedicated connections, often necessary for depot charging applications, may require two to three years for implementation and substantial customer investment in ductwork and infrastructure extending potentially thousands of feet from the utility network.

Engineering firms working on charging infrastructure projects noted that power availability represents the most significant variable in project timelines. In some cases, especially in constrained areas, utility upgrades can add four to 12 months to project schedules. The complexity increases dramatically when new transformers or switchgear are required, particularly for loads exceeding certain thresholds (which will vary based on the existing conditions).

2.5.3 Coordination Challenges Between Stakeholders

A recurring theme across interviews involved coordination difficulties between various stakeholders in the electrification process. Government fleet managers described challenges navigating utility processes, particularly with requirements that even smaller charging projects be classified as new service connections. This classification triggers more extensive review and approval processes than initially anticipated.

School district representatives highlighted coordination complexities when working with utilities on charging infrastructure. Despite years of coordination meetings for electric school bus pilots, stakeholders noted ongoing challenges in aligning charging infrastructure deployment with vehicle acquisition timelines. The mismatch between infrastructure lead times and vehicle delivery schedules (specifically that vehicles can be ordered and delivered more quickly than charging infrastructure can be installed) created operational complications for early adopters.

Private fleet operators emphasized that utility coordination must begin early in the planning process, though the engagement varies significantly depending on the utility and location. Some utilities have become more responsive to electrification requests as data centers have drawn attention to high-energy consumption applications, making fleet charging requests seem more manageable by comparison.

2.5.4 Site-Specific Infrastructure Challenges

Municipal and state government representatives described significant site-specific challenges in deploying charging infrastructure. Space constraints emerged as a common issue, particularly for older facilities that require electrical upgrades to meet current codes. In leased facilities, the approval process becomes more complex, requiring coordination with property owners and often resulting in additional delays.

The technical requirements for MHDV charging create unique infrastructure demands. Engineering firms noted that truck charging projects require thicker pavement, larger maintenance budgets, and careful consideration of vehicle and pedestrian safety. Retrofit projects for existing facilities present particular challenges, especially when older buildings require comprehensive electrical system upgrades.

Fire code compliance emerged as an area of uncertainty, with engineering representatives noting that regulators lack consensus on fire code interpretation for electric vehicle charging. This regulatory ambiguity can potentially impact or even block projects, requiring early conversations with fire marshals to ensure compliance.

2.5.5 Cost and Economic Considerations

The economic aspects of electrical infrastructure emerged as a significant concern across stakeholder groups. Fleet operators noted that customers typically bear 100% of electrical infrastructure costs on the customer side of the meter. For larger installations, these costs can reach hundreds of thousands of dollars. While the responsibility for costs on the utility side of the meter varies based on each utility's line extension policy, broadly speaking in much or all of Maryland the cost of transformers is socialized, meaning that the customer does not have to pay for this important equipment (exceptions may exist for high voltage service, however at such levels paying for the transformer may be economically beneficial to the customer). This is in contrast to certain utilities in other states where the commercial customer is responsible for the cost of the transformer at all voltages.

Demand charges represent a particular concern for fleet operators, with some reporting electricity costs significantly higher than projected. One private fleet operator described charging costs nearly five times higher on a per-kWh basis than initial projections due to low utilization, creating economic challenges that required manufacturer intervention to maintain project viability. With increasing utilization, demand charges can be spread across a sufficient amount of energy consumption (based on kWh) such that demand charges (based on kW) represent a smaller portion of the overall electricity bill. States such as New York offer a phased-in demand charge to account for low utilization in the early phase of EV infrastructure deployments. The Maryland Public Service Commission has previously considered proposals for specialty rates associated with public charging infrastructure and demand charges. The Commission did not approve modifications at the time but provided guidance that would allow for such changes to potentially be made in the future if warranted.

Government agencies emphasized budget constraints in infrastructure deployment, with state fleet managers noting that they fully fund charging infrastructure including networking costs. However, they are moving away from networked charging systems (chargers connected to a cloud network providing services such as access control, transaction reporting, and load management) due to monthly costs from the service provider and reliability issues, opting instead for non-networked solutions whereby a driver simply plugs in and charges.

2.5.6 Utility Rate Structures and Programs

Stakeholder discussions revealed varying approaches to utility rate structures for electric vehicle charging. Some utilities have introduced alternative rate structures that bill only by the kilowatt-hour (similar to most residential rates) rather than peak demand (used in most commercial rates), though adoption of these specialized rates remains limited. With regard to incentives to promote off-peak charging, utility representatives noted the challenge of balancing such with cost recovery requirements.

Several stakeholders mentioned utility pilot programs and incentive offerings, though experiences varied significantly. Some early charging infrastructure was deployed through utility pilot programs, though reliability issues were noted with these initial installations. The evolution toward customer-funded, utility-connected systems appears to be the current trend.

2.5.7 Regional and Geographic Variations

The interviews revealed significant regional variations in infrastructure readiness and utility approaches across Maryland. Urban areas generally have greater electrical capacity and shorter connection distances, while rural areas may face challenges with both capacity limitations and extended infrastructure requirements. This geographic disparity suggests that electrification readiness will vary considerably across the state.

Proximity to existing electrical infrastructure having excess capacity or the ability to be upgraded emerged as a critical factor in project feasibility and cost. Engineering firms emphasized that avoiding the need for new substation construction is essential for project viability, as new substations can add eight to nine years to project timelines and enormous costs.

2.5.8 Proactive Infrastructure Investment Considerations

Several stakeholders addressed the potential for proactive infrastructure investment to accelerate electrification. Utility representatives noted that there are programs aimed at increasing capacity in constrained areas, though these are not necessarily targeted at electric vehicle applications.

The concept of "pre-building" grid infrastructure to get ahead of electrification requests emerged in discussions with utility representatives. However, the regulatory framework in Maryland today does not encourage investor-owned utilities to make speculative infrastructure investments for electrification. Recent legislation passed in California, as well as a proceeding in New York, and additional legislation under consideration in Colorado, New Jersey, and Virginia seek to amend regulatory structures to enable the kinds of long-term planning as needed to support the longer timeframes needed for some MHDV charging projects.[36,56–59]

2.5.9 Technology and Operational Considerations

Stakeholders described the evolution of charging technology requirements and their infrastructure implications. The move toward higher-power charging systems requires more robust electrical infrastructure, with some installations requiring medium or primary voltage connections and large transformers. Software systems for managing charging loads and avoiding peak demand periods are also becoming increasingly important for economic operation.

Charging technology continues to evolve, with maximum charging power levels having increased from 50 kW a decade ago to megawatt-level systems now emerging, and even higher power levels in the future are likely. This will enable the electrification of an increasing portion of the MHDV fleet, as batteries and vehicle electrical components become increasingly designed to be compatible with higher power charging systems.

Interoperability emerged as both a technical and business consideration, with fleet operators noting concerns about charger compatibility across different vehicle manufacturers and charging networks. This concern extends to electrical infrastructure requirements, as different charging systems may have varying power and installation requirements.

2.5.10 Future Infrastructure Planning Needs

The interviews revealed a consensus that electrical infrastructure planning must evolve to accommodate the scale of electrification anticipated under the ACT regulation. Utility representatives emphasized the need for improved forecasting tools and better coordination with fleet operators to anticipate demand patterns.

Regulatory certainty is fundamental to driving the substantial investments required in electrical grid upgrades, charging infrastructure deployment, and electric vehicle product development. Current regulatory uncertainty—particularly regarding the status of California's federal waiver and its legal authority to implement the ACT regulation, as well as the future of states like Maryland that have adopted California's standards—creates significant barriers to progress. This uncertainty, which is in addition to the Public Service Commission's current position, deters utilities from making proactive grid investments, discourages private investment in charging infrastructure, and hampers manufacturers' ability to plan production as well as research and development investments for electric commercial vehicles.

The electrical infrastructure challenges identified through these stakeholder interviews highlight the complex, interconnected nature of fleet electrification implementation. Success will require coordinated efforts among utilities, fleet operators, government agencies, and engineering firms to address capacity constraints, streamline approval processes, and develop appropriate cost recovery structures for utility investment.

Chapter 3: Current Incentives and Funding Pathways

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Chapter at a Glance:

- Maryland has several financial incentive programs aimed at electrifying private vehicles, public fleets, and installing charging infrastructure around the state. These programs are supported through state, federal, and private funding. However, programs may be oversubscribed, and certain funding pathways, such as the Volkswagen Settlement program, are sunsetting or have had limited impacts.
- Other states in the U.S., particularly California, have implemented incentive programs using rebates, loans, point-of-sale incentives, and make-ready programs to increase adoption of MHD electric vehicles and charging infrastructure. These programs can provide programmatic and funding examples for Maryland such as tiered incentive programs and adopting clean fuel standards.
- Internationally, Canada and many EU countries have implemented successful incentive programs that provide broad eligibility, stackable rebates, and point-of-sale incentives for vehicle electrification.
- Investments should focus on covering the cost differential and offering point-of-sale rebates to fleets looking to purchase MHDVs in order to see the highest amount of adoption. Utility "make-ready" programs should also be implemented in order to speed up the process of purchasing and installing charging infrastructure necessary for increased deployment of BEVs.
- To avoid oversubscription of programs and promote vehicle acquisition and infrastructure build-out, a stable and sufficient funding source at the state level is needed.

Introduction

This chapter provides a comprehensive review and analysis of incentives and funding pathways that support electrification of MHDVs in the state of Maryland. Here we assess the current policy landscape, evaluate the effectiveness of existing programs (based on available information about outcomes), and identify opportunities for new or expanded incentives that align with Maryland's climate and fleet transition goals.

Given the rapidly evolving EV ecosystem and the need for responsive and forward-looking policy, the analysis includes benchmarking of successful models implemented in other U.S. states, cities, federal, and international contexts. The research also explores innovative, non-financial, policy mechanisms that could enable Maryland to scale and sustain its electrification efforts in both the short and long term.

The scope of the report encompasses six major areas: (1) a review of existing Maryland incentive programs for EV and ZEV adoption; (2) a review of incentive programs in other U.S. states, cities, and federal programs that are not available in Maryland; (3) a review of incentives implemented internationally; (4) a review of non-financial incentives; (5) an exploration of current and potential funding pathways; and (6) a summary of recommendations based on findings.

The objective of this work is to provide evidence-based, actionable insights to inform future policy development, program design, and implementation strategies in Maryland, with an emphasis on effectiveness, accessibility, and scalability.

Within this chapter, each major section begins with a summary table for clarity and ease of comparison, followed by a detailed narrative providing context, insights, and potential implications for Maryland's fleet electrification strategy. Each identified incentive program was categorized and assessed based on its structure, eligibility criteria, funding source, and—where available—its reach, uptake, and documented effectiveness. In addition to financial incentives, non-financial mechanisms (such as priority lane access, zero-emission loading zones, or EV-ready construction mandates) were also reviewed for their potential to support fleet adoption and reduce operational barriers. It is important to note that incentives included in this report are comprehensive, yet not exhaustive. Incentives included in this report are current as of May 31, 2025.

Additionally, it is noted that due to recent changes in record keeping at the federal level, there is information provided in this report on federal program impacts that is no longer publicly available. We have tried to include sources that have as much information as possible and at one point had information regarding the impacts of the federal programs. Dates for federal programs may also be incorrect as we continue to see the sudden freezing of federal funds for these initiatives.

3.1 Review of Existing Incentives in Maryland

This section provides a detailed analysis of Maryland incentives, assessing their impact on fleet electrification efforts. Table 3.1 summarizes the existing incentives.

Incentive Program	Program Managing Entity and Timeframe
1. Maryland Vehicle Excise Tax Credit	Maryland, 2011-present
2. Maryland Smart Energy Communities (MSEC) Program	Maryland, 2013-present
3. Maryland EV Infrastructure Program, EVSE funding	Maryland, 2014-present
4. Alternative Fuel Infrastructure Program (AFIP)	Maryland, 2016-2020
5. Public Transportation Bus grant programs / FTA Low- and No-Emission Bus Funding	Federal, 2016-2024
6. Volkswagen Mitigation Plan	Private, 2016-present
7. BGE, Pepco, Delmarva, Potomac Edison EV Charging Pilot Program	Private, 2019 - 2023
8. BGE, Delmarva, and Pepco Electric Vehicle Fleet Program	Private, 2022-present
9. Clean Heavy-Duty Vehicles Grant Program	Federal, 2024
10. Montgomery County Department of Transportation (MCDOT) Bus Fleet Order	Municipal, 2024
11. Medium-Duty and Heavy-Duty Zero-Emission Vehicle Grant Program	Maryland, 2024-present
12. Electric School Bus Grant Program	Maryland, 2025
13. MD-NJ-PA-WV Charging Ahead Partnership	Federal, 2025
14. Clean Corridor Coalition ("C3") Climate Pollution Reduction Grant Project	Private, 2025 - Present

Table 3.1. Incentive Programs in Maryland

3.1.1 Maryland Vehicle Excise Tax Credit (2011 - Present)

Summary

The Clean Cars Act of 2022 (codified as §13-815 of the Transportation Article) established an electric vehicle tax credit for Fiscal Years 2024 through 2027. For each fiscal year, the Maryland Energy Administration transfers up to $8,250,000 to the Transportation Trust

Fund for this tax credit.[60] The MVA administers the tax credit, which provides a one-time tax credit for qualifying zero emission plug-in electric or fuel cell electric vehicles. The amount of the tax credit depends on the type of vehicle.

- $1,000 for a 2-wheeled, zero emission plug-in electric drive or fuel cell electric motorcycle
- $2,000 for a 3-wheeled, zero emission plug-in electric drive or fuel cell electric motorcycle
- $3,000 for a zero-emission plug-in electric drive or fuel cell electric vehicle

The credit is limited to one qualifying vehicle per individual and 10 vehicles per business entity. A qualifying vehicle: (1) has not been modified from original manufacturer specifications; (2) is acquired for use or lease by the taxpayer and not for resale; (3) is purchased new and titled for the first time on or after July 1, 2023, but before July 1, 2027; (4) has a battery capacity of at least 5.0 kilowatt hours (only applies to zero emission plug-in electric drive vehicle) or if a motorcycle or auto cycle, has a battery capacity of at least 4.0 kilowatt hours; (5) has a base price not exceeding $50,000; and (6) has a maximum speed capacity of at least 55 miles per hour.

Impact

Between 2011 and 2022, the program successfully issued 12,836 rebates totaling approximately $28.7 million,[61] making it one of Maryland's most widely accessed EV incentive initiatives. Its popularity is evident; for FY2026, which started on July 1, 2025, its $8,250,000 budget was fully depleted within a month and half.[60]

However, because the funding was limited and therefore uncertain to the buyers at the time of purchase, it is difficult to determine how many vehicles would not have been purchased without the tax credit. When receipt of an incentive is not confirmed until after the vehicle purchase (e.g., when filing taxes or as some other sort of refund), and particularly when the funding is uncertain, it is generally more difficult to conclude that the incentive increased the likelihood of the purchase. This is because post-purchase credits do not directly lower the upfront cost of the vehicle, suggesting that the buyers may have the means to purchase the vehicle in the absence of the credit. Maryland's vehicle excise tax credit is a post-purchase credit which annually is oversubscribed. This experience is undesirable because it:

- **Creates Uncertainty and Deters Buyers**: When a tax credit is on a first-come, first-served basis with limited funding, it creates a significant amount of uncertainty for potential buyers. A consumer may be ready to purchase a qualifying EV, but if they learn that the funds for the credit have already been depleted for the fiscal year, a key part of their financial calculation is gone. This can cause them to delay or cancel their purchase.

- **Reduces Public Trust**: If a program runs out of money frequently or unexpectedly, it can erode public trust in government incentives. Consumers may become wary of relying on future credits, which undermines the entire purpose of the program.
- **Imposes an Impact on Dealers**: Dealers must often communicate the risk of limited funding to their customers, which can complicate the sales process and may lead to lost sales. In Maryland, for example, the MVA has had to instruct dealers to inform customers that they may not receive the credit if funding is depleted.
- **Creates Program Inefficiency**: The administrative overhead of a program that has a waiting list and requires communication about funding status can make it less efficient. It can also lead to a "boom-and-bust" cycle, where a rush of purchases happens at the beginning of a fiscal year, followed by a slowdown when funds run out.

Key Takeaways:

- Although the program is routinely oversubscribed, we cannot determine conclusively how many vehicles would not have been purchased in the absence of this incentive.
- When a tax credit is received after the vehicle purchase (e.g., when filing taxes or as a refund from the state), and particularly when the funding is uncertain, it is generally less effective at influencing consumer behavior than a point-of-sale rebate.

3.1.2 Maryland Smart Energy Communities (MSEC) Program (State, 2013–Present)

Summary

Launched in 2013, the Maryland Smart Energy Communities (MSEC) Program provides grant funding to support local governments, state agencies, non-profit organizations, educational institutions, and communities in adopting smart energy policies. Eligible entities include incorporated towns, cities, and counties across Maryland. The program supports initiatives such as transitioning vehicle fleets to zero-emission alternatives and installing EV charging infrastructure, alongside other clean energy projects like solar installations.

Impact

In FY2022, MSEC funded four electric transportation projects totaling $84,750 and reported annual gasoline savings of 2,452 gallons. As of the latest reports, the program has allocated $1.156 million in total funding. While EV-related projects are part of its portfolio, MSEC broadly supports clean energy goals. Funding is sourced from the Strategic Energy Investment Fund (SEIF), which is funded by proceeds from carbon credit auctions held through the Regional Greenhouse Gas Initiative. For FY2025, the program made up to $1.5 million in grants available, with applications closing on January 31, 2025.

Key Takeaways:

- Allows for replacement with either zero-emission or cleaner diesel vehicles
- $4.5 million grant opportunity (opened Feb 2025) for EV charging stations at commercial and nonprofit sites presents an opportunity to expand fleet charging access across Maryland.

3.1.3 Maryland EV Infrastructure Program, EVSE Funding (State, 2014 - Present)

Summary

The Maryland EV Infrastructure Program provided grant support for the installation of electric vehicle supply equipment (EVSE), targeting both public and private entities, including state agencies, commercial properties, and residential applicants. The program reimbursed up to 50% of installation costs, capped at $700 for residential chargers and $5,000 for commercial units.

Impact

From 2014 through 2022, this state-level initiative played a foundational role in Maryland's early EV charging network development. It helped expand access to Level 2 and DC fast chargers across public spaces and workplaces at a time when federal support was limited or unavailable. However, beginning in 2023, the landscape shifted: federal EV infrastructure funding surged, making state contributions proportionally smaller. As of January 27, 2025, the Maryland program closed applications for FY2025.

Key Takeaways:

- The program played a critical role in Maryland's early EVSE deployment, particularly for Level 2 and DC fast charging at workplaces and public sites, which are key locations for fleet vehicle access.
- As federal infrastructure support grew after 2022, state program's relative importance diminished

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3.1.4 Alternative Fuel Infrastructure Program (AFIP) (State, 2016–2020)

Summary

The Alternative Fuel Infrastructure Program (AFIP) provided financial assistance for the planning, installation, and operation of alternative fuel refueling stations, including electric vehicle (EV) charging stations, across Maryland. Operating from FY2016 to FY2020, the program was targeted at businesses located in the state to support the buildout of refueling infrastructure for a variety of alternative fuel types.

Impact

In FY2016 alone, the program awarded funding for 14 DC Fast Charging stations totaling $612,504, two compressed natural gas (CNG) stations totaling $1,000,000, and two propane stations totaling $91,400. While funding varied year to year, AFIP demonstrated a clear commitment to diversifying Maryland's fueling infrastructure. The program officially ended in April 2020.

Key Takeaways:

- By targeting businesses, AFIP encouraged private investment in public fueling stations.

3.1.5 Public Transportation Bus Grant Programs / FTA Low- and No-Emission Bus Funding (Federal, 2016-2024)

Summary

This federal program provides funding for new electric buses and related charging infrastructure to municipalities nationwide, supporting efforts to modernize public transportation fleets with ZEVs.

Impact

In FY2023, the University of Maryland, College Park received $39,863,156 to purchase battery-electric buses and associated charging equipment to replace older fleet vehicles. In FY2024, Prince George's County, Maryland, was awarded $25,475,520 to acquire battery-electric buses; this funding was in conjunction with resources from the Clean Heavy-Duty Vehicles Grant Program. As of now, no funding opportunity has been announced for FY2025.

Key Takeaways:

- Program has become foundational in U.S. fleet electrification policy, delivering substantial grants to support electric transit bus adoption across the nation.
- Funding covers both buses and essential infrastructure like charging stations, making it a comprehensive electrification solution.

3.1.6 Volkswagen Mitigation Plan (Private, 2016–Present)

Summary

Maryland leverages funds from the Volkswagen (VW) Mitigation Trust to accelerate the replacement of older, high-emission diesel vehicles (specifically 2009 to 2016 models that violated the Clean Air Act) with zero-emission alternatives, including electric vehicles. The program primarily supports state fleets, government agencies, and nonprofit organizations in their transition toward cleaner transportation technologies.

Impact

To date, Maryland has been allocated $75.7 million from the trust, of which approximately 15% ($11.3 million) is dedicated to light duty electric vehicle charging infrastructure. Funded projects under this plan include the deployment of six electric school buses, twenty-two electric transit buses, five electric forklifts, and numerous other replacements or upgrades. The program also supports the replacement of aging diesel vehicles with newer, cleaner diesel models, balancing emissions reduction with practical fleet needs.

On February 10, 2025, the Maryland Department of the Environment opened a grant application window for $4.5 million aimed at installing EV charging stations at businesses, nonprofits, and other eligible sites, further bolstering Maryland's EV infrastructure network.

Key Takeaways:

- Program prioritizes large cost-effective NO_x reduction projects, such as locomotives, marine vessels, and cranes, while also pursuing electrification of school buses and transit buses, which are sectors with significant exposure to vulnerable populations.
- Additional funding indicates sustained state commitment program adaptability.
- No impacts have been identified on whether recipients of VW settlements have used other funding sources or their own resources to continue investing in EVs.

3.1.7 BGE, Pepco, Delmarva, Potomac Edison, SMECO EV Charging Pilot Program (Private, 2019 - 2023)

Summary

In 2019, the Maryland Public Service Commission (PSC) issued Order 88997 approving a pilot program run by the four investor-owned utilities (BGE, Pepco, Delmarva, and Potomac Edison) to offer residential and non-residential EV charging incentives and the installation of public EV charging stations. SMECO was separately approved to run a public-charging pilot program. The pilot program offered over 3,000 residential rebates, over 1,000 non-residential charger rebates and/or utility-owned charging stations, and over 960 public, utility-owned charging stations.[62]

Impact

The EV Charging Pilot Program saw success in its goal of offering incentives to increase adoption of EVs and installation of residential, non-residential, and public EV charging stations across the state. The utilities reached their goals on charger installations for residential and public chargers and saw over 1.5 million charging sessions over the course of the five year program at residential and public charging stations. The PSC approved the installation of over 5,000 smart or Level 2 EV chargers through the pilot program.[63]

In 2024, the PSC evaluated the success of Phase I of the EV Charging Pilot Program and asked the utilities to create Phase II proposals that included residential rebates, residential data-sharing incentives, EV TOU rates and other load-shifting offerings, managed charging, public charging, multi-unit dwelling rebates and ownership, fleet and workplace charging, and cost recovery.[43]

Key Takeaways:

- Over the course of the pilot program, EV registrations increased from 22,144 to just shy of 84,000, a four times increase.[64]
- The success of the pilot program allowed for the utilities to continue forward with other PSC proposals
- The program impacted charging installation for residential, non-residential, and public charging allowing for larger access across the state for EVs to charge.

3.1.8 BGE, Delmarva, and Pepco Electric Vehicle Fleet Program (Private, 2022 - Present)

Summary

BGE, Delmarva, and Pepco currently offer commercial customers various advisory services and incentives for purchasing and installing charging infrastructure.[65,66] The Maryland Public Service Commission approved the continuation of all the companies' programs on August 6, 2025.

Under the first offering, referred to as "Technical Fleet Assessments / Fleet Advisory Services," the companies will evaluate a customer's fleet and present electrified alternatives, along with a financial and emissions analysis to help the customer make the case for electrification. The companies will also explain available incentives that can offset the costs of installing charging stations at the customer's facility. The companies will cover the cost of the fleet assessment—a service valued at $25,000—with only a $2,500 upfront contribution, which will be refunded if the customer does one or more of the following within one year of completing the assessment:

1. Purchase an EV to replace an internal combustion engine fleet vehicle

2. Complete a program application for utility make-ready rebates
3. Complete a program application for electric vehicle supply equipment (EVSE) and installation incentives

The companies' second offering is Make-Ready Incentives. Under this offering, qualifying applicants can take advantage of incentives to upgrade the electrical infrastructure necessary to support EV charging stations. It covers 90% of the cost—up to a maximum of $15,000. It also offers additional assistance to businesses serving disadvantaged communities, covering 100% of the cost—up to a maximum of $15,000.

The companies also offers EV Charger Rebates, under which the companies can cover 50% of the cost, or 60% of the cost for businesses in disadvantaged communities, up to $5,000 for purchasing qualifying chargers and installing Level 2 charging ports, and up to $15,000 for DC fast-charging ports—up to a maximum rebate of $30,000 per location.

Impact

As of the date of this report, the fleet programs have been in operation for approximately one year and a limited number of assessments have been performed. The companies generally report that they are actively driving outreach efforts to boost participation, generating interest from a variety of entity types throughout their service territory. The companies are collaborating with internal stakeholders, such as the small/medium and large customer services teams to reach as wide an audience as possible. Additionally, the companies present at community events and targeted industry events, both of which are opportunities to market the EV Fleet program. The EV program team regularly attends service request scoping meetings and ongoing project meetings that the company's new business team holds with commercial customers to ensure that these customers are fully aware of the EV Fleet program options available to them.

Key Takeaways:

The purpose of these programs is to break down barriers and show customers the path forward. BGE advised in its August, 2025 Semi-Annual Progress Report to the Public Service Commission that a significant barrier to adoption for the current Fleet Assessment product is the lack of actionable information for longer term capacity planning efforts in conjunction with electric fleet adoption and expansion. Specifically, as the assessment is currently structured, it does not evaluate the available grid capacity at a fleet's location(s) or provide estimates for the time and cost required to complete any necessary grid capacity updates. BGE further states that this information is crucial for fleets to effectively operationalize the assessment data and plan their desired EV deployment scope and schedule, and that such an evaluation and assessment are part of the scope included in BGE's enhanced fleet assessment included in its EV Program Phase II Proposal, which is currently under review by the Commission.

3.1.9 Clean Heavy-Duty Vehicles Grant Program (Federal, 2024)

Summary

The Clean Heavy-Duty Vehicles Grant Program provided federal funding in 2024 for new Class 6 and Class 7 zero-emission school buses, vocational vehicles, and supporting infrastructure. Funded through the Inflation Reduction Act and administered via the US Department of Transportation's Charging and Fueling Infrastructure Grant Program, this initiative allocated significant resources to several Maryland public school systems.

Impact

Howard County Public School System received $24,503,465 to support the purchase of 75 buses, Montgomery County Public Schools (MCPS) was awarded $58,422,000 for 214 buses, and Prince George's County Public Schools received $3,492,450 for 10 buses. The program closed after awarding one-time funds on December 11, 2024.

Key Takeaways:

- Delivered over $86 million in federal funds to Maryland school districts, representing one of the largest single-year public investments in fleet electrification in the state.
- Awards to multiple counties show that Maryland school districts are prepared to manage high-volume EV deployments, including vehicle acquisition and charging infrastructure.

3.1.10 Montgomery County Department of Transportation (MCDOT) Bus Fleet Order (Municipal, 2024)

Summary

In 2024, the Montgomery County Department of Transportation (MCDOT) invested $3.3 million in electric school buses to serve the Montgomery County School District. This municipal fleet purchase reflects the county's commitment to transitioning to ZEVs. As a direct investment by the county, the program is not accepting applications.

Impact

Montgomery County Public Schools (MCPS) initiated a contract in 2021 to transition its entire fleet to electric, starting with 326 buses over four years. This move represents the largest single procurement of electric school buses in North America. The electrification effort is projected to reduce carbon emissions by 25,000 tons annually, contributing significantly to the county's climate goals

Key Takeaways:

- MCDOT's $3.3 million investment in 2024 underscores the importance of dedicated funding and long-term planning in transitioning to zero-emission fleets.
- Montgomery County's efforts include building necessary charging infrastructure, ensuring the sustainability and efficiency of the electric bus fleet.

3.1.11 Medium-Duty and Heavy-Duty Zero-Emissions Vehicle Grant Program (State, 2024 - Present)

Summary

Established in 2024, the Medium-Duty and Heavy-Duty Zero-Emission Vehicle Grant Program aims to reduce the cost of acquiring newly manufactured, qualified zero-emission MHD fleet vehicles, as well as eligible heavy equipment property. Funded directly by the state of Maryland, this grant supports fleet electrification efforts across various vehicle and equipment types.

Impact

In FY2024, the program funded 12 transit buses, seven school buses, seven single-unit short haul trucks, one single-unit long haul truck, 23 combination short haul trucks, five tractors, and two loaders. Applications for FY2025 closed on February 14, 2025.

Key Takeaways:

- Specifically targets MHD ZEV adoption, addressing a critical sector often underserved by earlier EV incentive programs.
- Closure of FY2025 applications as early as February 2025 suggests robust demand, indicating the need for sustained or expanded funding to maintain momentum in MHDV fleet transitions.

3.1.12 Electric School Bus Grant Program (State, 2025)

Summary

The Electric School Bus Grant Program, launched in 2025, allocated $17 million in state funding to support the purchase and lease of electric school buses serving Maryland public school students. The program prioritized Title I schools and underserved communities to promote equitable access to clean transportation. Each grant was capped at a maximum of $3 million. Applications for FY2025 closed on March 18, 2025.

Impact

As a newly launched initiative, limited information is currently available.

Key Takeaways:

- Prioritizing Title I schools and underserved communities ensures that the benefits of clean transportation reach areas most impacted by air pollution and environmental health disparities.
- Reinforces school districts as early adopters of zero-emission fleet technologies, which can serve as visible models for broader MHDV electrification.
- New state funding pathways signals increased support of Maryland's electrification goals.

3.1.13 MD-NJ-PA-WV Charging Ahead Partnership (2025)

Summary

In 2025, the Maryland Department of Transportation (MDOT) will receive $3.4 million as part of an $18.6 million award from the Federal Highway Administration to support the deployment of alternative fueling infrastructure along the I-81 and I-78 corridors in Maryland, Pennsylvania, and New Jersey. The project focuses on expanding fast-charging infrastructure to support local fleet operations and strengthen regional freight corridor connectivity.

Impact

As part of the initiative, six fast charging stations will be installed across the participating states, including one station in Maryland. The Maryland site will include the purchase and installation of one station with four 350kW fast chargers, representing a $3.2 million investment. This is a federally funded project, and no applications are being accepted.

Key Takeaways:

- Supports the electrification of regional freight and delivery fleets by adding fast-charging infrastructure along major interstate corridors (I-81 and I-78), enhancing long-haul and intercity operations.
- While fleets cannot apply for funding, the program enhances infrastructure access that supports broader fleet electrification strategies and route planning.
- Federal investment into the electrification of delivery fleets showcases broad support for increased EV adoption and infrastructure.

3.1.14 Clean Corridor Coalition (C3) Climate Pollution Reduction Grant (Private, 2025 - Present)

In July, 2024, C3 was awarded a $249 million grant from the U.S. Environmental Protection Agency (EPA) Climate Pollution Reduction Grant (CPRG) program, which will be used primarily for development of MHDV charging infrastructure. The coalition is led by the New Jersey Department of Environmental Protection in partnership with the Connecticut Department of Energy and Environmental Protection, Delaware Department of Transportation, Maryland Department of Transportation, and Maryland Department of the Environment. In September, 2025, C3 issued an RFI seeking responses from all interested stakeholders, including fleet owners and operators, MHDV original equipment manufacturers, site developers, charging infrastructure technology providers, electric vehicle service providers, charging-as-a-service providers, and other subject matter experts or entities involved in fleet electrification and MHDV charging. The purpose of the RFI is to inform design of a future solicitation to deploy electric MHDV charging infrastructure along the I-95 corridor and adjacent freight segments in New Jersey, Connecticut, Delaware, and Maryland.

3.2 Review of Existing Incentives in Other U.S. States:

The table presented in this section provides a detailed analysis of the incentives currently available in U.S. states outside of Maryland, assessing their impact on fleet electrification efforts. The following table outlines the existing incentives and evaluates their effectiveness based on available data.

Incentive Program	Program Managing Entity and Timeframe
1. On-Road Heavy-Duty Voucher Incentive Program	California, 2009 - Present
2. California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project	California, 2011-Present
3. California Electric Vehicle Infrastructure Project (CALeVIP) (2017) & Fast Charge California	California, 2023
4. EnergIIZE On-Road Heavy-Duty Voucher Incentive Program	California, 2021 - Present
5. CalCAP Zero-Emission Truck and Bus Program	California, Ongoing
6. CARB Low Carbon Fuel Standard (LCFS)	California, Ongoing
7. Fast Charging Incentives for MHD	California, Ongoing

8. Zero-Emission Truck Loan Pilot Project	California, 2024–Present
9. New York Truck Voucher Incentive Program	New York, 2013-Present
10. Zero Emission Vehicle (ZEV) Rebate and ZEV Fueling Infrastructure Grant for Municipalities	New York, 2016 - 2026
11. New York's EV Make-Ready Program	New York, 2020-Present
12. Medium- and Heavy-Duty (MHD) EV Make-Ready Pilot	New York, 2021-Present
13. NY School Bus Incentive Program	New York, 2022-Present
14. Charge Ready NY 2.0	New York, 2023-Present
15. Vehicle Emissions Reduction and EV Charging Station Project Funding	New York, 2023-Present
16. Low-Income Electric Vehicle (EV) Rebates	Washington state, October 2024-Present
17. ComEd Business & Public Sector EV Rebate Program	Illinois, 2024-2028
18. Massachusetts MOR-EV program	Massachusetts, 2014-Present
19. Clean School Bus Program	Federal, 2022-2026
20. Congestion Mitigation and Air Quality (CMAQ) Improvement Program	Federal, 2021-2026

Table 3.2. Incentive Programs in Other U.S. States

3.2.1 On-Road Heavy-Duty Voucher Incentive Program (California, 2009-Present)

Summary

This program offers funding to small fleet owners (those with 10 or fewer vehicles), to replace older heavy-duty diesel or alternative fuel trucks with cleaner, low-emission models. Funded through the Carl Moyer Program and administered by local air districts, it aims to reduce emissions and improve air quality by targeting older, high-polluting vehicles within small fleets that often face barriers to upgrading.

Impact

The program has funded over 560 heavy-duty vehicle and equipment upgrades through regional air districts, contributing to an estimated reduction of 458 tons/year of NOx and 14 tons/year of particulate matter. It offers up to $410,000 per voucher for zero-emission truck replacements, supporting early adoption of cleaner heavy-duty vehicles among small fleets. As part of the broader Carl Moyer Program, which has awarded over $530 million and reduced 8,601 tons/year of NOx statewide, the voucher program plays a key role in promoting equitable access to cleaner transportation technologies across California.

Key Takeaways:

- Helps replace high-polluting older diesel or alternative fuel trucks with cleaner, low-emission models.
- Offers significant financial support to small fleet operators, with vouchers of up to $410,000 available.
- Managed through local air districts, allowing tailored implementation based on specific needs.

3.2.2 California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (2011-Present)

Summary

The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) provides point-of-sale vouchers to accelerate the adoption of ZEVs in California's heavy-duty transportation sector. The program supports the purchase of electric school buses, public transit buses, and other clean vehicle technologies. It is designed to help the state meet its greenhouse gas reduction goals and improve air quality by incentivizing early adoption of emerging ZEV technologies.

Impact

Since its start, the HVIP has funded over 14,000 clean vehicles, including 1,213 bus commitments. By the end of 2023, the program had invested more than $1 billion across California. In 2022 alone, funding requests surpassed $240.3 million, reflecting strong and growing demand for ZEV support.

Key Takeaways:

- HVIP's voucher system streamlines ZEV purchases by reducing upfront costs, making it easier for fleets to transition quickly.
- The program targets electric school buses, transit buses, and other heavy-duty vehicles, addressing major fleet segments that contribute significantly to emissions.
- Over 14,000 clean vehicles funded since 2011, including over 1,200 buses, demonstrates substantial progress toward fleet electrification in California.

- Funding requests exceeding $240 million in 2022 highlight robust interest and ongoing momentum for zero-emission heavy-duty vehicle adoption

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3.2.3 California Electric Vehicle Infrastructure Project (CALeVIP) & Fast Charge California (CALeVIP 2.0) (2017, 2023)

Summary

CALeVIP provides rebates for publicly accessible electric vehicle (EV) charging stations throughout California. It offers up to $7,500 per Level 2 charger and up to $100,000 per DC fast charging port. CALeVIP 2.0's Fast Charge California initiative, launching July 8, 2025, focuses on deploying high-powered DC fast chargers, providing up to $100,000 per connector or 50% of project costs. Both programs are funded by the California Energy Commission and prioritize installations in disadvantaged and low-income communities.

Impact

As of early 2025, CALeVIP has supported nearly 10,000 EV chargers across California. The program has funded more than 5,000 EV charging ports, with over 6,000 additional ports in progress. More than $80 million in charger incentives have been allocated to disadvantaged and low-income communities, significantly expanding equitable access to charging infrastructure.

Key Takeaways:

- Offers substantial rebates for public EV charging infrastructure, up to $7,500 for Level 2 chargers and $100,000 for DC fast chargers, lowering upfront costs for fleet operators.
- Prioritizes disadvantaged and low-income communities, supporting equitable expansion of EV infrastructure and enabling fleets in these areas to transition more easily to zero emissions.
- Has funded thousands of charging ports statewide, demonstrating broad support and infrastructure growth to meet increasing electric fleet demands.

3.2.4 EnergIIZE On-Road Heavy-Duty Voucher Incentive Program (California, 2021-Present)

Summary

EnergIIZE provides reimbursement-style grants to support deployment of ZEV infrastructure for commercial fleets in California. Eligible participants include medium- and heavy-duty vehicle operators, fleet owners, and site hosts. The program is funded by the

California Energy Commission and administered by CALSTART to reduce upfront infrastructure costs and accelerate clean transportation adoption.

Impact

As of early 2025, EnergIIZE has awarded over $100 million for nearly 200 projects. These efforts aim to install more than 1,500 EV chargers and approximately 60 hydrogen fueling dispensers. About 60% of applications come from disadvantaged communities, with 89% of funded projects meeting equity criteria.

Key Takeaways:

- EnergIIZE directly addresses one of the main barriers to fleet electrification (charging and fueling infrastructure) through reimbursement-style grants.
- The program is expected to enable over 1,500 EV chargers and 60 hydrogen stations, significantly increasing capacity for medium- and heavy-duty ZEV operation statewide.

3.3.5 CalCAP Zero-Emission Truck and Bus Program (California, 2021-2026)

Summary

CalCAP Zero-Emission Truck and Bus Program encourages lenders to finance zero-emission medium- and heavy-duty trucks and buses used primarily for business purposes in California. The program targets small businesses with vehicles that operate at least 51% of their mileage in the state. Administered by the California Pollution Control Financing Authority (CPCFA) and funded by the California Air Resources Board (CARB), it aims to reduce lender risk and expand financing access to accelerate ZEV adoption in smaller fleets.

Impact

By mitigating lender risk, the program has improved loan availability and financing options for small fleets, supporting greater ZEV adoption among small businesses. The program has helped increase financing for clean trucks and buses, though detailed impact metrics are currently limited as the program continues to grow.

Key Takeaways:

- This program focuses on small fleet operators, helping overcome financing barriers that often limit access to zero-emission trucks and buses.
- By reducing lender risk, the program encourages more favorable loan terms and increased availability of capital for ZEV purchases.

3.2.6 CARB Low Carbon Fuel Standard (LCFS) (California, Ongoing)

Summary

To encourage lower-carbon fuel usage, "carbon intensity" (CI) scores are assessed for each fuel, and compared to a declining CI benchmark for each year. Low carbon fuels below the benchmark generate credits, while fuels above the CI benchmark generate deficits. Credits and deficits are denominated in metric tons of GHG emissions. Providers of transportation fuels must demonstrate that the mix of fuels they supply for use in California meets the LCFS carbon intensity standards, or benchmarks, for each annual compliance period. A deficit generator meets its compliance obligation by ensuring that the amount of credits it earns or otherwise acquires from another party is equal to, or greater than, the deficits it has incurred.

Impact

The program has seen specific increases in use of lower carbon-intense fuel sources, including electricity, but especially for renewable diesel.[67]

Key Takeaways:

- Directly disincentivizes high-carbon fuel use through credits system.

3.2.7 Fast Charging Incentives for MHD (California, Ongoing)

Summary

MHD-FCI is a draft proposal by CARB which seeks to expand the current fast charging incentives to include Medium and Heavy-Duty vehicle charging. By providing credit revenue to charging site developers, MHD-FCI helps de-risk these projects and attract private investment. The program supports both private fleet depots and multi-fleet charging hubs, the latter being important for fleets without on-site charging capacity.

Impact

This program, in combination with programs such as EnergIIZE, contributed to the 16,327 charging and hydrogen fueling points for MHD vehicles across the state of California. The letter recommends maintaining high LCFS credit values to support early infrastructure deployment, for CARB to revise credit calculations to better reflect real-world truck charging patterns and power needs, and prioritizing infrastructure in disadvantaged communities and freight-heavy corridors. It also suggests offering short-term operational support for public charging sites to ensure financial viability during the early market phase.

Key Takeaways:

- Maintain high LCFS credit values to support early infrastructure deployment

- Offering short-term operational support for public charging infrastructure is helpful

3.2.8 Zero-Emission Truck Loan Pilot Project (California, 2024–Present)

Summary

This pilot program provides loan support to fleets purchasing zero-emission medium and heavy-duty trucks, including assistance for associated charging and fueling infrastructure. Funded with $5 million by the California Air Resources Board (CARB) and the California Energy Commission, the project aims to reduce financial barriers to fleet electrification and accelerate deployment of clean trucks in California.

Impact

Launched in 2024, the program is currently in the data collection phase, managed by the California Pollution Control Financing Authority (CPCFA). Evaluation efforts will focus on loan uptake, deployment of vehicles and infrastructure, and changes in borrower behavior. Impact data are forthcoming as the pilot progresses.

Key Takeaways:

- By providing loans specifically for zero-emission medium and heavy-duty trucks, the program helps fleets overcome upfront capital challenges.
- The pilot includes funding not only for vehicles but also for associated charging and fueling infrastructure, addressing a key hurdle in fleet electrification.

3.2.9 New York Truck Voucher Incentive Program (New York, 2013-Present)

Summary

NYTVIP provides point-of-sale vouchers to commercial fleets for purchasing or leasing zero-emission medium- and heavy-duty vehicles, including battery electric and hydrogen fuel cell models. The program supports the removal of older, high-emission diesel trucks and buses, accelerating the adoption of clean vehicle technologies across New York State. Administered by the New York State Energy Research and Development Authority (NYSERDA), it is funded by the New York State Department of Environmental Conservation and Department of Transportation.

Impact

Since its launch, NYTVIP has issued nearly $18 million in vouchers, funding approximately 100 zero-emission trucks and buses statewide. Incentive amounts vary by vehicle type and weight class, ranging from $100,000 to $385,000 per vehicle. The program contributes to New York's goals of reducing transportation emissions and improving air quality.

Key Takeaways:

- NYTVIP offers significant point-of-sale vouchers (up to $385,000 per vehicle) lowering the financial barriers to adopting zero-emission trucks and buses.
- By prioritizing the replacement of older, high-emission diesel vehicles, NYTVIP targets fleets with the greatest potential for emissions reductions and air quality improvements.
- With nearly $18 million in incentives already issued and around 100 vehicles funded, the program demonstrates progress in fleet electrification statewide.
- NYTVIP also included a controversial scrappage requirement where in the program applicants seeking vouchers for new vehicles are required to scrap qualifying old trucks before receiving funds for new BEVs.
    - Scrappage rules can help to make sure that older diesel vehicles are taken off the road and replaced with newer EV models, however it also has potential downsides. With the NYTVIP, many of the scrapped vehicles were ones that were already likely to be scrapped without the incentive in place meaning less of an environmental impact compared to a diesel vehicle that might be on the road for many more years.
    - If scrappage is required it can also impact smaller fleets that may not have as many vehicles that need to be scrapped or low-resource fleets as the costs to scrap a vehicle can outweigh the benefits of the program.

3.2.10. Zero Emission Vehicle (ZEV) Rebate and ZEV Fueling Infrastructure Grant for Municipalities (New York State, 2016-2026)

Summary

This program provides rebates to New York municipalities for the purchase of ZEVs and grants for the installation of public ZEV fueling infrastructure. Rebates are available for up to $7,500 per vehicle (with a $375,000 cap per municipality), and infrastructure grants cover up to $500,000 per municipality and at least 80% of eligible installation costs. Eligible projects must support publicly accessible charging or hydrogen fueling infrastructure. The program is administered by the New York State Department of Environmental Conservation (NYSDEC) through the Climate Smart Communities initiative.

Impact

Impact data is limited. NYSDEC has announced that the funding helps local governments reduce fleet emissions, expand public access to EV infrastructure, and meet state climate goals. However, no public data has been released to date on the total number of vehicles or chargers deployed through the program.

Key Takeaways:

- By offering up to $7,500 per ZEV and up to $375,000 per municipality, the program helps local governments reduce the cost of adopting ZEVs for their fleets.

3.2.11 New York's EV Make-Ready Program (2020-Present)

Summary

New York's EV Make-Ready Program, active since 2020, provides funding that covers up to 100% of the costs to prepare sites for electric vehicle charging infrastructure. The program supports both fleet and public depot installations, helping accelerate EV adoption by removing upfront infrastructure barriers.

Impact

As of March 15, 2025, the program has funded the installation of 28,621 Level 2 charger plugs with an investment of approximately $227.4 million, and 2,440 Direct Current Fast Charger (DCFC) plugs with nearly $97.9 million committed. This substantial buildout supports large-scale fleet electrification and public charging accessibility across New York.

Key Takeaways:

- By covering make-ready costs, the program reduces upfront expenses that often slow EV fleet adoption.
- Significant numbers of Level 2 and DC fast chargers enable fleets to transition efficiently.

3.2.12. Medium- and Heavy-Duty (MHD) EV Make-Ready Pilot (New York, 2021-Present)

Summary

This program helps medium- and heavy-duty fleet operators by covering a significant portion of the costs to install electric vehicle charging infrastructure. It funds up to 90% of utility-side infrastructure costs and up to 50% of customer-side costs, easing financial barriers and accelerating fleet electrification. Administered by NYSERDA in partnership with local utilities, the program supports New York's clean transportation goals.

Impact

As of November 2023, the pilot's budget was increased to $58 million, reflecting a commitment to expanding charging infrastructure for medium- and heavy-duty fleets. The program's focus on disadvantaged communities ensures equitable access to clean transportation options. Incentives are available on a first-come, first-served basis until December 31, 2025, or until funds are exhausted, encouraging timely participation from fleet operators.

Key Takeaways:

- The program covers up to 90% of utility-side and 50% of customer-side charging infrastructure costs, lowering one of the most prohibitive financial barriers to medium- and heavy-duty EV adoption.
- The program's expansion to $58 million as of late 2023 demonstrates both strong uptake and New York State's increasing commitment to supporting clean transportation infrastructure.

3.2.13 NY School Bus Incentive Program (New York, 2022-Present)

Summary

NYSBIP offers financial incentives to school districts and bus operators for purchasing or repowering zero-emission school buses, including associated charging infrastructure. The program aligns with New York's mandate for all new school bus purchases to be zero-emission by 2027 and the entire fleet to be zero-emission by 2035. Administered by NYSERDA and funded through the Clean Water, Clean Air, and Green Jobs Environmental Bond Act, NYSBIP aims to reduce transportation emissions and improve air quality in communities across the state.

Impact

As of August 2024, NYSBIP has received applications from over 75 school districts, totaling requests for approximately 350 electric school buses. Notably, 51 of these districts are located in disadvantaged communities. The program has allocated $300 million in funding, with an additional $200 million announced in August 2024 to further support the transition to zero-emission school buses. Incentive amounts start at $114,000 per bus, covering up to 100% of the incremental cost, and additional funding is available for charging infrastructure and fleet electrification planning.

Key Takeaways:

- The program has committed $300 million and added another $200 million in 2024, signaling sustained financial backing and long-term policy commitment to school fleet electrification.
- Over 75 school districts have applied for roughly 350 electric buses, over 10% of the annual turn over numbers, indicating strong statewide momentum toward clean school transportation. Note: school bus ownership arrangements vary by county in Maryland; whether buses are owned by the school or contractors varies.

3.2.14 Charge Ready NY 2.0 (New York, 2023-Present)

Summary

Charge Ready NY 2.0 provides rebates for the installation of Level 2 EV chargers at public parking facilities, workplaces, and multi-unit residential buildings. The program, administered by NYSERDA, aims to expand EV charging infrastructure to meet growing demand and support equitable access, particularly in disadvantaged communities. Rebates of up to $3,000 per charging port are offered, with an additional $1,000 available for sites located in disadvantaged communities. By incentivizing installations across various property types, the program helps increase EV charger availability for fleet operators and the general public, contributing to the acceleration of EV adoption statewide.

Impact

In the past year, Charge Ready NY 2.0 has facilitated the installation of over 1,000 Level 2 charging ports across the state. This initiative contributes to New York's broader goal of increasing EV adoption by enhancing the availability of charging infrastructure.

Key Takeaways:

- The program has facilitated the installation of over 1,000 Level 2 charging ports across New York State, expanding EV infrastructure and providing more opportunities for fleet operators to charge electric vehicles.
- Rebates are available for public parking facilities, workplaces, and multi-unit residential buildings, addressing the needs of both private fleets and the general public, which encourages widespread adoption of EVs.
- Offering up to $3,000 per charging port helps reduce the initial financial burden for fleet operators and property owners, making it more cost-effective to deploy EV charging infrastructure.

- By targeting widespread installations, the program helps ensure that infrastructure keeps pace with growing demand for electric vehicles, supporting New York's broader goal of accelerating EV adoption.

3.2.15 Vehicle Emissions Reduction and EV Charging Station Project Funding (New York, 2023-Present)

Summary

This program, administered by the New York State Department of Environmental Conservation (NYSDEC), offers funding through the Volkswagen Environmental Mitigation Trust to reduce diesel emissions and promote EV infrastructure. It supports the replacement or repowering of diesel medium- and heavy-duty vehicles (including Class 4–8 trucks and buses) as well as the installation of EV charging stations. The program focuses on high-emission sectors such as freight, transit, and public transportation, with an emphasis on projects located in disadvantaged communities. The overarching goal is to accelerate the shift to cleaner transportation options across New York State while addressing environmental justice and public health concerns.

Impact

As of 2024, the program has supported the replacement of approximately 185 buses, including school, transit, and paratransit vehicles, with electric or low-emission alternatives. It has also funded the replacement of 65 large freight trucks and 95 medium-duty trucks with newer hybrid or electric models. In addition to vehicle upgrades, $19.2 million has been allocated to expand light-duty electric vehicle charging infrastructure. These efforts are expected to result in a reduction of 4,500 tons of nitrogen oxide (NOx) emissions over the life of the funded projects, which is an impact comparable to removing roughly 65,000 passenger cars from the road for a decade. The program demonstrates a comprehensive approach to fleet electrification, targeting both vehicle emissions and infrastructure gaps while aligning with statewide climate and equity goals.

Key Takeaways:

- Allocated $19.2 million for expanding light-duty EV charging networks, which supports broader fleet and public EV adoption across the state.
- Prioritizes projects in environmental justice communities, ensuring equitable distribution of clean transportation benefits and aligning with NY's environmental equity goals.
- Enables fleet upgrades in freight, transit, school bus, and paratransit sectors, making it versatile for a range of fleet electrification needs.

3.2.16 Low-Income Electric Vehicle (EV) Rebates (Washington state, October 2024-Present)

Summary

This program offers substantial rebates to support electric vehicle purchases by low-income individuals in Washington state. New EVs are eligible for up to $9,000 in rebates, and pre-owned EVs for up to $2,500. Qualifying applicants must have household incomes at or below 300% of the federal poverty level, or be enrolled in an income-qualified program. The program also offers a $9,000 rebate option for a three-year lease. Funding comes from the Electric Vehicle Incentive Account, created in 2022 with support from state general funds.

Impact

Within just two months of launch, the program issued 3,351 rebates, averaging $7,292 per rebate and using 55% of its $45 million budget. Of these, 64% were leases. The program is projected to generate $2.84 in benefits over 5 years for every $1 spent. These benefits include avoided social costs of carbon (such as improved health outcome), fuel savings from switching to electric vehicles, and reduced upfront costs (both now and when leased vehicles return to the market). One critical measure of the program's effectiveness is that 90% of recipients state that they could not have afforded an EV without the rebate.

Key Takeaways:

- Rapid rebate issuance and high utilization indicate strong demand among eligible individuals, suggesting that financial incentives effectively reduce adoption barriers, a principle that could inform fleet programs targeting small or nonprofit fleets with limited budgets.
- The inclusion of a significant lease rebate option (64% of rebates) demonstrates a pathway to lower-cost vehicle access, which fleets with budget constraints might leverage through lease or rental arrangements.

3.2.17 ComEd Business & Public Sector EV Rebate Program (Illinois, 2024-2028)

Summary

$70 Million in rebates for light-, medium- and heavy-duty electric cars, trucks, and buses, in 2025. Program also has funding for EV charging. Applicants who meet the Low-Income/EIEC community requirements are eligible for a 50% higher rebate than other communities. Program began on February 15, 2024 with $87 Million, and was reinstated for 2025 on February 6, 2025.[68] The $70 Million for 2025 were used up on May 17, 2025.[69] ComEd will invest another $168 million from 2026-2028 to continue this program.

Impact

The 2024 fund propelled nearly 3,500 residential and commercial charging Level 2 and DCFC ports, both public and private. Additionally, over 200 new and pre-owned EV fleet vehicles were added for municipal, business customers, and school districts. More than half of the funds were directed to low-income customers and to support projects in equity-eligible communities.

Key Takeaways:

- Increased funding amount for LI/EIE communities, leading to these communities receiving over half of the funds in 2024.
- Funded a greater number of charging ports than vehicles.

3.2.18 Massachusetts MOR-EV program (Massachusetts, 2014-Present)

Summary

The Massachusetts MOR-EV program offers scalable grants to support the electrification of truck fleets across the state. Eligible fleet operators can receive up to $7,500 per truck to help offset the higher upfront costs of medium- and heavy-duty electric vehicles. The program is part of the state's broader efforts to reduce greenhouse gas emissions and improve air quality through transportation electrification.

Impact

As of the latest data, the MOR-EV Trucks program has issued over $6.5 million in rebates, supporting more than 610 electric truck purchases or leases across Massachusetts. These incentives have helped both public and private fleets transition to ZEVs, contributing to the state's greenhouse gas reduction targets and improved air quality. Rebates range up to $90,000 per vehicle depending on class, facilitating adoption among medium- and heavy-duty fleets statewide.

Key Takeaways:

- Provides scalable rebates to support fleet electrification, with amounts up to $90,000 per vehicle.
- Targets medium- and heavy-duty vehicle classes (3–8), helping to decarbonize high-impact segments.
- Over 610 rebates issued since 2021, totaling $6.5 million in funding.
- The program's substantial rebates lower the barrier to entry for fleets considering the switch to electric trucks, making the transition more economically feasible.

- The program is open to a wide range of applicants, including individual residents, businesses, and non-profit organizations, promoting widespread adoption of electric vehicles.

3.2.19. Clean School Bus Program (Federal, 2022-2026)

Summary

The Clean School Bus Program provides federal funding to school districts across the United States to support the purchase of "clean" and zero-emission school buses. The initiative aims to improve air quality, reduce greenhouse gas emissions, and protect children's health by accelerating the transition to cleaner transportation technologies in school fleets.

Impact

As of the most recent funding cycle, the program has awarded a total of $2.78 billion, with $1.8 billion allocated specifically for electric school buses. This funding has supported the replacement of 5,692 older buses with electric models and resulted in 864 successful rebate applications nationwide.

Key Takeaways:

- With $2.78 billion awarded, including $1.8 billion dedicated to electric school buses, the program provides a major funding source to accelerate fleet electrification in the school transportation sector.
- 864 successful rebate applications indicate strong demand, suggesting a competitive funding environment that fleets must navigate strategically.

3.2.20. Congestion Mitigation and Air Quality (CMAQ) Improvement Program (Federal, 2021-2026)

Summary

The CMAQ Improvement Program is a flexible federal funding source available to state departments of transportation, local governments, and transit agencies for transportation projects that help meet Clean Air Act requirements. To qualify, projects must demonstrate emissions reductions and be located in or benefit an EPA-designated nonattainment or maintenance area. Eligible transportation investments include the purchase of diesel vehicle replacements and MHD ZEVs, along with related charging infrastructure.

Impact

In New York State in 2021, CMAQ funding primarily supported complete streets projects, such as improved bike and pedestrian infrastructure. A total of $178.8 million was awarded to 75 projects. Of these, one notable award related to fleet electrification was a $5 million grant to the Niagara Frontier Transportation Authority for the purchase of battery electric buses to serve communities across Western New York.

Key Takeaways:

- CMAQ offers a versatile funding source for states, local governments, and transit agencies to support projects that reduce emissions, including ZEV purchases and related infrastructure.
- Eligible investments include replacing diesel vehicles with zero-emission alternatives, addressing key segments in public and commercial fleets.

3.2.21. Comparison of Funding Between Maryland, New York, and California

Maryland Funding Compared to Three Other U.S. States: Several of the state incentive programs occur in California and New York and it makes sense to examine dollars spent in these states to Maryland. Maryland has spent approximately $34 Million on 194 electric vehicles and $2.4 Million 65 DC fast chargers. Based on the review provided above, California spent approximately $1.7 billion for 15,100 vehicles and $354 million for 11,500 chargers, while New York spent $376 million on 450 vehicles and $334 million for 32,000 chargers. Please note that these numbers are estimates based on the searchable data on the internet and these numbers should be interpreted with caution as not all information is available and searchable online.

3.3 Review of Existing Incentives Globally

The table presented in this section provides a detailed analysis of the incentives currently available globally, assessing their impact on fleet electrification efforts. The following table outlines the existing incentives and evaluates their effectiveness based on available data.

Incentive Program	Program Managing Entity and Timeframe
1. Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles	Canada (Federal), July 2022 - Present
2. CleanBC Go Electric Other Rebates	Canada (Provincial): British Columbia
3. Écocamionnage Program	Canada (Provincial): Quebec, 2021 - Present

4. Local low-emissions zones	Europe, 1996 - Present
5. Ending Tax Breaks for Fossil Fuel Company Cars	European Union, Drafted 2025
6. Fit for 55 plan Emissions Trading System	European Union: Since 2023, Updating in 2027
7. E-MHDV incentives	Austria
8. KsNI Programme	Germany
9. Truck Road Toll	Germany, 2005-Present
10. VAT exemption	Iceland, 2020-2023
11. Heavy-duty electric vehicle subsidy	Norway, 2024
12. MOVES incentives	Spain, 2021-Present
13. Royal decree on electric commercial vehicle tax deductions	Thailand, 2024-2025
14. Various tax incentives	Indonesia, 2024 - Present

Table 3.3. International Incentive Programs

3.3.1 Canada (Federal): Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) - (July 2022-Present)

Summary

Launched in July 2022, this program offers incentives of up to CAD $200,000 per vehicle for eligible organizations purchasing or leasing zero-emission MHD vehicles. The incentives apply to commercial Medium- and Heavy-Duty battery electric, plug-in hybrid, and fuel cell electric vehicles, and are available for vehicle purchases or leases of 12 months or more.

Impact

This program, as well as other MHDV programs, has remained within budget and successfully continued to provide funding for MHDVs while Canada's federal passenger ZEV incentive program had its $71.8 million fund exhausted in a weekend in early 2025.[70]

Key Takeaways:

- Offers significant incentives (up to CAD $200,000) for MHD ZEVs.
- Program has remained within budget, contrasting with oversubscribed passenger ZEV incentives.

- Supports long-term leases as well as purchases.

3.3.2 British Columbia (Canada - Provincial): CleanBC Go Electric Other Rebates

Summary

The CleanBC Go Electric Other Rebates Program is designed to support the adoption of ZEVs in a variety of applications including zero-emission motorcycles, low-speed vehicles, electric cargo bicycles (cargo e-bikes), utility vehicles, and a variety of medium- and heavy-duty vehicles. This is a unique program as it is specifically designed to provide rebates for electric vehicles that are not personal cars. Most vehicle types, including cargo bikes, only have rebates available for business and organizations. This program incentivizes fleets to diversify their modes of transportation where possible, something that few other programs do.

This program provides post-purchase rebates. For 24 and 36 month fleet leases, applicants are eligible for 100% rebates. Specifically, Medium- and Heavy-duty vehicles can get rebates from CAD $10,000 (Class 2b) - CAD $150,000 (Class 8). Cargo E-Bikes are eligible for up to $1,700 rebates.

Impact

This program has seen increases in sales of vehicles, chargers, and improved workforce development.

Key Takeaways:

- Encourages fleets to diversify transport modes, due to the program's broad eligibility across unique vehicle types beyond passenger cars.

3.3.3 Quebec (Canada - Provincial): Écocamionnage Program (2021-Present)

Summary

Since 2021, Quebec's Écocamionnage program has been the core pillar of Quebec's 2030 Green Economy Plan. For the 2024-25 year, it offered a budget of $30 million, with a subsidy up to $175,000 for a zero-emission MHDV purchase. The rebate was stackable with the federal rebate. This program was halted in September 2024 when it ran out of funding. Since then, an additional $35 million was added, expected to last until March 2025.

Impact

The funding for the 2024 program ran out in September 2024. Many industry leaders felt that the funding was insufficient, as evidenced by the funds being depleted early. The $30 million yearly budget can subsidize 171 trucks, a low number in the second most populous province in a country with 700,000+ medium- and heavy-duty vehicles.

This program has, however, contributed to Quebec being the highest ZEV adopting jurisdiction in Canada.

Key Takeaways:

- Generous rebates with stackable incentives.
- Funding exhausted early, due to high demand.

3.3.4 Europe (General): Local Low-Emissions Zones (Since 1996)

Summary

Since being introduced in Sweden in 1996, low-emissions zones have been used in many cities across Europe. This type of incentive places restrictions on higher-emission vehicles entering certain areas of a city. These areas, often in densely populated and highly-trafficked areas of the city, will either ban, charge fees, or require emission retrofits on higher-emission vehicles. In the United States, similar incentives have been introduced, such as electric vehicle access to HOV lanes.

Impact

Low-emissions zones have improved local emissions, reduced congestion, and incentivized ZEV purchases. In Germany, LEZ helped to increase the share of vehicles with stricter emission standards due to access restrictions.[71]

Key Takeaways:

- Non-financial incentive based on restricted access for internal combustion engine vehicles.
- Proven emissions and congestion reductions.
- Influences vehicle purchasing behavior through access control.

3.3.5 European Union: Ending Tax Breaks for Fossil Fuel Company Cars (Drafted 2025)

Summary

As of March 2025, the European Commission is drafting an end to tax breaks for petrol or diesel-powered company cars.

Impact

Has not been put into effect yet.

Key Takeaways:

- Currently, the IRS allows businesses to deduct vehicle costs and mileage for internal combustion engine vehicles used for business purposes.
- This measure is still in the legislative phase, so we have not seen its effects.
- Another financial incentive for fleet electrification.

3.3.6 European Union: Fit for 55 Emissions Trading System (Since 2023, Updating in 2027)

Summary

The EU now has legally binding emissions targets aiming to reduce emissions by 55% by 2030. Part of the plan includes the new Regulation for the Deployment of Alternative Fuels Infrastructure (AFIR), which sets mandatory deployment targets for electric recharging and hydrogen refueling infrastructure along European roads. Additionally, the EU Emissions Trading System incentivizes fleet electrification. This is a "cap-and-trade" scheme, which sets a cap on the total amount of GHGs that can be emitted by sectors covered under the system. Companies receive or buy emission allowances and can trade them. If they emit less than their allowance, they can sell the surplus; if they emit more, they must buy extra allowances or face penalties. ETS2, starting in 2027, specifically includes road transportation and buildings. This directly incentivizes EV adoption by making electricity comparatively cheaper and reducing the lifetime operating costs of electric fleets.

Impact

While ETS2 starts in 2027, the broader ETS has successfully reduced emissions in other sectors. Early adoption of infrastructure targets is underway.

Key Takeaways:

- Makes EVs more cost-competitive via cap-and-trade pricing.
- ETS2 will directly target transportation emissions.

3.3.7 Austria: E-MHDV Incentives

Summary

Austria offers federal bonuses up to €130,000 for electric buses and up to €65,000 for other commercial vehicles. These bonuses can be combined with any other community/provincial bonuses.

Impact

The program funded the procurement of 289 electric buses across various regions, including Vienna, Linz, and Klagenfurt, with a total investment of approximately €122 million.

Key Takeaways:

- Funding for electric buses.

3.3.8 Germany: KsNI Programme (2021-2024)

Summary

Germany's KsNI program provided funding for the purchase of new battery electric and fuel cell electric vehicles in categories N1, N2, and N3, as well as for the retrofit of existing N2 and N3 vehicles to electric drivetrains. Companies could receive up to 80% of the additional investment costs per vehicle. The total funding cap was €25 million per company per calendar year, which also includes subsidies (up to 50%) for charging infrastructure and feasibility studies. This initiative was part of Germany's broader strategy to decarbonize commercial transport and support green logistics.

Impact

When the program was launched in mid-2021, the program saw overwhelming demand and was quickly oversubscribed. It ultimately closed in 2024. Though it initially generated strong momentum, the program struggled with increases in supply-side prices; prices rose by 20–30% after the program started, a common side effect of targeted subsidies. Many of the manufacturers also failed to meet tight deadlines for vehicle production. Hyundai was able to supply around 100 series-production vehicles, but no other OEM or vehicle converter was able to deliver more than three vehicles to a single customer. Additionally, this program directed €24.6 million from the Federal Ministry of Digital Affairs and Transport towards incentives for the purchase of 151 Volta Zero trucks.

Key Takeaways:

- Generous funding for both vehicles and infrastructure.
- High initial demand, temporarily closed due to oversubscription. Program also experienced supply-side bottlenecks.

3.3.9 Germany: Truck Road Toll (2005 - Present)

Summary

In 2005, Germany implemented a distance-based truck toll, with the goal of shifting freight traffic to railways and low-emission vehicles. Part of this plan includes reducing the tolls for electric and natural gas vehicles. This plan continues to be in use.

Impact

In 2020, the state income from the toll amounted to €7.4 Billion. The greatest challenge with this law was costly system implementation, including upfront costs for construction, maintenance and operation of federal trunk roads (€6.6 Billion), and annual costs for harmonization measures (€537 Million), and expenditures related to the collection of truck tolls (€1.1 Billion). It took a “couple of years of operation” to see a return on investment. It was also noted that industrial and social acceptance can be gained by tax discounts or returns as well as improvements in infrastructure and alternative mobility.

Key Takeaways:

- Tolls for diesel and gas MHDVs, reduction in toll for electric MHDVs.
- Generates revenue while promoting ZEV adoption.
- High implementation cost but long-term payoff.

3.3.10 Iceland: VAT Exemption Program (2020–2023)

Summary

From January 1, 2020 to December 31, 2023, Iceland waived VAT at customs (up to €8,800 or ISK 1,320,000) and exempted VAT on the retail price up to €36,600 (ISK 5,500,000) for battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs), with full VAT applied only to the amount exceeding that threshold. In 2023, a special discount also applied to battery electric trucks, capped at €2.6 million (ISK 400 million). VAT has the benefit of being applied at point of sale, as opposed to tax rebates which are applied later.

Impact

Information on passenger EVs is more readily available than for MHD EVs. MHD EVs were comparatively more incentivized than passenger EVs. By 2023, electric vehicles accounted for over 70% of total car sales in the last three months of the year, up from 25% before the program in 2019, allowing the exemption program to ultimately close.

Key Takeaways:

- Waived VAT—point-of-sale savings increased accessibility.

- Major spike in EV adoption—program phased out after achieving large interest in electric vehicles.

3.3.11 Norway: Heavy-Duty Electric Vehicle Subsidy (2024)

Summary

Provides businesses with subsidies covering up to 60% of the additional purchase cost for heavy-duty electric vehicles. Additionally, businesses benefit from VAT exemptions and reductions for electric vehicles. This program is funded by the business development agency Enova.

Impact

This program did allow for a significant increase in electric heavy-duty truck sales. The program launched in April 2024, and during this year the country saw a 91% increase in the registration of heavy-duty electric trucks over 12 ton, totaling 371 units, accounting for 7.8% of all heavy-duty trucks sold that year.

For this program in 2024, Enova allocated 136.5 million Norwegian kroner (approximately €11.6 million), which was used to support the procurement of 108 heavy-duty electric vehicles.

Key Takeaways:

- Subsidies for heavy-duty vehicles, as well as VAT exemptions.
- Significant growth in electric truck adoption.
- Strong financial support per vehicle.

3.3.12 Spain: MOVES Program (2021-Present)

Summary

Spain's MOVES III program provides incentives for many different types of commercial vehicles (up to €190,000), as well as charging incentives. Interestingly, for charging construction, it provides larger incentives (10% higher subsidies) for smaller municipalities (pop. under $5,000). This model could be used in the United States to help expand the charging network to more rural areas which generally don't have as much access to electric vehicle charging. Additionally, the MOVES Corridors program aims to improve EV charging coverage along highways where infrastructure is currently insufficient, addressing so-called "charging blackspots" in rural and underserved zones.

Impact

A lack of enforcement by regional governments has made it unclear how many fuel stations are actually complying with the legal requirement to install high-power charging points, potentially undermining efforts to ensure equitable infrastructure rollout as outlined in the MOVES program.

Key Takeaways:

- Increased financial incentives for rural areas.
- Could be a model for underserved U.S. areas.

3.3.13 Thailand: Royal Decree on Electric Commercial Vehicle Tax Deductions (2024-2025)

Summary

As of March 27, 2025, companies purchasing domestically manufactured electric trucks and buses can deduct expenses at twice the actual vehicle price (with no price ceiling), while those purchasing imported EVs can deduct 1.5 times the vehicle's price. These expense "deductions" provide companies not only with free electric vehicles, but pay companies to buy them. Such incentives are incredibly expensive but are large investments in the EV manufacturing market in Thailand. These incentives are valid until December 31, 2025 and aim to accelerate the adoption of electric commercial vehicles.

Impact

This program is under two months old and as such does not have many documented outcomes yet. However, given U.S. electric vehicle costs and budget, such a program is not currently feasible in Maryland.

Key Takeaways:

- Aggressive, high-value tax incentives.
- Increased incentives for vehicles that are locally manufactured.

3.3.14 Indonesia: EV Tax Incentives (Since 2024)

Summary

Indonesia, hoping to produce 600,000 EVs by 2030, has given various EV-related tax benefits, including for MHDVs, which have been developing over the past few years. For FY2024, the government removed the luxury tax on EVs, and reduced the VAT for EV buyers from 11% to 1%. These benefits ended in 2024 and were replaced by a suspension of import tax, implemented until the end of 2025. Since 2025, to support locally-made EV's, electric buses that are built with a minimum of 20% local components are entitled to a five percent VAT subsidy. These incentives are designed to boost domestic demand and attract investment in the EV sector.

Impact

After the implementation of the VAT-DTP program, there was a significant increase in the sales of battery-based electric vehicles. In April, there was an increase of 1,345 units sold, a 44% increase compared to March's 928 units sold.

Key Takeaways:

- Tax cuts stimulate short-term EV sales.
- Increased incentives for locally made vehicles to encourage local manufacturing.
- Rapid market response to fiscal changes - possibly confusing to buyers.

3.4 Review of Existing Non-Financial Incentives

The table presented in this section provides a detailed analysis of the non-financial incentives currently available, assessing their impact on fleet electrification efforts. The following table outlines the existing incentives and evaluates their effectiveness based on available data.

Current Incentive Program	Program Managing Entity
1. Dedicated Zero-Emission Loading Zones	Santa Monica & Portland
2. Zero-Emission Freight Corridors	Federal DOT
3. Greenlane EV Charging Corridor	I-15: CA-NV
4. California Charging Corridor Project	Volvo & Shell
5. HOV Lane Access for EVs	AZ, VA, FL, GA, NC, UT
6. Right-of-Way (ROW) Charging Access	Portland

Table 3.4. Non-Financial Incentive Programs

3.4.1 Dedicated Zero-Emission ("Green") Loading Zones

Summary

Zero-emission or "Green" loading zones are a type of curb management strategy designed to prioritize access for zero-emission commercial vehicles, such as electric delivery vans. These zones aim to reduce tailpipe emissions, decrease urban congestion, and by providing conveniences to drivers of electric vehicles. (While the term "green loading zone" is sometimes used more broadly to refer to any loading zone that is part of a city's sustainability plan, it most often refers to a designated space with specific rules that favor or are exclusively for electric and other zero-emission delivery vehicles.)

Green loading zones typically work in one of two ways:

1. Exclusive Use: The loading zone is designated for the exclusive use of zero-emission commercial vehicles. A gas-powered vehicle that parks in this zone would be subject to a citation.
2. Preferential Access/Incentives: The zone may be a general commercial loading zone, but ZEVs are given preferential treatment, such as a longer permitted loading time or a reduced fee.

These zones are often located in dense urban areas where commercial delivery activity is high, and air quality is a concern. The goal is to provide a reliable, convenient parking space for EV delivery drivers, thereby encouraging companies to switch their fleets to electric.

Specific Examples and Policies

While the concept is relatively new, several cities have piloted or implemented green loading zone policies:

- Santa Monica, California: Santa Monica launched what is believed to be the nation's first Zero Emission Delivery Zone in 2021, covering a one-square-mile area in downtown. The program aimed to reduce emissions and congestion by prioritizing curb access for ZEVs, including electric cargo and light-duty electric trucks. However, the pilot was voluntary, meaning enforcement was limited and other vehicles could not be penalized for using the designated zones.
- Portland, Oregon: In 2024, the Portland Bureau of Transportation (PBOT) launched a pilot program called the "Zero-Emission Delivery Zone" (ZEDZ) in its downtown core. This was one of the first regulated ZEDZs in the United States. During the six-month demonstration period, certain truck loading zones were temporarily reprioritized for zero-emission commercial vehicles only. The project used parking sensors to collect data on curb use and test the effectiveness of the policy. The goal was to understand how a regulated system could support the transition to cleaner delivery fleets and reduce emissions. This pilot was funded by a $2 million grant from the U.S. Department of Transportation's SMART program.
- Los Angeles, California: The Los Angeles Department of Transportation (LADOT) has an ordinance that authorizes the installation of "Zero-Emission Vehicle Commercial Loading Zones." These zones are designated for the exclusive use of zero-emission commercial delivery vehicles. The ordinance also provides an incentive for ZEVs by allowing them a longer parking duration (up to one hour) in these specific zones

compared to the standard 30-minute limit for gas-powered vehicles in regular commercial loading zones.

- New York City, NY: While NYC has been a leader in installing public EV charging infrastructure, its approach to "green loading zones" has been more in the planning and surveying stage. The city has expressed interest in a policy that would use curb regulations to incentivize low-emission vehicles. This is part of a broader strategy to electrify the city's freight distribution network and reduce truck miles and greenhouse gas emissions.

Impact

While specific quantitative data on emissions reduction or delivery efficiency improvements in Santa Monica have not been publicly released, the pilot provided valuable insights into the implementation of ZEDZ.

In Portland, the pilot's outcomes are still being evaluated. Depending on results, Portland may apply for additional funding to expand the program.

Key Takeaways:

- Reduces Emissions: By prioritizing ZEVs, these zones directly contribute to better air quality in urban centers, which is a major public health benefit.
- Improves Delivery Efficiency: Knowing there is a dedicated and available spot can reduce the time EV drivers spend circling the block looking for parking. This saves time, reduces "double parking," and improves the efficiency of last-mile deliveries.
- Encourages Fleet Electrification: The policy provides a tangible benefit to commercial fleets that invest in electric vehicles, making the business case for electrification stronger.
- Data Collection: Pilot programs like Portland's can provide valuable data on how commercial vehicles use the curb, which helps city planners and transportation departments make smarter, data-driven decisions about future urban freight policies.
- Monitoring and Enforcement: Portland's 2024 pilot introduced monitoring technology and legal enforcement, addressing a key limitation of Santa Monica's voluntary approach.

3.4.2 Zero-Emission Freight Corridors (Federal DOT)

Summary

The U.S. Department of Transportation (DOT) is developing designated freight corridors for zero-emission medium- and heavy-duty (MHD) trucks. These corridors will include integrated charging infrastructure and route planning support to facilitate long-haul electric freight movement across states.

Impact

While still in early stages, the designation of these corridors prioritizes federal funding and demonstrates long-term commitment to zero-emission freight. The initiative is expected to improve freight efficiency, streamline infrastructure planning, and support regional coordination for fleet electrification.

Key Takeaways:

- Designated corridors become eligible for focused federal funding, accelerating infrastructure development and reducing cost barriers.
- This effort shows how the federal government is working to cut emissions from long-haul trucking by setting up specific routes designed for zero-emission trucks.

3.4.3 Greenlane EV Charging Corridor (I-15: CA-NV)

Summary

Greenlane, a joint venture between Daimler Truck North America, NextEra Energy, and BlackRock, is developing a 280-mile charging corridor along Interstate 15 between Los Angeles and Las Vegas. The corridor is specifically designed to support heavy-duty electric truck operations with strategically placed charging infrastructure.

Impact

Still in early implementation, with site plans underway as of 2024, the project represents a leading example of private-sector collaboration in EV infrastructure development. It has the potential to accelerate long-haul fleet electrification and serve as a scalable model for other regional corridors.

Key Takeaways:

- The project highlights how major industry partners are teaming up to build out essential EV infrastructure without relying solely on public funding.
- By targeting a busy freight route with heavy-duty charging stations, Greenlane aims to make electric trucking more practical for long-distance hauls.
- With site planning underway, the project is still in its early stages, but it marks a strong step toward real-world implementation of freight electrification.

3.4.4 California Charging Corridor Project (Volvo & Shell)

Summary

Volvo and Shell are collaborating to install charging stations for medium- and heavy-duty electric vehicles (MHD EVs) across key freight corridors in California. The project targets high-volume trucking routes to support the transition to electric freight transport.

Impact

The project is seen as a foundational effort to enable regional electric freight movement. State-level support enhances infrastructure feasibility and encourages early fleet adoption, addressing a key barrier to MHD EV deployment.

Key Takeaways:

- Backing from California helps streamline implementation and signals public-private alignment on transportation electrification goals.

3.4.5 HOV Lane Access for EVs (AZ, VA, FL, GA, NC, UT)

Summary

Certain states allow medium- and heavy-duty electric vehicles (MHD EVs), when properly registered, to use high-occupancy vehicle (HOV) lanes regardless of passenger count. This policy extends a traffic benefit traditionally reserved for light-duty vehicles (LDVs) to commercial EVs.

Impact

Though primarily benefiting LDVs, access for eligible commercial EVs can improve route efficiency and reduce delivery times, particularly in congested metro corridors. This non-financial incentive can support operational gains for electrified fleets.

Key Takeaways:

- Allowing MHD EVs in HOV lanes can shorten delivery times and improve scheduling reliability in traffic-heavy areas.
- This policy supports fleet electrification without requiring major infrastructure investment or subsidies.
- Tangible on-road benefits may motivate companies to adopt EVs sooner, especially for routes through congested urban corridors.
- Extending HOV access to commercial EVs reflects growing recognition of the unique needs and benefits of electrifying heavier fleet vehicles.

3.4.6 Right-of-Way (ROW) Charging Access (Portland)

Summary

Access to rights-of-way is highly complementary to green loading zones, because installing charging in rights-of-way near loading zones enables the vehicles to charge while loading and unloading. Portland's Right-of-Way (ROW) Charging Access policy, for example, permits the installation of electric vehicle chargers in public spaces such as curbs and sidewalks.
In addition to green loading zone, this approach also benefits neighborhoods where off-street parking is limited, expanding charging opportunities outside traditional private property locations.

Impact

By allowing chargers in public ROW, Portland increases infrastructure availability for smaller fleets and contractors who operate in dense urban areas. This policy also raises public awareness and visibility of EV charging, helping normalize electric fleet operations in neighborhoods with tight parking constraints.

Key Takeaways:

- Enables fleets to charge in public spaces where private parking or charging is unavailable.
- Provides practical charging solutions for operators without dedicated off-street parking.
- More visible chargers promote EV acceptance and demonstrate municipal support for electrification.

3.5 Review of Current Funding Pathways

Throughout Sections 1–5 of this report, we described numerous current incentive programs and, where applicable, identified their corresponding funding sources. Examples of these funding sources included federal grants (such as the Inflation Reduction Act and the Clean School Bus Program), utility investments, state-appropriated funds, and multistate partnerships. However, two key funding sources consistently reemerged across multiple Maryland-based programs and merit closer examination: the Volkswagen (VW) Settlement Fund and the Strategic Energy Investment Fund (SEIF). In this section, we take an in-depth look at VW and SEIF funding as potential areas of focus.

These two funding sources (VW and SEIF) are widely used across Maryland's environmental and energy programs. The VW Settlement fund originates from the 2016 legal settlement over VW's emissions cheating scandal. The total national settlement is $14.7 billion, with $2.7 billion allocated to the Environmental Mitigation Trust for state-led nitrogen oxide (NOx) reduction projects. Maryland received approximately $75.7 million from the settlement, and the Maryland Department of Environment (MDE) oversees the use of these funds through its

Volkswagen Mitigation Plan. These funds have been used to support MHD operators, such as school districts in transitioning to zero-emission MHD vehicles by funding the transition from older diesel-powered vehicles to battery electric vehicles (see section 3.2.6). Furthermore, up to 15% of Maryland's allocation is used to expand light duty public charging infrastructure across diverse communities. These projects prioritize deployment in communities disproportionately impacted by air pollution.

SEIF is another widely used funding source supporting Maryland's clean energy and emissions reduction initiatives. SEIF currently funds the transition to battery electric vehicles through multiple programs, including $10 million per year through the Medium-Duty and Heavy-Duty Zero-Emissions Vehicle Grant Program and $17 million in 2025 and 2026 through the Electric School Bus Grant Program. SEIF is primarily funded through proceeds from Maryland's participation in the Regional Greenhouse Gas Initiative (RGGI), a multi-state (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont) cap-and-invest program aimed at reducing power sector carbon emissions.

While RGGI funds could be used to help fund incentive programs it cannot always be relied upon to have a steady funding amount. RGGI contributions over the past four years have increased dramatically, growing from $77 million in FY2021 to $214 million in FY2024.[72] This trend is unlikely to persist, therefore relying on recent revenues may lead to underfunding certain programs moving forward.

A central goal of SEIF is to promote energy equity by ensuring that underserved communities benefit from clean energy investments and incentives for clean energy technology adoption. The Maryland Energy Administration (MEA) administers SEIF funds, directing them towards a broad range of programs. SEIF has supported the deployment of electric vehicle charging infrastructure and provided incentives for clean energy technology adoption. Future SEIF allocations should continue to prioritize equitable clean transportation projects, grid modernization, and incentives that encourage decarbonization across residential, commercial, and public sectors. Coordinating SEIF investments with federal programs and local initiatives could amplify their impact and support long-term climate resilience.

3.6 Incentive and Funding Recommendations for Maryland

Based on our research and conversations with key stakeholders, we developed incentive and funding recommendations to assist Maryland in transitioning MHD fleets to EV and ZEV options. We also looked at incentive and funding recommendations for installing charging infrastructure and make-ready programs.

Much of the funds to pay for these incentive programs will come from the SEIF which had $561 million across all revenue sources in FY2024.[72] However, the amount available through SEIF has varied tremendously through the last few fiscal years, for example it more than doubled in FY2024 compared to the previous two fiscal years. This was mainly due to a larger than normal increase in revenue from RGGI ($214 million compared to $140 million) and a nearly 4x increase in alternative compliance payment revenue.[72] To date, SEIF funding has been adequate to fund all state fleet vehicle transitions to EVs; notwithstanding recent increases in SEIF revenue from RGII, SEIF might not always be sufficient.

While in the past federal incentive programs have been used by Maryland and other states, today federal funds either are no longer or are uncertain in their availability. With this being the case, Maryland cannot rely on federal funds or programs to be available to assist with transitioning MHDVs.

In its Climate Pollution Reduction Plan, Maryland previously identified six potential new funding pathways to support GHG reduction activities in the state, including providing BEV incentives.[11] These potential new pathways include:

- Green Revenue Bonds
- Carbon Fees
- Hazardous Substance Fees
- Clean Air Toll
- Pollution Fee on Fuel-Burning Vehicles

The state should continue to explore these funding options to support the incentive strategies recommended below.

Incentives should also be targeted at low-income and historically underserved communities, including state agencies that serve those populations. Focus for how these communities should be determined should mirror other Maryland state standards for determining overburdened and underserved communities defined in MD Code, Environment § 1-701.[73] The state should also focus on the Maryland Climate Vulnerability Score for communities that are in the high percentile.[74] Other categories of burden include climate change risks, high energy burdens, higher health issue rates, high traffic volume and pollutants, and other economic determinants.

Through conversations with the Maryland Department of the Environment, we broke down our recommendations based on short (0-3 years) and long (3-10 years) term incentives, as well as low- and high-cost incentives to give multiple options for how MHD vehicles in Maryland can transition to ZEVs.

3.6.1 Short-Term Recommendations

These recommendations focus on accelerating adoption through direct financial support, infrastructure expansion, and targeted pilot programs.

1. **The MHD ZEV Grant Program**
    a. Increase annual funding to meet high demand where possible.
    b. Introduce tiered incentives similar to California's HVIP or New York's Truck Voucher Program. These programs offer higher rebates for early adopters, small fleets, and disadvantaged communities.
    c. Allow point-of-sale vouchers to reduce upfront capital requirements. Based on key stakeholder interviews, we found that point-of-sale vouchers have a larger impact on fleet adoption compared to tax and after-sale rebates.

2. **MHD EV Charging Infrastructure "Make-Ready" Program**
    a. Provide "make-ready" incentives to cover all or part of the cost of electrical infrastructure on the utility and/or customer side of the meter; such programs are often funded through electric utilities, with the approval of the Public Service Commission, though a similar offering (with a different funding source) could be provided by other agencies as well.
    b. Cover up to 100% of utility-side and 50% of customer-side charging infrastructure costs modeled on New York's MHD EV Make-Ready Pilot. A study can be done to determine the lowest amount that can be offered to incentivize installation.
    c. Prioritize fleet depots, public freight corridors, and underserved areas.
    d. When funded through utilities, projects should be evaluated and prioritized based on their benefits and costs to ratepayers.

3. **Small Fleet & Independent Operator Support**
    a. Introduce a voucher program for fleets with fewer than 10 vehicles to replace older diesel trucks with zero-emission alternatives, modeled on California's On-Road VIP.
    b. Provide low-interest financing or loan forgiveness for small operators, coupled with grants through the Maryland Green Bank.
    c. Designate a single state office as a "one-stop-shop" for EV-related incentives designed to help the market understand and utilize each of the applicable offerings.
    d. Voucher amounts scaled by weight class and greenhouse gas emission reductions.

4. **Infrastructure & Vehicle Bundled Grants**
    a. Offer combined funding for vehicle acquisition and depot charging equipment to simplify applications and ensure readiness.
    b. Offer matching grants for developers to build multi-fleet hubs and contracted state fleets.

5. **Regional Freight Corridor Charging Incentives**
    a. Build on the MD-NJ-PA-WV “Charging Ahead” partnership by incentivizing private-sector investments in multi-fleet charging hubs near ports, warehouses, and interstate corridors.
    b. Program provides high-powered charging needed for longer-haul operations and other vehicles.
    c. Once vehicle travel and depot data is updated, Maryland can determine the corridors most traveled by state vehicles.

6. **Proportional Credit Program**
    a. Allocate credits to manufacturer credit balances based on their California sales proportions relative to state-specific sales.
    b. Program offers early-year compliance relief, particularly to manufacturers with existing California ZEV programs.

3.6.2 Long-Term Recommendations

These recommendations focus on building a self-sustaining MHD EV market through regulatory certainty, operational savings, and workforce development.

1. **Statewide MHD EV Purchase Requirement**
    a. Set phased targets for new MHD EV purchases based on updated Advanced Clean Truck rules. If the state moves away from California’s timeline, create a steadfast timeline that is unlikely to change.

2. **Clean Fuel Standard**
    a. Create a credit trading system similar to California’s Low Carbon Fuel Standard (LCFS) to generate ongoing revenue for fleet electrification and charging infrastructure. Additional credits should be provided to disadvantaged communities and low-income areas to ease regressive effect of credit system.
    b. New Mexico has a similar Low Carbon Fuel Standard that Maryland can model its LCFS after. New Mexico’s LCFS allows for all alternative fuels to be used and for a goal of 20% reduction in carbon intensity by 2030 and 30% reduction by 2040.[75]

3. **Long-Term Financing & Loan Program**
    a. Partner with green banks or state bond programs to offer long-term, low-interest financing for vehicle and infrastructure investments.
    b. Focus on dedicated MHD EV financing window with 10-15 year amortizations.
    c. Include pre-approved lender network for quick deployment.

4. **Depot Electrification Readiness Mandates**
    a. Require new or substantially renovated freight facilities and bus depots to be "EV-ready" with installed conduit, electrical capacity, and space for chargers.
    b. Amend building and land use codes to require EV-ready electrical infrastructure for new depots and major renovations.
    c. Provide targeted grants for retrofits in underserved communities.

5. **State-Funded Technical Assistance Programs**
    a. Offer fleet transition planning, total cost of ownership analysis, and utility coordination to fleets, particularly small operators and municipal agencies.
    b. Such offerings will allow fleet operators to be prepared for the installation of EV chargers and adoption of EVs. The state may choose to prioritize public and nonprofit entities; commercial entities may be asked to share in the cost of these services or to receive free services contingent on purchasing a predetermined number of MHD EVs.
    c. Helps create readiness and application quality for state fleets to apply for private and federal grants or other financing.

6. **Workforce Development & Just Transition**
    a. Fund EV technician training, high-voltage safety programs, and retraining initiatives for diesel mechanics in partnership with community colleges and technical schools.
    b. Incentivize manufacturers to locate service centers in Maryland with tax credits for EV service facilities.

7. **Performance-Based Incentives**
    a. Provide ongoing operational incentives tied to verified emissions reductions, mileage, and uptime. These incentives can help fleets manage total cost of ownership over time.
    b. Consider short-term operational support for public chargers to ensure financial viability in low-utilization early years.

3.6.3 Low-Cost Recommendations

These recommendations look at lower upfront fiscal impact for the state of Maryland, while offering high leverage impact potential.

1. **Regulatory & Policy Signals**
    a. Update Advanced Clean Truck rule deadlines and dates to fit the state's current timeline.
    b. Update state procurement policies to prioritize zero-emission MHDV purchases for public fleets.

c. Create high impact as it creates long-term market certainty.
d. Minimal direct costs only requiring MDE staff time.

2. **Technical Assistance & Fleet Planning**
    a. Establish a "One-Stop" MHD EV Technical Assistance Hub offering services including total cost of ownership tools, route and infrastructure planning, and utility coordination support.
    b. Can be hosted by the MEA or another contracted nonprofit organization.
    c. Increases impact through improving application quality and readiness for other grant applications.

3. **Small Pilot "Make-Ready" Grants**
    a. Offer competitive grants for utility-side and customer-side electrical upgrades for depots.
    b. Impact focuses on enabling early charging sites that fit MHD EVs.
    c. Focus on a statewide program including all electric utilities.
    d. Start with lower cost to test program design and gather cost data. Can build up to higher costs, pulling from SEIF funding.

4. **Utility Tariff Changes**
    a. The Public Service Commission can consider implementing new rates such as a demand charge phase-in rate or a rate under which commercial EV charging customers can earn financial incentives by reducing EV charging during designated peak periods and increasing EV charging during overnight hours, both of which have been approved in New York.[76] Acknowledging that demand charges in Maryland tend to be lower than in New York, nonetheless these types of rates could prove beneficial.
    b. Primary purpose is to lower operating costs for fleets adopting electric MHDVs.

5. **Recognition & Labeling Programs**
    a. Launch a "Maryland Clean Fleet Leader" recognition program for early adopters, giving reputational benefits and media coverage.
    b. Minimal budget for outreach efforts to increase awareness of programs and of awardees.
    c. Can be used to boost visibility of early adopters and increase peer influence to showcase success.

6. **Targeted Outreach & Equity Grants**
    a. Provide small planning grants to small fleets and minority-owned operators to prepare competitive applications for federal/state incentives.

   b. Can focus on $10 - 25k planning grants for small/minority-owned fleets or fleets that specifically impact these communities across the state.
   c. Increases equitable participation and impact across the state.

3.6.4 High-Cost Recommendations

These recommendations look at higher upfront fiscal impacts for the state of Maryland compared to low-cost methods. While these recommendations incur higher upfront fiscal costs, they offer higher adoption impact compared to low-cost methods.

1. **MHD EV Grant & Voucher Program**
   a. Significantly increase funding to meet demand as FY2025 program closed early due to oversubscription.
   b. Offer point-of-sale vouchers covering up to 90-100% of incremental vehicle cost for small fleets and disadvantaged communities.
   c. Through stakeholder interviews, we have found that point-of-sale vouchers have the biggest impact in driving early adoption. Covering 90-100% of incremental costs also decreases the biggest barrier to adoption which is the higher purchase cost of ZEV alternatives. Covering incremental costs also lowers total cost of ownership for ZEVs, increasing likely adoption for smaller and disadvantaged communities.

2. **MHD EV Charging Infrastructure "Make-Ready" Program**
   a. Provide "make-ready" incentives to cover all or part of the cost of electrical infrastructure on the utility and/or customer side of the meter; such programs are often funded through electric utilities, with the approval of the Public Service Commission, though a similar offering (with a different funding source) could be provided by other agencies as well.
   b. Cover up to 100% of utility-side and 50% of customer-side infrastructure costs. Study can be done to determine the lowest amount that can be offered to incentivize installation.
   c. Prioritize freight corridors, transit and other fleet depots, and underserved areas.
   d. When funded through utilities, projects should be evaluated and prioritized based on their benefits and costs to ratepayers.
   e. Helps to make the state and state depots ready for the installation of needed charging infrastructure.

3. **Corridor Charging Hubs**
   a. Provide capital cost-share for higher-power charging hubs along key freight and logistics corridors.
   b. Offer initial operational subsidies to stabilize early usage.

    c. Covering key travel corridors for fleet usage allows for vehicles to be charged during their day of use.

4. **Low-Interest Financing & Loan Guarantees**
    a. Through the creation of a Maryland Green Bank, offer 10-15 year low-interest loans for vehicles and infrastructure
    b. Provide a loan loss reserve to de-risk lending to small operators.
    c. This option has higher costs, but it expands financing access to help cover vehicle and charging infrastructure costs not covered by other programs.

5. **Performance-Based Operational Incentives**
    a. Pay fleets annual performance credits based on verified GHG and pollutant reductions, uptime, or V2V/V2Z participation.
    b. Supports operational economics for fleets making the transition to ZEVs.

3.6.5 Additional Incentive Options

1. **Diesel Tax:** Maryland could add a surcharge to the state diesel excise tax, disincentivizing diesel truck usage and providing new revenue for grants to help trucking companies purchase zero-emission trucks. Caution must be taken to not overly penalize small operators or stifle overall movement of goods.
2. **VMT Tax:** Maryland could charge diesel trucks a VMT-based fee that scales with weight class - the heavier and more polluting the vehicle, the higher the per-mile charge. Caution must be taken to not overly penalize small operators or stifle overall movement of goods.
3. **Advanced Clean Fleets Rule:** Maryland may eventually follow California and other states in adopting the Advanced Clean Fleets (ACF) regulation, which requires fleet operators and state/local governments to purchase an increasing share of zero-emission vehicles over time. California has withdrawn its request to the EPA for a waiver to implement the ACF, therefore its impact on Maryland will depend on whether it is revived in the future.
4. **"Old Trucks" Rule:** Maryland could expand the Port of Baltimore's existing "old truck" restrictions by gradually tightening age limits for drayage trucks serving the port and linking compliance to electrification incentives. For example, as older diesel trucks are banned, the state could offer scrappage payments or discounts on electric drayage trucks, accelerating turnover in one of the most concentrated heavy-duty truck markets.
5. **Age-Based Registration Fees:** Registration fees could be tiered by vehicle age, so older trucks cost more to register than newer trucks.
    a. These fees can add undue stress to smaller and lower-resourced trucking companies. A lower fee or waiver should be given to companies and state agencies that have a lower operating budget.

Conclusion

Financial incentives are most effective at driving consumer adoption when they are provided at the point-of-sale incentive, as compared to post-purchase. Funding for such incentives should also be stable and consistent and be at a level that can keep pace with demand without leaving long waiting lists. A post-purchase credit with limited funding, like Maryland's, can still provide a benefit to some buyers but is a far less powerful and reliable policy tool for achieving broad-based EV adoption.

While a wide range of incentive programs and funding mechanisms were identified through this review, it is important to note a key limitation: many of these programs were relatively new. As such, comprehensive outcome data—especially regarding long-term vehicle deployment, emissions reduction, and cost-benefit effectiveness—were often not yet available. Readers are encouraged to interpret early impact data with caution and to consider that the effectiveness of many programs would be best assessed over time as more performance metrics became available. Despite these limitations, the program descriptions above provide a robust foundation for understanding Maryland's current and potential incentive landscape, and identifying evidence-informed pathways to accelerate its clean fleet transition. The findings and recommendations are intended to support policymakers, agency leaders, and implementation partners in making strategic, data-driven decisions to shape the future of transportation in Maryland.

Chapter 4: Transitioning State-Owned Vehicles to Zero Emissions

Authors: Alexis Blomqvist, Lucas Washburn, Alexander Baad

Chapter at a Glance:

- Fewer than 250 MHDVs in the state fleet (4.3%) have identical BEV replacement options (this excludes transit buses, which are covered not by the ACT but by the Zero-Emission Bus Transition Act).
- Maryland state vehicles whose specifications are similar or identical may be used for vastly different purposes, some of which can be accomplished by EVs and others which cannot. Vehicles required for emergency use (including events such as snow removal) and 24/7 response are generally not currently suitable for electrification but may become so as technology advances.
- Many vehicles in the state fleet could accomplish their mission as ZEVs, recognizing that certain changes such as where they park overnight might need to be changed. The Department of Budget and Management should expand its review of ZEV suitability to include medium- and heavy-duty vehicles.
- It would cost the state an additional $18 million to replace all 242 exact BEV-replaceable ACT compliant vehicles (excluding transit buses) between 2027 and 2035. This number represents the additional incremental cost between the $35 million cost for BEV replacements and $17 million for internal combustion engine vehicles.
- Because installing charging infrastructure takes longer than purchasing EVs, we recommend (1) identifying specific internal combustion engine vehicles for which suitable EVs exist, (2) determining the primary parking locations for these vehicles, and (3) initiating the installation of make-ready infrastructure (i.e., all electrical infrastructure other than the charger itself) at least 24 months in advance of the expected vehicle delivery date. Chargers can be installed relatively quickly once a vehicle is ordered.
- Nearly 40% of the state fleet's greenhouse gas emissions are from transit buses, which although not subject to the ACT are scheduled for replacement under the Zero-Emission Bus Transition Act.

Introduction

In this chapter, we assess the timeline, economic feasibility, and models available for transitioning MHDVs in the state vehicle fleet to ZEVs. Transit buses are not covered by the

ACT regulation; however, due to their greenhouse gas emissions and public visibility, we chose to address them in limited scope. We performed a comprehensive state fleet analysis using the U.S. Department of Energy's Zero-Emission Vehicle Planning and Charging (ZPAC) tool to determine timelines and comparable MHD electric vehicle replacements for current Maryland state fleet vehicles. Our analysis is limited to four representative agencies which collectively operate more than half of the state vehicles. Technical documentation is included so that the analysis can be repeated once additional information, such as model availability or specific dwell locations, is available.

The state government's MHDV fleet includes a range of vehicle types, with some emitting more greenhouse gases than others; greenhouse gas reductions can be maximized by targeting those vehicles with the highest greenhouse gas emissions, factoring in both fuel economy and vehicle miles traveled. For example, our analysis shows that transit buses account for approximately 25% of the state's fleet, but these vehicles emit nearly 40% of the total fleet's greenhouse gases. Overall, four specific vehicle types, constituting approximately 3,000 vehicles or half of the state fleet, produce more than 75% of overall emissions. Unlike many other MHDVs, which for many reasons currently lack suitable ZEV alternatives, electric transit buses are commercially available.

4.1. Vehicle and Infrastructure Procurement Overview

Guided by the Climate Solutions Now Act of 2022 and the Zero-Emission Bus Transition Act, Maryland's effort to transition the state-owned fleet of MHDVs to ZEVs touches every agency. The state's annual vehicle procurement process begins with each individual agency developing a list of desired vehicles. Such vehicles generally fall into approximately 22 "Types," which are defined by the State of Maryland Fleet Vehicle Technical Purchase Standards and range from Compact Sedan (Type 1) to Class 7 trucks (Type 22), in addition to specialized vehicles. Many of the Vehicle Types contain sub-types, or variants. For example:

- Type 6 specifies a ½ ton pick-up truck;
- Type 6-C is a V-6 Flex Fuel engine with a 6.4-foot bed;
- Type 6-E-1 is fully electric with a 6.4-foot bed; and
- Type 6-E-2 is fully electric with a 4.6-foot bed.

The Technical Purchase Standards also include examples of each vehicle type or sub-type. In the case of Type 6 trucks:

- Type 6-C includes the Ford F-150, the Chevrolet Silverado 1500, and the Dodge Ram 1500;
- Type 6-E-1 is the Ford F-150 Lightning and Type 6-E-2 is the Rivian R1T or the Chevrolet Silverado EV.

We note that Maryland's budget coding and operations are different from the ZPAC's, which creates certain challenges that we resolve to the extent possible, as described below.

Agency requests for vehicles are submitted to the Department of Budget and Management (DBM). A DBM analyst reviews each request to determine whether electric vehicle options exist in cases where the agency did not select one. DBM then engages with the agency to determine whether an electric version would satisfy the agency's needs. Together, DBM and the agency take into account considerations that include the agency's number of miles driven per day (to ensure the EV's range can satisfy the agency's mission), access to charging, and ability of the vehicle to perform specific tasks such as hauling or snow removal.

As discussed below, a vehicle which is classified as "identical" is identical based on the vehicle's technical specifications. However, other factors such as aftermarket modifications and the manner or purpose for which a vehicle is used may result in an electric version not being a true substitute. When DBM and the agency agree on an electric option, DBM records relevant information in a spreadsheet referred to as the DA-8. The spreadsheet is divided by agency and contains data such as the vehicle's daytime location, overnight location, whether the overnight parking location is gated, the EV make and model along with the fossil fuel comparable vehicle, the cost of each, and the cost difference. One purpose of this information is to guide the installation of charging infrastructure.

Currently, this process is followed only for light-duty vehicles. We recommend that DBM expand this process to include all vehicles that the state purchases or contracts, and that additional resources be provided so that DBM can remain current on new MHD EV technology and capabilities, which is necessary to engage with state fleet managers and make informed decisions about replacing internal combustion engine vehicles with electric versions.

Because charging is critical to the successful operation of electric vehicles, DBM collaborates with the Department of General Services (DGS) to install charging where needed. To achieve this, DGS consults with the requesting agency and assesses the facility's parking options and electrical capabilities. DGS identifies the most economical location at a designated property, and if the agency selects an alternate location which is more expensive the agency must pay the difference in what is referred to as an upgrade fee. To date, most locations without charging are able to utilize existing electrical capacity to support chargers, though some have required upgrades to support charging. As additional chargers are added, new capacity will likely be needed and will result in the per-port cost being higher. DGS utilizes an electrical engineer to develop the necessary plans for the selected location(s); this work is performed either by an employee or by a contractor. Construction is always performed by a contractor. Installation and two years of maintenance costs associated with charging infrastructure are paid for by DGS.

4.1.1 Methodology Overview: Naming Conventions

To perform the analysis key to the feasibility of transitioning the Maryland fleet to ZEVs, a review of the state's naming convention for vehicles must be completed. This convention plays a parallel role to the Special Item Number (SIN) system used in federal procurement: namely, establishing a standardized shorthand to classify vehicles by type, size, driveline, fuel type, and intended use. These conventions create consistency across procurement systems so that agencies, vendors, and contractors can quickly match a vehicle request to an established category. Maryland's convention works slightly differently than SINs, which rely on a combination of GVWR, drive type, body cab style, and body type to assign SINs, while Maryland's system uses body type description, towing capacity, passenger capacity, fuel type, body cab style, and fuel type to differentiate. Understanding how the fleet is categorized between SINs and ZPAC versus Maryland's internal system is crucial for leveraging the insights from ZPAC into any future fleet planning the state does, including introducing telematics systems and using data-based tools for analysis.

Maryland Internal System Naming		Vehicle	ZPAC/Federal System Naming	
Type #	Description		SIN #	SIN Segment
8-X	1-Ton Pick-up Truck, gas (Ext. Cab), 6.4' Bed 4x4	Ford F350	MD Pickup-49	Pickup Trucks (4x4) Full Size, Extended Cab, 8000/10001/ 9201 GVWR

Table 4.1. Comparison of Maryland and ZPAC/federal system naming for vehicles

The most important difference in the notation is the difference in how pickup trucks are written. In Maryland's system, the technical specification uses ton specifications. The "½-ton," "¾-ton," and "1-ton" classifications are legacy classifications that date back to when trucks' payload capacities roughly equaled 1,000, 1,500, and 2,000 pounds, respectively. Over time, vehicle engineering advanced and actual Gross Vehicle Weight Ratings (GVWR) increased significantly, but the shorthand persisted as a consumer- and industry-friendly way to describe relative size and capability. Today, a "1-ton" pickup typically falls into the Class 3 truck category with a GVWR between 10,001 and 14,000 pounds, far above the literal 1-ton payload.

4.2 Fleet Analysis

To identify and prioritize state-owned vehicles for which electric options exist, we assessed Maryland's state fleet using the ZPAC tool. This process includes vehicle-level VIN decoding, ZEV replacement identification, and a charging infrastructure needs assessment. The initial dataset received from the Motor Vehicle Administration (MVA), from which personally identifiable information was redacted, indicated that the state (excluding counties) owns 6,446 vehicles. After identifying records that lacked data necessary for our analysis, the final dataset of state-owned MHDVs totaled approximately 5,600. Our analysis is limited to four representative agencies which, collectively, control more than half of the state vehicles.

4.2.1 Models Available for Transitioning to ZEV

The State of California maintains a database of ZEVs which qualify for the California Air Resources Board's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). We filtered this database for ZEVs from Class 2b and up, and which have a model year of 2025. The complete results are contained in Table B.2 in Appendix B. Included with each vehicle type is the amount of the incentive that California currently offers.

Agency Name	Count	Percentage of Fleet
State Highway Administration	1,315	36.5%
Department of Natural Resources	515	14.3%
Maryland Transportation Authority	374	10.4%
University of Maryland, College Park	264	7.3%
Maryland Transit Administration	199	5.5%

Table 4.2. Number and percentage of vehicles for agencies with most fleet vehicles (transit buses excluded).

4.2.2 Agency Fleet Analysis

Motor Vehicle Administration (MVA) records show approximately 50 distinct state entities owning one or more MHDV (excluding transit buses, which are not covered by the ACT). Of these, five represent more than 60% of all state-owned vehicles; no other agency owns more than five percent of the overall vehicle population. For illustrative purposes, we describe in detail two large agency fleets: the State Highway Administration (SHA) and the Department of Natural Resources, each of which faces a different pathway toward electrification. High-level vehicle data is provided for additional agencies.

Definitions

Truck: Typically pickup trucks (GVWR 8,501+), cab chassis vehicles, and cutaways.
Dump Truck: Typically traditional small bore and big bore dump trucks including single-, tandem-, and tri-axle. May also include cab-chassis with dump bodies.
Tractor: Class 8 tractors, typically used to pull trailers.

Note: Numbers below may not total due to rounding and other categories such as tow trucks, loaders, graders, and snow removal equipment; while electric options may exist for some of these vehicles, the volumes are low and best addressed individually.

State Highway Administration (SHA)

The State Highway Administration (SHA) is the Maryland governmental agency that maintains Maryland's numbered highways and bridges. MVA registration data shows a total of approximately 1,300 MHDVs in SHA's fleet, comprised of the following types:

Class Description	Vehicle Count	Percentage of Agency Fleet
Truck	722	54.9%
Dump Truck	560	42.6%
Tractor or Truck Tractor	33	2.5%
Total	1,315	100.0%

Table 4.3. State Highway Administration vehicle types

Trucks: SHA's fleet of more than 700 trucks consists primarily of ¼-ton, ½-ton, ¾-ton, and 1-ton pickup trucks. As shown in the table below, nearly all have ZEV counterparts that are similar but not identical. SHA's work vehicles are selected based on highly specific performance capabilities, therefore a vehicle that has similar specifications may not be suitable for the intended use. Most of SHA's pickup trucks are used more than 12 hours per day during snow, and sometimes 24 hours per day for tasks such as road monitoring, and therefore are not conducive at this time to being electric without increasing the number of vehicles in the fleet.

SHA also operates a fleet of lighter duty trucks as pool vehicles, typically Class 2b, that do not work during winter storms because they are used for traffic, project development, and construction such as major road projects, paving, bridge repair, overlays, and utility coordination. While these vehicles may at times be deployed to other parts of the state, their use is generally flexible enough to accommodate charging and these vehicles may therefore be converted to electric without an unacceptable reduction in service.

Dump Trucks: SHA's dump trucks are used year-round for a wide range of uses, but winter operation is the most significant constraint we identified in evaluating the fleet and determining whether ZEV alternatives are viable. The SINs for the majority of dump trucks do not have electric counterparts. Nonetheless, because electric dump trucks are emerging as viable options, we investigated whether electric dump trucks would be suitable alternatives to the existing diesel fleet.

Winter operations run continuously with two 12-hour shifts per day (referred to as "slip seating") until all roads are free from snow and ice. Winter conditions can persist for several weeks uninterrupted, sometimes in excess of 30 days particularly in Western Maryland. Even in other parts of the state where clearing roads may take one to three days, trucks work 24-hours a day, and trucks from other districts are often requested when availability allows.

Minimizing interruptions is essential to maintaining SHA's desired level of service. Strict measures designed to maximize efficiency and availability include directing drivers (including contractors) to:

- Communicate the need for fuel or meals prior to leaving the assigned snow route;
- Coordinate all refueling; and
- Potentially make shift changes on the assigned snow route or at a predetermined location rather than take time to return a vehicle to its depot.

"Winter operations" are triggered during snowfalls according to the following phases:

- Phase 1: (0–1-inch forecast or <0.1 inches of freezing precipitation) Includes only SHA Trucks.
- Phase 2: (1–2-inch forecast or 0.1 to 0.2 inches of freezing precipitation) Includes Phase 1 trucks and hired spreader trucks to supplement SHA work forces on designated routes where there are no assigned SHA trucks.
- Phase 3: (2–4-inch forecast or >0.2 inches of freezing precipitation) Includes Phase 2 trucks and hired spreader trucks to supplement the SHA work forces during heavier snowfalls.
- Phase 4: (>4-inch forecast or major freezing precipitation) Includes all Phase 3 trucks and hired push trucks to supplement SHA work forces on designated routes as roadway conditions warrant.

Winter operations phases are addressed here because they trigger the hiring of privately owned vehicles to supplement the SHA fleet. Hired trucks are held to the same standard of performance as SHA vehicles and SHA will not pay for down time on equipment that extends beyond one hour, even when equipment is involved in an accident, at fault or not.

Sharing of trucks and 24-hour usage also occurs during other times of the year. For example, District 6 in Western Maryland has requested trucks from District 1 on the Eastern Shore to help during a flood, and the reverse occurred in a hurricane. Rapid response and the ability to operate with maximum up-time in these cases is essential.

Based on today's battery technology, electric vehicles' range decreases and charging time increases in cold weather. Electric trucks therefore cannot currently operate as many hours per day as their diesel counterparts. One solution to accommodate downtime for charging and still maintain SHA's target level of service is purchasing additional vehicles. However, given that some of the existing fleet is not being replaced on schedule due to budget constraints, we do not anticipate the future budget will permit adding to the fleet. Finally, in the event the budget does permit additional vehicles to be purchased, this would result in more trucks and therefore more plowing capacity, which would be preferable to more trucks and the same capacity due to required downtime.

Our conclusion is that electric dump trucks are not currently feasible for the vast majority of SHA's fleet, based primarily on the operational requirements during winter operations. However, improvements in battery energy storage and extreme fast charging, including potential new ways to charge vehicles, may emerge, which could make electric vehicles suitable for even SHA's uses.

Tractors: Each of SHA's 31 shops is assigned a Class 8 tractor. These tractors tend to stay within their shop boundaries, which generally but not exclusively follow county boundaries. For example, District 6 has three shops, one at Keyser Ridge (Garrett County), one in LaVale (Allegany County), and one in Hagerstown (Washington County).

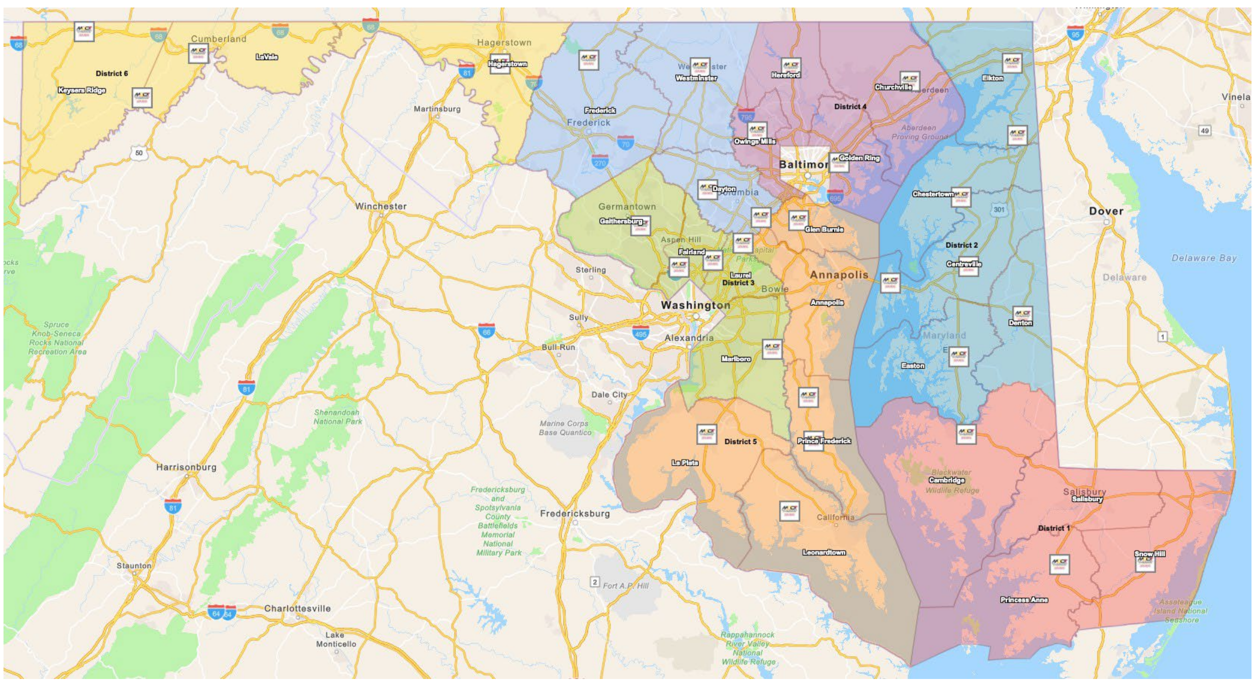

Figure 4.1. State Highway Administration Districts

SHA's tractors are used for daily tasks including hauling equipment such as dump trucks for repairs, and heavy loaders, heavy mowers, and other large equipment to job sites for repair. Tractors are not typically used for winter operations other than to occasionally transport heavy equipment to another part of the state to aid in snow removal or in the event of a natural disaster. Overall, they tend to stay within their shop districts.

Two additional tractors are assigned to the Fleet Department for delivering new equipment to the designated district, old equipment to auction, broken equipment in for repair, or other purposes that equipment needs to be moved across the state.

Because SHA's Class 8 tractors generally do not drive more than 100 miles per day, and when they do they have time to charge if needed, we conclude that the Class 8 tractors which are assigned to shops are reasonable candidates for electrification.

The table below shows that the overwhelming majority of SHA's MHDVs, which are primarily dump trucks and Class 8 tractors, do not have identical or similar BEV replacements.

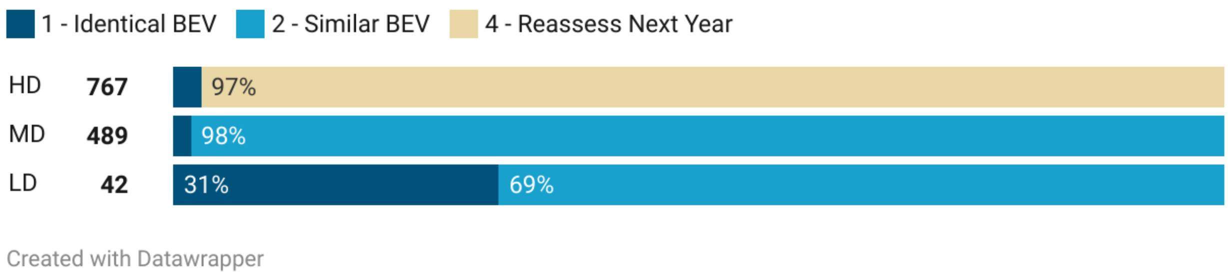

Figure 4.2. State Highway Administration: BEV Availability

In the HD category, primarily dump trucks, 747 out of 767 were classified as "reassess next year" and the remainder have identical BEV replacements. The term "reassess next year" does not necessarily suggest that there will be an identical or similar BEV replacement in a year, rather the term is used to encourage buyers to revisit the market to determine whether new options have emerged.

In the MD (medium-duty) category, nearly all (98%) of the approximately 500 vehicles have similar BEV counterparts based on specifications. MVA records show that the medium-duty pickup trucks are defined by 10 different SINs, which illustrates the specific and varying needs of particular vehicles and demonstrates that buyers such as SHA select vehicles based on particular features that the internal combustion engine vehicle market, which is mature, can satisfy. The ZEV market, on the other hand, does not yet contain the multitude of options and therefore may preclude selecting a ZEV based on missing capabilities.

As SHA has no vehicles in the excluded transit bus class, there are no changes for this agency under proposed ACT regulation.

Department of Natural Resources (DNR)

The Department of Natural Resources is the state agency that manages and conserves Maryland's natural resources. Its sub-units include the Maryland Park Service, Forest Service, Wildlife and Heritage Service, Engineering and Construction, and Fishing and Boating. DNR operates a fleet of approximately 500 vehicles. Approximately three-quarters of these have similar BEV counterparts based on their SIN, many of which are SIN 49, which equates to a Chevy Silverado EV and can be effective for DNR depending on vehicle use case. A majority of DNR's pickup trucks are assigned either to the Parks Service or to Wildlife and Heritage.

Parks: DNR is responsible for maintaining approximately 75 parks across the state, and each park typically has at least one pickup truck assigned to it. These trucks are used for tasks such as patrol, trash collection, emergency response, public relations and other informational purposes. Many parks, but not all, also have a utility body truck which is used for maintenance and snow removal. The largest parks, such as Gunpowder, Patapsco, and Seneca Creek, have more than one of each type of vehicle. The smaller parks typically have a patrol vehicle, and they may share a maintenance truck.

The patrol trucks typically never leave their assigned parks. In the smallest parks they may run only a two-mile loop, resulting in relatively low miles per year. While this study did not examine mileage or fuel data specifically, based on interviews we understand that these vehicles spend a lot of time idling which results in a low number of miles per gallon. This is one of the characteristics that favors electric vehicles, because idling uses a *de minimis* amount of energy even when the heat or air conditioning is running. Fixed routes, a consistent parking location, and a lot of idling all support electric vehicles. In addition to the financial benefits of electrification, it would be hard to overstate the value of converting DNR's vehicles to electric as being consistent with its core mission and as favorable for public relations.

Wildlife and Heritage: The Wildlife and Heritage Service is the specific agency within DNR tasked with managing wildlife species in the state. This service monitors wildlife populations, establishes hunting seasons, manages habitat on public Wildlife Management Areas, protects endangered species, and provides advice on wildlife issues. Examples of specific tasks requiring the use of DNR vehicles include hauling bear traps (including bears when captured), responding to nuisance complaints, tracking, and survey work in the field. Most of this work is remote, particularly in Western Maryland and on the Eastern Shore. Despite these areas being relatively remote, we believe that today's electric vehicles, including pickup trucks, can satisfy many of Wildlife's off-road and hauling needs.

We have identified a different challenge to EVs being successful replacements for the Wildlife service. The constraint is that pool vehicles are housed at the Tawes Motorpool, located at DNR's headquarters in Annapolis, and must drive long distances just to get to the far ends of the state. This requires biologists, foresters, and others to drive into Annapolis, then out to the field to perform their work, adding time and mileage. One example of such trips is foresters finding places to plant trees, visiting nurseries, and trying to replace trees killed by the ash borer as part of the state's Five Million Trees Initiative. Others include biologists doing survey work such as inspecting water quality and surveying streams for fish and insects, as well as surveying, tracking, and potentially relocating wildlife. Considering current EVs' range diminish in the cold, making trips from Annapolis to the far reaches of the state would be challenging. If EVs were distributed around the state rather than all parked in Annapolis, EVs could successfully replace many combustion engine vehicles. Currently, DNR has a small number of Ford Lightnings that are assigned to biologists and foresters who go out in the field but are not assigned their own vehicles; initially they will be dispatched in a limited radius, for example to Taneytown but not to Cumberland.

Heavy-Duty Trucks: Most of DNR's heavy-duty dump trucks are tandem axles, which means two rear axles; the most common configuration is two tires on each side of each axle for a total of eight tires on the rear. The Parks service also has two single-axle Ford 550s with dump beds. Many of these trucks are assigned to the Park Service, Forestry, Fishing and Boating, and Engineering and Construction; these are used for tasks such as general hauling, forestry, and pulling trailers, bulldozers, or other fire suppression equipment. Dump trucks that are not used to clear snow and ice and that travel limited and predictable routes are candidates for electrification. Examples of vehicles which appear to be suited for electrification are the dump trucks assigned to Fishing and Boating which are used for hauling oyster shells. The Fisheries sub-unit tends to have ¾-ton and 1-ton trucks which are used to haul boats, large fish tanks, oysters, and a mobile lab.

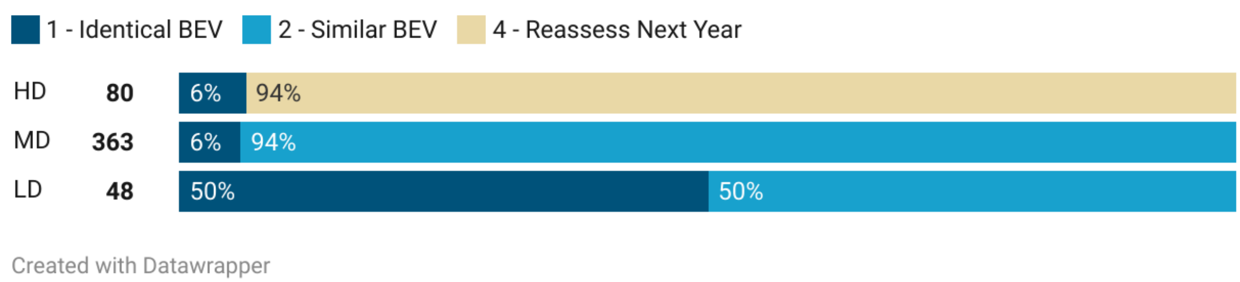

Figure 4.3. Department of Natural Resources: BEV Availability

Class Description	Vehicle Count	Percentage of Agency Fleet
Truck	507	98.4%
Dump Truck	5	1.0%
Tractor or Truck Tractor	2	0.4%
Tow Truck and Rollback	1	0.2%
Total	515	100.0%

Table 4.4. Department of Natural Resources vehicle types, excluding transit buses

Maryland Transit Administration (MTA)

In total, 2,260 vehicles were analyzed in MTA's fleet. Over half of the fleet (58%) had an identical BEV replacement, or 1,314 vehicles, nearly all of which are HD vehicles due to most of MTA's fleet consisting of transit buses. More than 200 MTA vehicles have "similar" BEV counterparts, half of which are heavy-duty and half of which are medium-duty. More than 700 vehicles are classified as "reassess next year;" approximately 85% of these are incomplete cutaways, which is a vehicle class that is today not widely offered as zero-emission. An incomplete cutaway truck is a chassis with only the front cab and partial body provided by the manufacturer, leaving the rear open for customization. It is commonly used as the base for commercial vehicles like delivery vans, shuttle buses, ambulances, and RVs.

When excluding transit buses (SIN 377 and 386), which are not covered by the ACT, the share of MTA's fleet drops by 63% to just 858 vehicles. In this scenario, less than 1% of vehicles have an identical BEV replacement and 84% of the fleet is categorized as "reassess next year". MTA is by far the agency most impacted by the transit bus exclusion, however transit buses are required to be zero-emission by a different statute, the Zero-Emission Bus Transition Act.

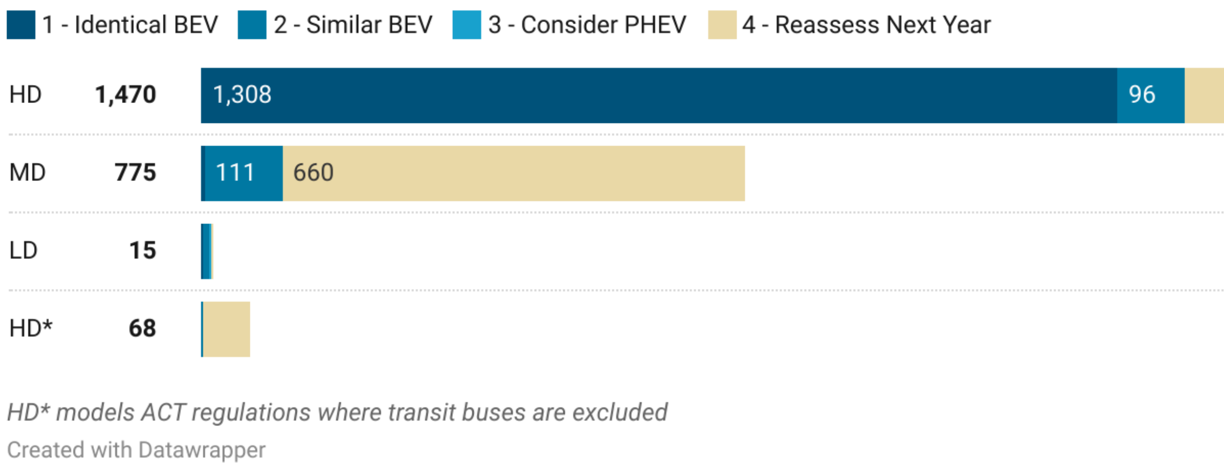

Figure 4.4. Maryland Transit Administration: BEV Availability, excluding transit buses

Class Description	Vehicle Count	Percentage of Agency Fleet
Truck	192	96.5%
Tow Truck and Rollback	5	2.5%
Dump Truck	2	1.0%
Total	199	100.0%

Table 4.5. Maryland Transit Administration vehicle types, excluding transit buses

Maryland Transportation Authority

The Maryland Transportation Authority had 355 vehicles for analysis in their fleet, over half of which were HD vehicles (202). Over 99% of these HD vehicles were not eligible for replacement; instead, MD vehicles dominated similar BEV replacements (85%) and LD vehicles dominated identical BEV replacements (38%). Overall, a little over a third of the fleet had a similar BEV, and less than 10% had an identical BEV. The identical BEVs were largely mapped to the Chevrolet Silverado electric pickup which represented 74% of the BEV replacement recommendations.

We note that the Transportation Authority operates with different systems and budgeting protocols than other agencies due to its enterprise funding structure, toll-driven revenues, and board of directors' management structure. As an example, MDTA does not utilize R*Stars.

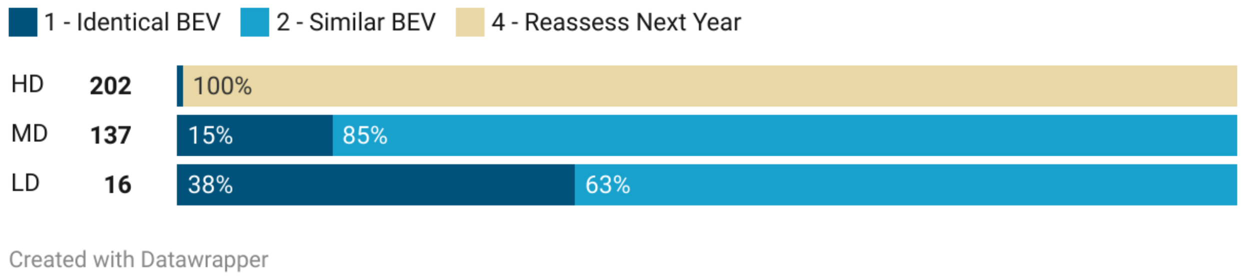

Figure 4.5. Maryland Transportation Authority: BEV Availability

Class Description	Vehicle Count	Percentage of Agency Fleet
Truck	226	60.4%
Dump Truck	127	34.0%
Tractor of Truck Tractor	16	4.3%
Tow Truck and Rollback	5	1.3%
Total	374	100.0%

Table 4.6. Maryland Transportation Authority vehicle types, excluding transit buses.

Contracted Vehicles

There are 49 vehicles* in the contracted vehicle fleet, 35% of which are pickup trucks. A majority of these pickup trucks (58%) are light duty 4x4 trucks, such as the Ford F-150, Ram 1500, and Chevy Silverado. Only 6% of pickup trucks are electrified, which is lower than the overall contracted vehicle electrification rate of 10%. This suggests that the electrification of pickup vehicles in the contracted fleet is a good starting point, especially because there is already an electric option (6-E-1) being used in the contracted fleet. If the three other trucks in this type number and description were electrified, the electrification rate would jump to 30% on vehicles already rated to do the same work per the technical specifications.

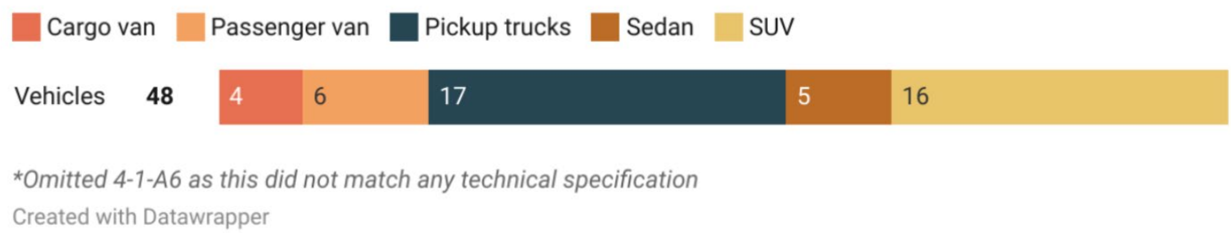

Figure 4.6. Contracted vehicle types

The next largest share of vehicles are SUVs, which make up another third of the contracted fleet. These vehicles are listed as sport utility vehicles, a large portion of which (47%) are rated for police pursuit or other police use. This group has the highest BEV availability of any vehicle group type at 88%, which means that nearly nine in ten SUVs have an identical BEV option available. This group also has the largest current electrification rate at nearly 19%, which means that any vehicle of this use case is a good study in the practical potential for electrification. If the electric models of these vehicles are performing to a similarly high standard as the internal combustion engine equivalents, the pathway towards full electrification is clear.

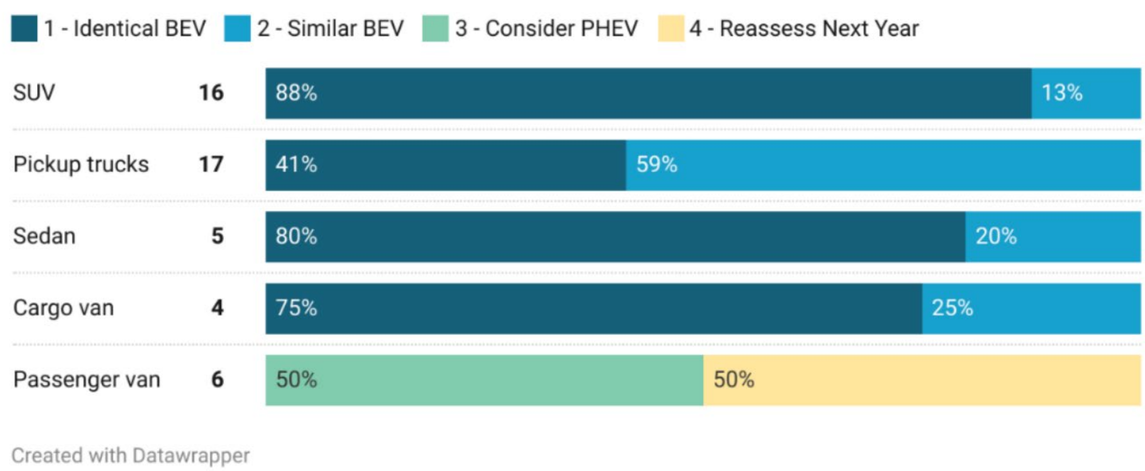

Figure 4.7. BEV availability by vehicle type for contracted vehicles.

Sedans and cargo vans together make up 19% of the contracted vehicles and have similarly high electrification potential. However, none of the cargo vans offered are currently electric, and just 1 passenger van is hybrid. Reasons for why these contracted vehicles have not been electrified - particularly in the case of cargo vans - are a strongly recommended next step, given their high electrification potential. Passenger vans on the other hand do not have any identical BEV models but do offer plug-in hybrid electric vehicle (PHEV) models in this class and vehicle type. One of the passenger vans in the contracted fleet is already hybrid, so understanding the performance capacity of the hybrid vehicle in comparison to the internal combustion engine vehicles would be helpful in assessing whether it would be feasible - and preferable - to transition the potential PHEVs in this vehicle class.

4.2.3 BEV Replacements and Model Types

Based on GSA and ZPAC tool data, each vehicle in the fleet is determined to have either an identical BEV replacement model, similar BEV replacement model(s), or no similar/identical BEV replacement model. For this overall fleet assessment, we assume that all vehicles with an identical or similar BEV match can be replaced by it, which may not work in certain circumstances, such as vehicles that need to be in use 24/7. Vehicle count by BEV replacement status is shown in the chart below.

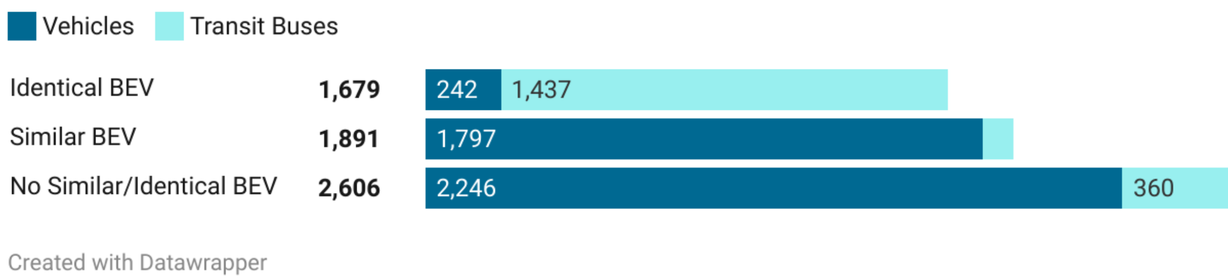

Figure 4.8. Fleetwide BEV replacements

After adjusting the state's MHDV fleet to exclude transit buses, which are covered not by the ACT but by the Zero-Emission Bus Transition Act, we determined that 242 MHDVs in the state fleet (4.3%) have exact BEV replacements:

- Pickup trucks (131 units, SIN numbers 56 and 57, $45,000-$80,000)
- Tractor units (51 units, SIN number 624, $400,000-$500,000)
- SUVs (60 units, SIN numbers 95 and 96, $38,000-$60,000)

There were 1,891 internal combustion engine vehicles with similar, but not identical BEV replacements. Most common were light and medium-duty pickups, with 1,514 units between SIN numbers 41, 44, 46, 49, 51, 52, 55, 57, 59, 60, 61, 66, 73, 74, 77, 79 having similar BEV replacements. Other notable examples of internal combustion engine vehicles with similar BEV are MD-Other (243 units, SIN numbers 92, 94, 95), and Heavy-Duty Buses (94 units, SIN number 386).

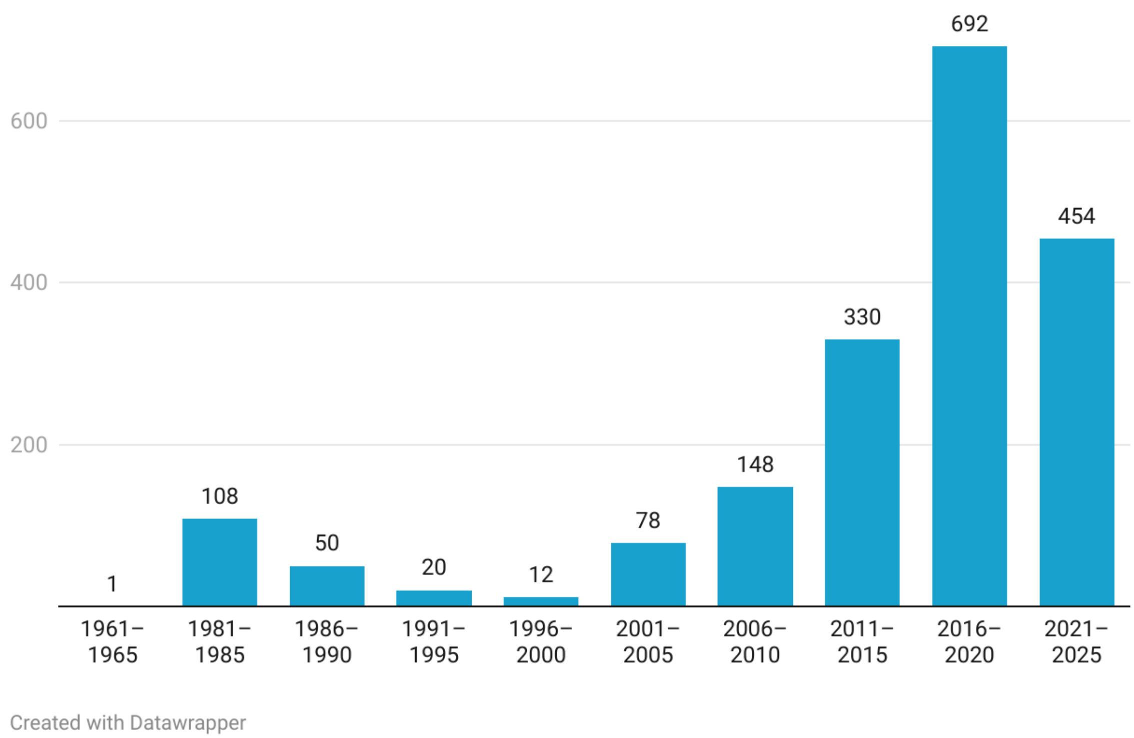

Figure 4.9. Model year for vehicles with similar BEV replacements (N = 1891)

There are 2,606 units which, according to GSA data, do not have a similar or identical BEV unit. Amongst this group, there are 729 dump trucks, which could potentially be replaced by a BEV not included in GSA data, such as the Peterbilt 520EV. Additionally, there were 96 Class 7 and 374 Class 8 trucks, which were mostly heavy-duty box trucks or cab/chassis. Other vehicles include higher-GVWR pickups, full-size refuse trucks, and smaller buses.

4.2.4 Economic Feasibility

For the purpose of the analysis, we assumed that all vehicles are purchased new using the full pricing outlined in the FY24 GSA Fleet Zero Emission Vehicle Fact Sheet. Pricing may vary over time, and actual incentives do not always cover the full cost of the vehicle. The remainder of the vehicle fleet does not currently have BEV replacement models available, so pricing for those vehicles will be determined later. It would cost the state an additional $18 million to replace all exact BEV-replaceable ACT compliant vehicles (excluding transit buses) between 2027 and 2035. This number represents an additional incremental cost between the $35 million cost for BEV replacements and $17 million for internal combustion engine vehicles. This number includes a total of 242 vehicles; 191 Class 2b-3 trucks, nine Class 4-8 trucks, and 42 Class 7-8 tractors. 88 of these vehicles will be eligible for BEV replacement in 2027, the first year of the program. Replacing all the identical BEV-eligible vehicles in the Department of Natural Resources, for example, would cost $4.8 million.

Vehicle Type	SIN	Average Unit Price
Pickup Truck	56	$49,995
Pickup Truck	57	$48,623
Tractor	624	$472,842
Van	95	$77,539
SUV	96	$51,190
Transit Bus	377	$1,121,022

Table 4.7. Prices of exact BEV replacements

When looking at pricing, BEV models are more expensive than internal combustion engine models, a difference which is least significant for the half-ton pickup trucks, which average $4,699 more than the internal combustion engine version. Models like the Police Pursuit Rated and Police Special Service SUVs and Sedans are upwards of $10,000 more expensive than their internal combustion engine counterparts, which paves a path for considering feasibility in terms of financial costs, though it should be noted that police vehicles may idle for long periods of time with the air conditioning or heating running, and this application strongly favors electric over gasoline.

Vehicle description	Electric	Hybrid	Internal Combustion Engine
½ Ton Pick-up Trucks	$49,494		$44,795
Compact Sports Utility Vehicles	$38,494	$38,279	$28,444
Mid-Size and Full-Size Sports Utility Vehicle		$45,995	$51,169
Mini Van/Wagon		$50,494	$38,489
Police Pursuit Rated and Police Special Services	$54,574	$46,492	$44,168
Sedan	$37,865	$28,260	$29,608
Average	**$45,107**	**$41,904**	**$39,445.50**

Table 4.8. Cost comparison between electric, hybrid, and internal combustion engine versions of common fleet vehicles.

4.2.5 Tools Utilized to Perform Analysis

The ZPAC tool,[77] developed by the Federal Energy Management Program (FEMP) and National Renewable Energy Laboratory (NREL), was utilized for this analysis. This tool is designed to assist agencies in planning for future zero-emission vehicle (ZEV) acquisitions and deployment of electric vehicle supply equipment (EVSE, commonly referred to as EV chargers). In particular, the tool was developed to support Executive Order 14057: Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability Efficient Federal Operations, which was later revoked by President Trump in 2025.[78]

Given its federal use case, the ZPAC tool is especially designed to be used with federal level data, including the Federal Automotive Statistical Tool (FAST), the General Service Administration's (GSA) procurement portal and vehicle catalogue, and federal agency level information such as Billing Office Address Codes (BOACs) and integrated tools like FleetDash. As such, the Project Team had to do a significant amount of data preprocessing in order to effectively use the tool because Maryland data is organized differently from federal data. More on these barriers can be found in Section 2: Data Sources and Preprocessing.

Components of the tool

Figure 4.10. Necessary information for the ZPAC tool

The ZPAC tool is composed of multiple interactive worksheets, each designed to perform a specific role in the analysis pipeline—from mapping fleet locations to forecasting future EVSE requirements. An understanding of the tool's structure is important for Section 4.2 and helps to illustrate the barriers and solutions that the Project Team pioneered to get a result with the ZPAC tool in a non-federal fleet. For detailed information on the content of each worksheet, see Table B.3 in Appendix B.

At the outset, the tool requires detailed site-level inputs that define the physical locations where fleet vehicles are stationed. This geospatial granularity is essential for accurately projecting EVSE needs at each site. Vehicle-level data, such as fuel type, drive type, model year, and agency-assigned site names, are then combined to assess ZEV suitability. The tool evaluates whether a BEV or PHEV is available for each vehicle's type and function and calculates a candidate quality score by factoring in modeled range concerns, emissions reduction potential, and availability of comparable ZEVs.

The ZPAC tool also estimates the number and type of additional charging ports required by comparing the current and planned infrastructure against projected ZEV adoption. A summary tab compiles these recommendations into a site-level snapshot, which can be visualized or exported for operational planning.

Critically, ZPAC's annual planning outputs rely on decision-point inputs that include estimated replacement years and planned acquisition timelines. These inputs allow the tool to generate year-over-year projections of ZEV uptake and corresponding charger installations. However, in this research context, a key limitation was the absence of yearly acquisition plans, which constrains the tool's ability to produce forward-looking projections with full fidelity.

The following summary table breaks down what each piece of information is used for in the ZPAC tool and gives an explanation of its use to give an idea of what data the Project Team needed from MDE and other sources to generate outputs. It outlines the categories of data needed to run the ZPAC tool, their role in the analysis, and how MDE's data aligned with these needs.

Input Category	Required For	Purpose
Site Names & Location Data	Site-level EVSE projections	Required to define unique locations for charging infrastructure planning
Vehicle Type & SIN (Special item number)	ZEV availability matching	Enables cross-referencing with ZEV availability database
Fuel Type, Model Year, VIN	Range and emissions modeling	Critical for assessing ZEV suitability and replacement potential
Modeled Range & Emission Concerns	Quality scoring for BEV/PHEV candidates	Required to evaluate the feasibility and benefit of ZEV replacement
Existing & Planned Chargers	EVSE recommendations	Informs how many additional chargers are needed per site
Modeled Range Concerns	Predicting public charging needs	Uses vehicle daily VMT to categorize travel behavior to public charging needs. Currently unavailable due to lack of telemetric vehicle data
Decision Points (e.g., timeline for adoption)	Annual ZEV and EVSE timeline projections	Currently unavailable in MDE dataset; major limitation for time-based planning

Table 4.9. Description of information used in the ZPAC tool

4.3 Data Sources and Preprocessing

4.3.1 Data sources and ZPAC compatibility

Several datasets were used to populate the ZPAC tool, each with varying levels of compatibility with the tool itself. As previously explained, federal fleets can leverage the FAST database to pre-populate fleet information, including VINs, SINs, and financial billing code, which was not available for MDE. For the Maryland data, several solutions were employed:

- **MVA CTA Study Data 04/10/25 - serves as our core dataset**: This source dataset included over 200,000 vehicles that are owned by 6 different customer types: trust, non-profit, individual, cooperative, business, and government. Each vehicle came with a partial VIN containing ~10 characters, which is notably shorter than the typical 17-character VIN number.

- **FY24 Rate Bulletin for Customers CONUS (3) - serves as SIN category for MHD vehicles**: This source dataset was released by the U.S. General Services Administration (GSA) and includes standardized monthly lease and mileage rates for a wide array of vehicle types available for federal customers within the continental United States (CONUS) during Fiscal Year 2024 (October 1, 2023 – September 30, 2024). The dataset categorizes vehicles by descriptive attributes such as drive type, vehicle body style, weight classification, make, and model. These categories are critical for matching customer vehicles to equivalent lease rate classes in the ZPAC tool.

- **FY24 GSA Alternative Fuel Vehicle Configurations (As Awarded) - serves as SIN catalog for vehicles where an alternative fuel model exists**: This dataset provides FY24 award data for alternative fuel and ZEVs available through GSA Fleet, including light-duty vehicles (LDVs), vocational trucks, ambulances, wheelchair vans, and buses. It is published annually and is intended to support procurement aligned with federal sustainability mandates. Each entry includes the awarded vendor, fuel type, drivetrain, SIN (Standard Item Number), and technical or descriptive notes such as seating capacity, GVWR, battery range, and chassis type.

- **Alternative Fuels Data Center (AFDC) Station Locator - serves as master list for all charging stations in MD**: This source data contains all the alternative fueling stations available for public use in the US and Canada. It includes fuels such as diesel (B20 and above), Compressed Natural Gas (CNG), Electric, Ethanol (E85), Hydrogen, Liquefied Natural Gas (LNG), Propane (LPG) and Renewable Diesel (R20 and above). It also allows for location specific parsing, either by state, county, city, zip, or even address, with an optional radius feature to limit results. The data also allows users to see access by public/private use, available and planned stations, and vehicle accessibility by weight class. All results queried can be downloaded, either by station location or port count.

4.3.2 Data Quality Issues and Solutions

Incomplete/Inaccurate VINs

As stated in the previous section, the VIN data lacked sufficient information to map vehicles to SINs. Examples of excluded descriptors included body class, drive type, trim, and body cab type. This information is part of the VDS (vehicle descriptor section) of the VIN and is critical for assigning correct SIN information. The following table shows differences in vehicles all classified as trucks in the MVA data but have clear differences that result in significant variations to SIN allocations. In this selection of five configurations - which are not comprehensive of all the variations found in the dataset - there were 104 possible matching SINs, which have significant implications for the ZEV availability mapping in the ZPAC tool.

	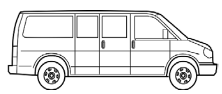	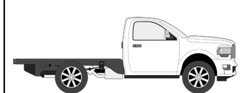	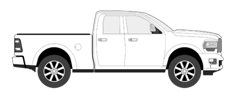	
Body class: Incomplete - Cutaway **Drive typ**e: 4x2 **SIN type:** Cab and Chassis (4x2) **GVWR**: Class 3-4 **# of possible SINs**: 3	**Body class:** Cargo Van **Drive type**: 4x2 **SIN type**: Cargo-Vans (4x2) **GVWR**: Class 2-3 **# of possible SINs**: 16	**Body class:** Incomplete - Chassis Cab (Single) **Drive type**: 4x4 **SIN type:** Cab and Chassis (4x4) **GVWR**: Class 2-5 **# of possible SINs**: 15	**Body class:** Pickup truck **Drive type:** 4x4, 4x2 **SIN type**: Pickup Trucks (4x2) **GVWR:** Class 1-3 **# of possible SIN**s: 55	**Body class:** Truck **Drive type**: 4x4 **SIN type**: Utility Trucks (4x4) **GVWR**: Class 5+ **# of possible SINs**: 15

Figure 4.11. Different truck configurations, VDS variations and possible SIN count

Missing drive types, cab styles, or GVWR

While some information was extracted from the partial VINs and/or included in the MVA dataset, such as weight, fuel type, and vehicle type, it was not possible to match that level of information with the SINs. In particular, the data did not include anything on drive types (4x4, 4x2, 6x4, etc), cab styles (crew, extended, regular, cab behind engine (CBE), cab over engine (COE), MHD conventional, etc.) or GVWR classes (such as Class 2E, 2F, 3, 4, etc.). A large portion of the partial VINs were able to be batch decoded in order to extract this information. However, nearly a quarter of the vehicles had VINs that did not return one or more pieces of this crucial information. The following list describes how these ambiguous cases were handed:

- In cases where drivetrain, cab style, or body class information was missing from individual VINs, we did not assume uniform issues across all records of a given make and model. Instead, we used a targeted, hierarchical approach. When multiple vehicles of the same make, model, and year existed in the dataset, we inferred likely configurations for incomplete records by comparing them to similar vehicles with complete information. For example, if five 2022 Ford Transit vans were present and four had RWD and regular roof designations, the fifth incomplete record was assigned the same attributes unless contradictory details were present.

- When a vehicle with a missing configuration was the only instance of its type, we referenced market data and fleet usage patterns to determine the most common configuration for that specific model and year, such as defaulting to a gasoline-powered regular cab for Ram 2500s unless diesel or crew cab attributes were known to be more typical for that sub-model. In these cases, the decision-making process was documented. All assumptions were made conservatively and prioritized matching to known AFV or Rate Bulletin records where possible. Ambiguous cases with no reasonable inference path were flagged for manual review.

Ultimately, the VINs of 541 vehicles did not provide us with enough information to assign SIN numbers to them.

*Cross-referencing with R*Stars*

For procurement processes, financial billing codes are often included in a fleet analysis to help aggregate different fleets who fall under the same budgetary umbrella. This is particularly helpful for Total Cost of Ownership (TCO) modeling and budgetary planning. In the case of federal fleets, this information is likely to be prepopulated, but for Maryland's fleet, there was no such process. For this use case, the Project Team did research to find Maryland's R*Stars directory, which was located on the Accounting Procedures Manual and Forms hosted on the Comptroller of Maryland's website. The document contains operating agencies and capital agencies, their department name, a financial agency code, a STARS code and an R*STARS unit. All three columns were referenced for the dataset preprocessing, but only the financial agency code went into the ZPAC tool as this was the only variable that has a value for each agency listed.

To account for multi naming conventions for the agencies, a confidence interval level was assigned to account for uncertainty in the agency allocation. High confidence assignments made up over half the data, while medium confidence assignments made up 37% and low confidence <8%. Another 5% of data was listed as "unknown" due to no matching entry in the R*Stars directory or inclusion of an agency that was not a state agency. The following table shows examples of agencies and the owner names matched to them, displayed exactly as they were listed in the MVA data, and its associated confidence level to give an idea of the variations seen in the naming conventions.

Confidence level	Assigned R*Star Agency	Registered Owner Name
Medium	Maryland Transit Administration	STATE OF MD MASS TRANSIT ADMIN
		STATE OF MARYLAND MASS TRANSIT ADMINISTRATION
		MASS TRANSIT ADMINISTRATION
		MASS TRANSIT ADM
		MARYLAND TRANSIT ADMINISTRATION
		DEPT OF TRANSPORTATION MASS TRANSIT ADMINISTRATION
Low	Motor Vehicle Administration	STATE OF MARYLAND MOTOR TRANSPORTATION FACILITY
		STATE OF MARYLAND MOTOR VEHICLE ADMINISTRATION
		STATE OF MARYLAND MOTOR TRANSPORTATION FACILITY

Table 4.10. Example agencies and associated owner names by confidence level

4.4 ZEV Replacement Match

4.4.1 Replacement mapping process

The ZPAC tool works using the ZEV replacement table 8 of the spreadsheet. This table consists of 6 columns that summarize key vehicle details: the segment SIN key, the vehicle weight class, vehicle type, existing SIN and BEV or PHEV SIN. The result of these columns corresponds to four potential outcomes in the BEV and PHEV columns that tell the user what the status of replacement is for each vehicle. The following table gives an example of how this matching process works.

Segment SIN Key	Existing vehicle weight class	Existing SIN	BEV SIN	PHEV SIN
LD Pickup 4x2-41	LD	41	55	-
This is a unique value that combines the SIN and existing vehicle type for each vehicle. This value is not actually used in the ZEV selection tab.	2 letter summary code of the GVWR category class each vehicle falls into. Only two options are available: LD and MHD.	This SIN value corresponds to GSA's bulletins and the AFV configurations sheet. A full SIN may also have letters (such as 41D) that are collapsed into a single number.	If there is a BEV replacement, this column will show the BEV replacement SIN. In this case, any variation of a LD pickup 4x2 matches the Ford F-150 Lightning (BEV).	If there is a PHEV replacement, this column will show the value. Some vehicles have both a BEV and PHEV replacement, but this represents only about 11% of EV availability.

Table 4.11. Example of SIN matching process

Depending on the combination of PHEV and BEV SINs, there are four possible outcomes for a vehicle in each type of ZEV, summarized below. Only LD SUVs (either 4x2 or 4x4 configurations) and Sedan/station wagons (compact, large, midsize, and subcompact) have both a PHEV and BEV option for their SINs, which did not occur in the MDE dataset. Overall, each vehicle was assigned to either a BEV or PHEV replacement category.

BEV SIN Availability	Definition
1 - Identical BEV	A BEV is available in the same SIN as the vehicle being replaced
2 - Similar BEV	A BEV is available in a similar SIN as the vehicle being replaced
3 - Consider PHEV	No BEV is available in a similar SIN at present, but there is a PHEV option
4 - Reassess Next Year	There is no BEV or PHEV option available in a similar SIN at present

Table 4.12. Possible outcomes for BEV replacement potential based on SINs.

PHEV SIN Availability	Definition
1 - Identical PHEV	A PHEV is available in the same SIN as the vehicle being replaced
2 - Similar PHEV	A PHEV is available in a similar SIN as the vehicle being replaced
3 - Consider BEV	No PHEV is available in a similar SIN at present, but there is a BEV option
4 - Reassess Next Year	There is no BEV or PHEV option available in a similar SIN at present

Table 4.13. Possible outcomes for PHEV replacement potential based on SINs.

With over 361 rows in the ZEV availability tab, it becomes easy to see why correct SIN assignments are important, as well as the correct configuration of the vehicle. For example, SIN number 75 corresponds to two different vehicle types - MD Other-75 and MD Van (cargo)-75. Without differentiating information on the vehicle configuration (such as cargo vs cab and chassis), the vehicle would either have a BEV replacement or get a reassess-next-year flag. These pieces of differential data are crucial for accurate ZEV replacement matching Lastly, some vehicles had multiple SINs associated with their SIN segment. For example, a Cab and Chassis 4x4 Extended Cab, 8000/10001/12000 GVWR vehicle is matched to SINs 77C, 78C, 79C. The ZPAC tool does not allow for multiple SIN entries into the ZEV selection tab, so one SIN needs to be assigned to each vehicle. However, the ZEV availability table accounts for this by creating a row for each of the SINs and assigns them all the same BEV/PHEV replacement status.

The following table gives an example of the Cab and Chassis 4x4 Extended Cab 8000-12000 GVWR. Regardless of what SIN this vehicle is assigned, it results in a 57 BEV replacement match. In fact, the BEV SIN of 57 matches 32 variations of a MD pickup vehicle, illustrating how redundancy is used to match different vehicles to the same BEV replacement. In the final dataset, all SINs for each vehicle were recorded. As some vehicles ended up with multiple SIN matches, the Project Team chose to simplify them for the purposes of the ZPAC tool. Only the numbers from the first SIN ID in the list were kept, using a formula which removed all characters including and after the first non-numeric character of the string.

Segment SIN Key	Existing Vehicle Weight Class	Existing Vehicle Type	Existing SIN	BEV SIN	BEV	PHEV SIN	PHEV
MD Other-75	MHD	MD Other	75	-	4 - Reassess Next Year	-	4 - Reassess Next Year
MD Van (Cargo)-75	MHD	MD Van (Cargo)	75	34, 162	2 - Similar BEV	-	3 - Consider BEV

Table 4.14. Example of vehicle matching by SIN

Segment SIN Key	Existing Vehicle Weight Class	Existing Vehicle Type	Existing SIN	BEV SIN
MD Pickup-77	MHD	MD Pickup	77	57
MD Pickup-78	MHD	MD Pickup	78	57
MD Pickup-79	MHD	MD Pickup	79	57

Table 4.15. Example of multiple SINs associated with a single vehicle

4.4.2 Projected Timeline for Adoption

Generating annual plan summaries for each agency requires assigning a planned acquisition year to every vehicle. The following plan follows ACT guidelines and excludes transit buses.

According to the U.S. Department of Energy's ZPAC tool, the average lifetime of an agency-owned MHD vehicle is 20 years. Based on this lifetime and the total fleet size, the implied replacement rate is 180 MHD trucks and 129 transit buses per year. Over the past 10 years, however, the fleet's actual average acquisition rate was 200 trucks and 133 transit buses, including possible fleet expansion.

For this analysis, we assume an average replacement rate of 190 trucks and 131 transit buses. Each year, replacement vehicle types are allocated in proportion to the overall fleet composition: 45% trucks, 12% dump trucks, 1.4% tractors or truck trailers, and 42% transit buses. In terms of ACT weight classes, non-passenger bus vehicles are 47.1% Class 2b-3, 51.2% Class 4-8, and 1.7% Class 7-8 tractor. The BEV availability data for these classes is shown in the table below: note that Class 7-8 tractors are the only class that has a majority of vehicles with identical BEV replacements. If all the trucks with identical BEV replacements were electrified, the electrification rate would be 7%, and if all the trucks with similar BEV replacements were electrified, the BEV replacement rate would be 52.2%.

Class	1 Identical BEV	2 Similar BEV	4 Reassess Next Year
Class 2b-3	11.9% (N=191)	86.9% (N=1399)	1.2% (N=20)
Class 4-8	0.5% (N=9)	21.4% (N=365)	78.1% (N=1334)
Class 7-8 Tractor	76.4% (N=42)	0% (N=0)	23.6% (N=13)

Table 4.16. BEV replacement status by vehicle weight class. Class 3 not included in order to look at ZEVs for replacement.

According to Maryland vehicle procurement policy, vehicles are considered eligible for replacement if they are at least 10 years old, although some vehicles are retained longer. Certain vehicles are retained significantly longer, including some which were acquired more than 20 years ago (see age distribution in Figure 4.9). For purposes of this analysis, we adopt the 10-year replacement timeline for all vehicles, including those older than 10 years which are assumed to be eligible in 2027 which is the first year considered for replacement This results in a larger-than-average number of potential replacements in the first year. First-year eligibility based on this 10-year threshold for identical BEV replaceable trucks (excluding transit buses) through 2035 are shown in the table below.

To estimate the number of vehicles in each class that can be electrified in a given year, we calculate the cumulative total of eligible vehicles up to that year and subtract those already electrified in prior years. The average annual replacement rate is applied as the maximum allowable limit to determine the total number of vehicles replaced each year within each class.

The results are summarized in Table 4.17; each year, the maximum number of eligible identical BEV replacements for each year across the fleet are shown below. By 2035, 200 or 12.4% of Class 2b-3 trucks will be electrified, nine or 0.5% of Class 4-8 trucks will be electrified, and 29 or 50% of Class 7-8 tractors will be electrified. The total cost of BEV vehicle acquisition between years 2027-2035 for the vehicles listed in the table below is $29 million. This assumes the 2024 GSA standard and does not include infrastructure or other costs.

Year	Class 2b 3	Class 4 8	Class 7 8 Tractor
2027	56 (63%)	8 (8%)	3 (100%)
2028	38 (42%)	0 (0%)	3 (100%)
2029	19 (21%)	0 (0%)	4 (100%)
2030	8 (9%)	1 (1%)	3 (100%)
2031	11 (12%)	0 (0%)	3 (100%)
2032	7 (8%)	0 (0%)	3 (100%)
2033	49 (55%)	0 (0%)	4 (100%)
2034	1 (1%)	0 (0%)	3 (100%)
2035	2 (2%)	0 (0%)	3 (100%)

Table 4.17. Fleet Replacement Plan. Number of vehicles in the total state fleet that should be replaced with a BEV equivalent for a given year and weight class, with the percentage in parenthesis showing the share of each weight class's annual vehicle turnover that will have an electric replacement.

We can also conduct a similar analysis for a particular agency. For example, the SHA has 1,315 trucks, consisting of 560 dump trucks, 33 tractor or truck tractors, and 722 regular trucks. Sixty-six vehicles will be replaced each year, on average. The SHA has 41 trucks with identical BEV replacement models (21 Class 2b-3, one Class 4-8, and 19 Class 4-8 Tractor), and 510 trucks with similar BEV replacement models (300 Class 2b-3 and 200 Class 4-8). Due to usage requirements, only around 10% of Class 2b-3 trucks, or 32 vehicles, can be electrified.

Using the same techniques described in the overall fleet analysis above, an identical BEV allocation timeline is created, shown in Table 4.18. Vehicle acquisitions according to this table would cost a total of $7.2 million.

Year	Class 2b 3	Class 4 8	Class 7 8 Tractor
2027	1 (6%)	1 (2%)	1 (100%)
2028	13 (81%)	0 (0%)	2 (100%)
2029	5 (31%)	0 (0%)	1 (100%)
2030	2 (13%)	0 (0%)	1 (100%)
2031	0 (0%)	0 (0%)	2 (100%)
2032	0 (0%)	0 (0%)	1 (100%)
2033	0 (0%)	0 (0%)	1 (100%)
2034	0 (0%)	0 (0%)	1 (100%)
2035	0 (0%)	0 (0%)	2 (100%)

Table 4.18. Number of vehicles in the SHA fleet that should be replaced with a BEV equivalent for a given year and weight class, with the percentage in parenthesis showing the share of each weight class's annual vehicle turnover that will have an electric replacement.

The same analysis is done again for the DNR. Total cost of vehicle acquisitions in this table would be $4.8 million.

Year	Class 2b 3	Class 4 8	Class 7 8 Tractor
2027	15 (80%)	4 (3%)	1 (100%)
2028	14 (75%)	0 (0%)	0
2029	8 (43%)	0 (0%)	0
2030	2 (11%)	0 (0%)	0
2031	3 (16%)	0 (0%)	0
2032	0 (0%)	0 (0%)	0
2033	0 (0%)	0 (0%)	0
2034	1 (5%)	0 (0%)	0
2035	2 (11%)	0 (0%)	0

Table 4.19. Number of vehicles in the DNR fleet that should be replaced with a BEV equivalent for a given year and weight class, with the percentage in parenthesis showing the share of each weight class's annual vehicle turnover that will have an electric replacement.

4.5 Greenhouse Gas (GHG) emissions reduction

A significant factor in determining the prioritization of replacing combustion vehicles with ZEV alternatives is the GHG emissions avoided by converting to ZEV. To calculate the GHG emission reduction potential of each vehicle, estimates for each pollutant and their emissions factor were gathered from the Dashboard for Rapid Vehicle Electrification (DRVE) tool.[79] To begin, there were two different types of emissions from which to choose: well-to-wheel and tailpipe emissions, each of which provides different insights into a vehicle's total emission profile. Well-to-wheel emissions account for all greenhouse gases released from producing and delivering fuel to its final use, while tailpipe emissions measure only what comes directly out of a vehicle's exhaust. Together these two approaches provide different but complementary ways to calculate the full climate impact of transportation technologies and energy sources. For a fleet analysis, tailpipe emission calculations were used to simplify the calculation process and provide a clearer comparison to battery electric vehicles, whose tailpipe emissions are zero, but may have different well-to-wheel calculations.

4.5.1 Benefits of Converting to ZEV

Substantial benefits derive from complying with the ACT by transitioning fleets to EVs, especially in terms of environmental benefits such as reducing greenhouse gas emissions and mitigating climate change. In particular, fleets with high proportions of MHD vehicles have the potential to provide the most benefit under high electrification scenarios. These vehicles, like Class 8 tractors (the type that pulls trailers), delivery vans, and pickup trucks make up only about 10% of vehicles on the road but contribute 45% of the nitrogen oxide (NO_x) emissions in the United States and 57% of the $PM_{2.5}$ emissions, making them high-value targets for electrification.[80]

In addition to playing a major role in reducing harmful emissions, fleet managers of MHD fleets can expect to experience savings across the lifecycle of an electric vehicle compared to a traditional diesel or gas equivalent. According to Lawrence Berkeley National Laboratory, driving an electric tractor trailer is 13% cheaper per mile than a diesel truck, which can net fleet managers $200,000 in savings across a 15-year lifetime, using a base energy price of $0.16 cents per kWh and $3.30 per gallon diesel.[80] The multiplying effect of electrification also means that fleet managers can sometimes also benefit from vehicle-to-grid (V2G) or vehicle-to-building (V2B) technology, which allows each vehicle to serve as an energy storage system that communicates intelligently with the grid to store excess energy during times of low demand and export energy back to the grid or building when demand peaks, in return for compensation or savings. Technology to enable V2G and V2B is underway and represents a new horizon of potential benefit that electrification can bring, especially for MHD fleets due to their battery capacities.

4.5.2 Developing Calculations

Table 4.19 shows the emission factor values used in the calculation, giving values for CO_2, GHG-100, NO_x, SO_x, VOC, PM_{10}, and $PM_{2.5}$, which were eventually standardized in units of grams per megajoule (g/MJ) for all pollutants. First, annual fuel usage was calculated for each internal combustion engine vehicle based on fuel efficiency and vehicle miles traveled data for a vehicle's given weight class and body type. Using these values, using base energy conversion factors from gallons of fuel to Joules, annual energy usage in megajoules was found for each vehicle.

Once an estimate of megajoules was developed per vehicle, that value was multiplied by the emission factor for the seven pollutants in Table 4.31. Emissions of CO_2 and GHG-100 were the highest by weight. For the calculation of proportion of emissions per vehicle, the sum of GHG-100 was used as the climate metric because it converts three major greenhouse gases (CO_2, CH_4, and N_2O) into a common unit of CO_2-equivalent based on their global warming potential over 100 years. This allows emissions from these gases to be directly compared and summed into one value that reflects long-term climate impact. In contrast, pollutants such as NO_x, SO_x, VOC, PM_{10}, and $PM_{2.5}$ were kept separate to reflect their role in local air quality and health rather than climate forcing.

Pollutant	Market	Emission Type	Vehicle Class	Emissions
CO_2 (g/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	74.72
GHG-100 (gCO_2e/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	75.49
NOx (mg/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	190
SO_x (mg/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	0.52
VOC (mg/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	19.02
PM_{10} (mg/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	2.19
$PM_{2.5}$ (mg/MJ)	U.S.	Tailpipe	Heavy-Duty Vehicles (Class 7-8)	2.01
CO_2 (g/MJ)	U.S.	Tailpipe	Medium Duty Vehicles (Class 3-6)	74.84
GHG-100 (gCO_2e/MJ)	U.S.	Tailpipe	Medium Duty Vehicles (Class 3-6)	75.12
NO_x (mg/MJ)	U.S.	Tailpipe	Medium Duty Vehicles (Class 3-6)	49.95
SO_x (mg/MJ)	U.S.	Tailpipe	Medium Duty Vehicles (Class 3-6)	0.52
VOC (mg/MJ)	U.S.	Tailpipe	Medium Duty Vehicles (Class 3-6)	4.14

Table 4.20. Pollutants and Emission Factor Key

4.5.3 Analysis by Special Item Number (SINs)

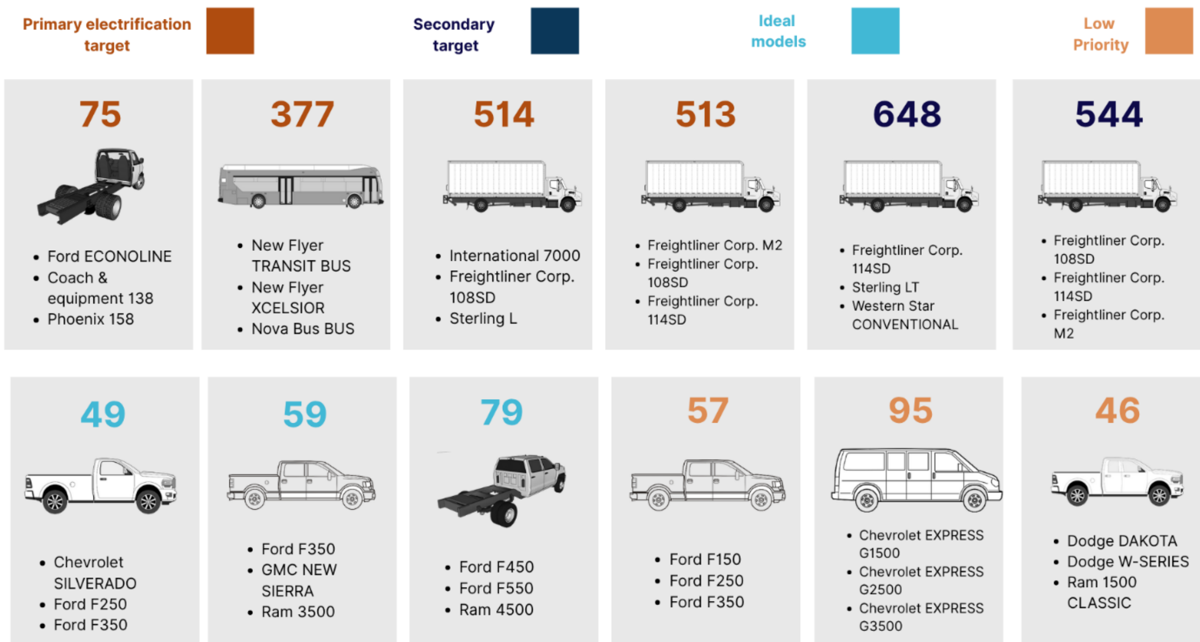

Figure 4.12. Description of vehicles by SIN

The first analysis looked at emissions by SIN to aggregate vehicles of similar characteristics under a comprehensive category. There were over 170 different make and models in the overall state fleet while there were less than 60 SINs, which made the data easier to visualize. On average, there were six make and models per SIN, which made it a helpful metric to aggregate by. Figure 4.12 maps out each SIN to its top three make and models to give a better idea of what vehicles fall under each SIN. Vehicles that exceeded the average share of total emissions were chosen to illustrate the vehicle types with the highest culpability in contributing to emissions. However, some of these vehicles - such as SIN 744 - make up less than 1% of the overall fleet but are high emitters as standalone vehicles. These represent makes and models that agencies should avoid adding to the fleet moving forward as they have the highest potential emission factor. The relationship between share of emissions and share of fleet size is explored and visualized in the next section.

4.5.4 Key Findings

The analysis shows clear disparities between the share of vehicles and their share of emissions across SIN categories. For example, dump trucks represent just 11.8% of the fleet but contribute 33.6% of total emissions, while other categories such as SIN 49 (pickup trucks) account for more than 10% of vehicles but only a small share of emissions (<2%). These imbalances indicate that targeted interventions such as electrification, efficiency upgrades, or replacement strategies should prioritize the high-emitting categories such as dump trucks that disproportionately drive the fleet's carbon footprint to close the gap between vehicle emissions and proportion of the fleet that each SIN represents. Addressing these categories first offers the greatest potential for emissions reduction, especially for agencies or governments that are prioritizing emissions reduction in their vehicle replacement strategy.

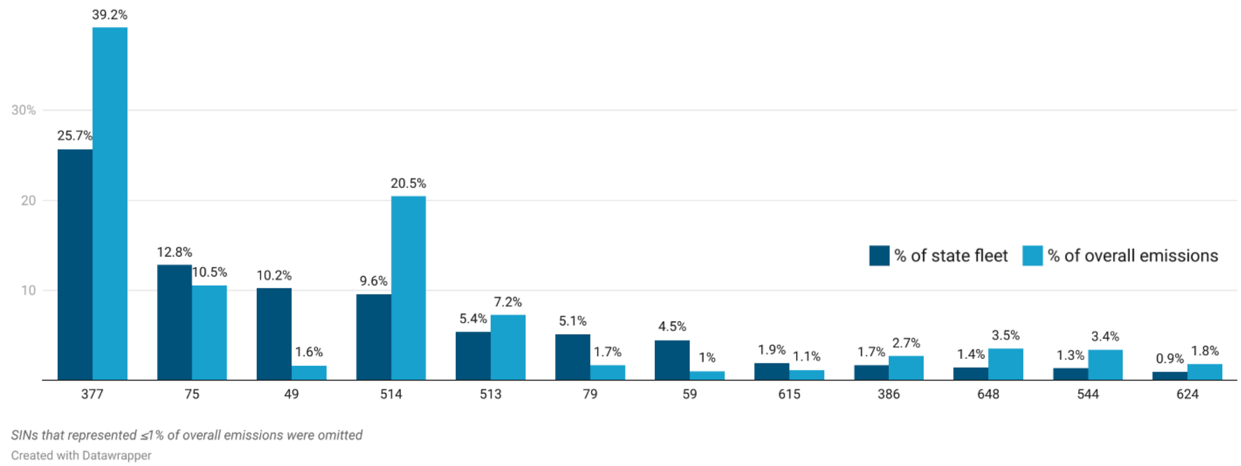

Figure 4.13. Fleet share versus emissions share by vehicle SIN, highlighting disparities between fleet size and emissions contribution by vehicle category.

To summarize these findings, the following quadrant was developed that helps to better understand the relationship between fleet size and emissions contribution. By plotting SIN categories against these two dimensions, the framework highlights which vehicles are primary electrification targets, which are secondary targets, which represent ideal models to maintain, and which are lower priority. This visualization provides a clear decision-making tool for identifying where electrification efforts will have the greatest impact. Each bubble is also sized according to the number of vehicles in the state fleet to give a better idea of the scope of replacement for each associated SIN.

Each vehicle was plotted first according to the share of vehicles that SIN represents in the overall fleet. Each bubble is sized according to its proportion; larger bubbles mean that the SIN category is more numerous in the fleet. Then, two axes were formed: the x-axis maps the percentage of the overall state fleet, and the y-axis maps the percentage of overall emissions in the state fleet that SIN represented. These values were generated on the x-axis by summing the entire state fleet and dividing that number by the sum of each SIN. For the y-axis, the sum of GHG-100 was taken from the entire fleet and divided by the sum of GHG-100 per SIN. Lastly, reference lines were added to form a quadrant using the average of the state fleet axis and the average of the overall emissions axis. The axes were scaled logarithmically to account for the wide variation in both fleet share and emissions share across SIN categories. Without this scaling, the plot would be dominated visually by the largest categories, and smaller but still meaningful categories would be compressed near the origin and effectively invisible. The log transformation ensures that both high- and low-volume SINs can be compared on the same chart, highlighting relative differences across the entire distribution of the fleet rather than just the largest emitters.

In the end, four visible quadrants were developed that provide actionable insights into electrification by GHG-100 emissions.

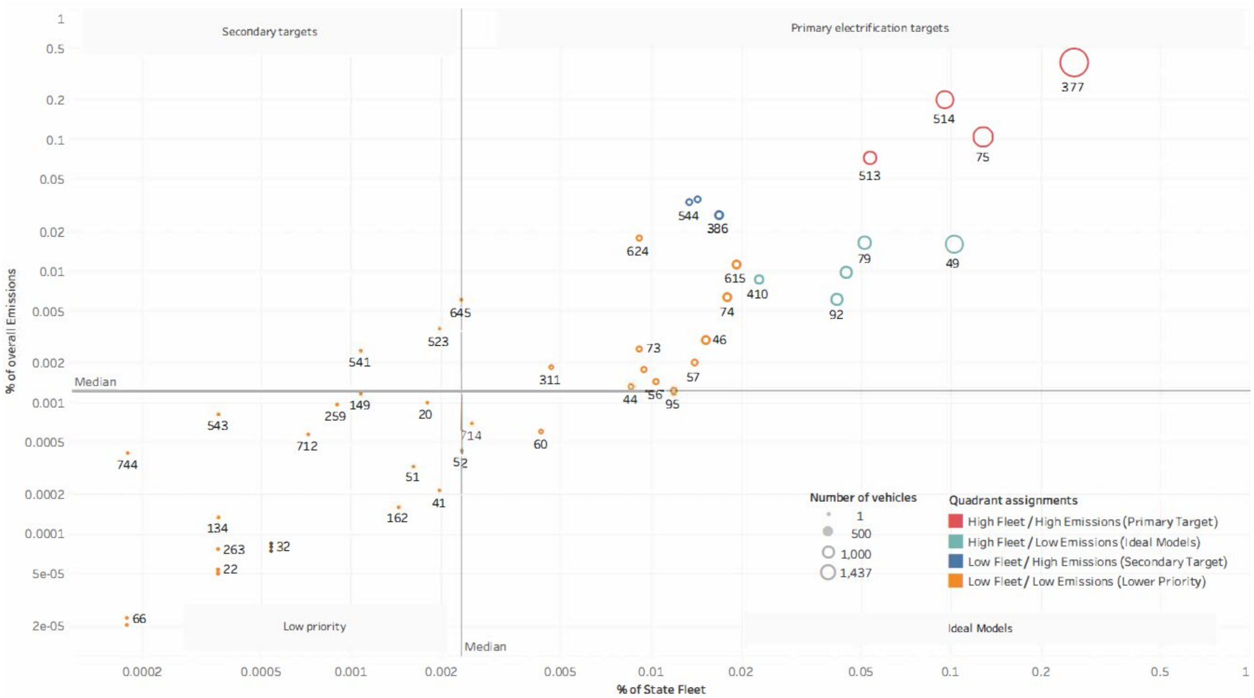

Figure 4.14. Priorities for state fleet electrification. The highest priority vehicle types for electrification are those in the top right quadrant. Vehicle types are separated by SIN (simplified), and each data point shows the percentage of vehicles in the state fleet vs. percentage of fleet emissions associated with a given SIN. Data labels indicate the SIN associated with that data point. Colors indicate electrification priority based on quadrants. Size shows the sum of the number of vehicles in the state fleet associated with a given SIN. Axes are logarithmic.

Primary electrification targets

The upper right quadrant is titled primary electrification targets as these are vehicles that make up a greater than average share of the state fleet and a greater percentage of emissions. These vehicles are high value electrification targets as they disproportionately contribute to emissions relative to their presence. Prioritizing the replacement or electrification of these categories offers the greatest near-term reduction potential, while also preventing smaller but high-emission vehicle types from becoming a larger share of the fleet in future procurement cycles.

Together, these four SINs represent over 2,990 vehicles, or 53% of the overall state fleet but 77% of overall emissions, demonstrating their status as primary electrification targets if the end goal is maximum emissions reduction potential. Of these vehicles, SIN 377 makes up 38% of the vehicles in the upper right quadrant and has a 100% electrification potential, making it not only the clear target for electrification, but also the most feasible. This would not impact ACT adoption as transit buses are not covered under ACT.

SIN	Top 3 Make and Models	Electrification Potential	Agency with Largest share
377	New Flyer TRANSIT BUS New Flyer XCELSIOR Nova Bus	Identical BEV - 100%	Maryland Transit Administration - (91% or 1, 309 vehicles
514	INTERNATIONAL 7000 Freightliner Corp. 108SD Sterling L	Reassess next year - 100%	State Highway Administration - 66% or 356 vehicles
513	Freightliner Corp. M2 Freightliner Corp. 108SD Freightliner Corp. 114SD	Reassess next year - 100%	State Highway Administration - 54% or 164 vehicles
75	Ford ECONOLINE Coach & equipment 138 Phoenix 158	Similar BEV - 2% Reassess next year - 98%	Maryland Transit Administration - 93% or 666 vehicles

Table 4.21. Primary targets for electrification by SIN

Secondary Targets

Secondary targets are represented in the upper left quadrant and are vehicles whose emissions share is higher than average, but their share of the overall fleet is lower than average. They are secondary targets from a pure emissions reduction potential perspective as their share in the overall state fleet is not significant, but their emissions are more than double their share of the state fleet. The magnitude of their electrification would be low both in terms of emissions reduction and share of overall state fleet, which are ≤ 10% for each metric. However, depending on the standpoint, these vehicles could also be considered low hanging fruit that would not be as costly to electrify as the primary targets even if their emissions reduction would be relatively marginal. Overall, their share of the fleet is 3%, but their emissions are three times greater than their share at 10%, which highlights their position in this quadrant.

In this group, there is no identical BEV option, so yearly evaluations of new model availability are required to identify improvements in these vehicles' electrification potential.

SIN	Top 3 Make and Models	Electrification Potential	Agency with Largest share
648	Freightliner Corp. 114SD Sterling LT Western Star CONVENTIONAL	Reassess next year - 100%	State Highway Administration - 75% or 60 vehicles
544	Freightliner Corp. 108SD Freightliner Corp. 114SD Freightliner Corp. M2	Reassess next year - 100%	State Highway Administration - 92% or 69 vehicles
386	Flxible (formerly Flexible) TRANSIT BUS	Similar BEV - 100%	Maryland Transit Administration - 100% or 94 vehicles

Table 4.22. Secondary targets for electrification by SIN

Low priority

Low priority models are shown in yellow of the bottom left quadrant of Figure 4.14. These are vehicles whose emissions share and whose share of the state fleet is lower than average. This category represents 39 SINs, but just 16% of the state fleet and 7% of overall emissions. However, due to the high number of different SINs in the low priority group, there are still useful insights that can be extrapolated, such as vehicles that should be avoided for future procurement cycles and vehicles that can be good internal combustion engine substitutes for high emitters with no electrification alternative. Anything above the horizontal reference line are SINs which should be avoided for future procurement cycles, as their emissions are near or above average for their SIN class. Increasing their share of the state fleet could increase emissions and offset progress made by electrifying other SINs. Vehicles below the emissions line show low emitting SINs that are being offset by partial electrification already, such as SIN 57, whose electrification rate is 10% compared to the overall state fleet average of <1%, and electric vehicles whose share could be increased to add zero net impact to emissions while maintaining the same fleet size and vehicle function.

Ideal Internal Combustion Engine Vehicle Models for Rightsizing

It may be the case that certain internal combustion engine models will have to be replaced by other internal combustion engine models at the end of their lifetime, based on budget or BEV availability constraints. These models should be replaced by "Ideal Rightsizing" models, which are defined as models whose vehicle share is higher than average in the state fleet, but whose emissions are lower than average. This is an important category as it demonstrates SINs whose emissions are not contributing a disproportionate amount relative to their share of the state fleet: for example, a group represents 26% of all the state fleet vehicles but just 6% of its emissions. Adding more vehicles of this SIN type should not negatively impact the state fleet's overall emissions profile and can offer a middle path for models who do not yet have an electrified option.

SIN	Top 3 Make and Models	Electrification Potential	Agency with Largest Share
49	Chevrolet SILVERADO Ford F250 Ford F350	Similar BEV - 100%	Department of Natural Resources - 36% or 204 vehicles
59	Ford F350 GMC NEW SIERRA Ram 3500	Similar BEV - 100%	State Highway Administration - 35% or 88 vehicles
79	Ford F450 Ford F550 Ram 5500	Similar BEV - 100%	State Highway Administration - 62% or 179 vehicles
92	Ford ECONOLINE Chevrolet EXPRESS G2500 Chevrolet EXPRESS G3500	Similar BEV - 100%	University of Maryland, College Park Campus - 33% or 76 vehicles

Table 4.23. Low priority vehicles for electrification by SIN

4.5.5 Analysis by Agency

Unlike the SINs, agency ownership of a vehicle does not necessarily convey information about the emissions potential of the vehicle. Instead, as the agency rollup section demonstrates, the composition of each agency's fleet determines its GHG emissions contribution. In general, the more vehicles that an agency has, the greater its emissions will be. However, if the composition of the fleet leans towards heavy duty vehicles with diesel fuel types, the emissions contribution will be significantly higher. This type of analysis helps to identify which agencies have fleet compositions that lean towards heavy emitters, helping to identify agency level adjustments that need to be made to reduce emission impact. For example, DNR has an emissions profile that is 4x higher than its share of vehicles in the overall state fleet, indicating an agency whose fleet electrification would not be as costly but still have a high impact. This agency was largely made up of medium duty vehicles with a similar BEV, 94% of which had a similar BEV. For DNR, evaluating the use case of each vehicle would be important towards determining if a similar BEV option can achieve the same job. The same applies for University of Maryland, College Park campus and - to a lesser degree - Maryland Environmental Services and the Maryland Aviation Agency.

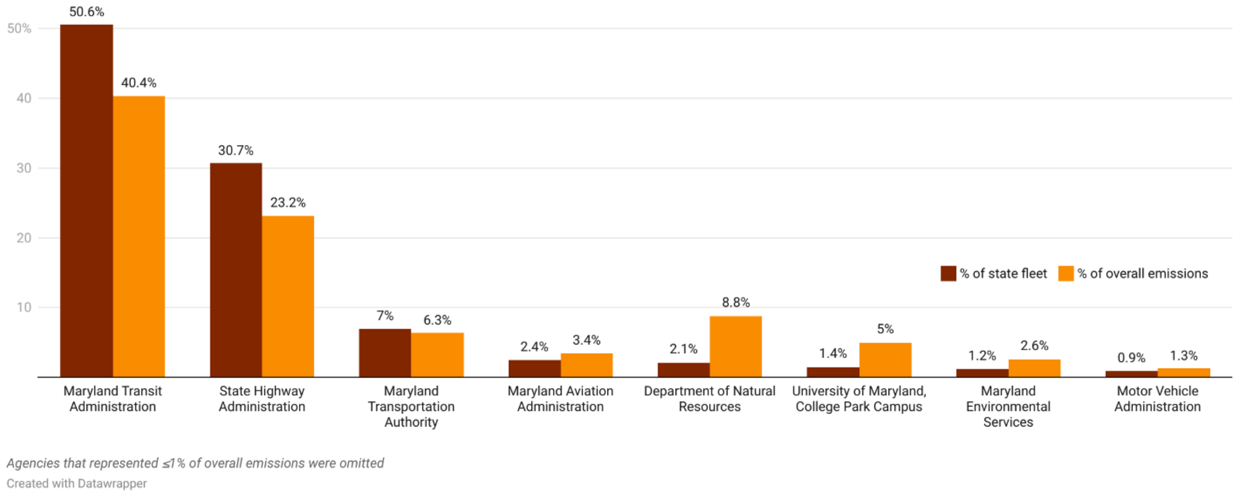

Figure 4.15. Fleet share versus emissions share by state agency, highlighting disparities between fleet size and emissions contribution by state agency. MTA includes transit buses, which are not included under the ACT.

4.6 Key Informant Interview Analysis

An additional aspect of our analysis came through interviews with key stakeholders involved with MHD vehicles with the State of Maryland, city and county agencies, and with private entities and stakeholders. This analysis was gathered through interviews with these stakeholders to get a better understanding of the current landscape, challenges, and opportunities within the state's transition to MHD electric vehicle and EVSE adoption to reach the state's ACT schedule.

4.6.1 Current MHD Landscape

Through our interviews with state agencies, we learned that while the state has been moving to increase the adoption of electric vehicles, many of the successes so far have been in the light-duty vehicle and school bus spaces. The state procurement process is currently run through both DBM and DGS for agencies to determine which new vehicle purchases can be ZEVs, what the infrastructure/charger needs will be for the vehicles purchased, and the process of procurement of these vehicles. For the new vehicle purchases, the funds to cover the incremental costs of the vehicles come primarily from MEA's SEIF funding, which covers 75% of the incremental costs. Many of the vehicles that have been switched over to zero-emission alternatives are light-duty. Based on interviews with DBM, there has been no issue so far in transitioning the LDV fleets from gas to electric. However, they have transitioned very few MHD vehicles. This may be due to how MEA determines which vehicles to transition, as they focus on the GHG impact reductions per cost to transition the vehicles. As many LDVs have lower cost differences between gas and electric vehicle models, this may be a reason that transitioning to ZEVs currently focuses on the light-duty fleet.

4.6.2 Challenges

Through our interviews with government agencies and key stakeholders, we came across three main challenges that hampered the adoption of MHD EVs: Infrastructure & Charging, Procurement & Market Readiness, and Data & Fleet Management. For the stakeholders, especially state and city agencies who have already begun the process of purchasing and implementing EVs in their fleets, infrastructure costs, timelines, and reliability were the largest concern and challenge for fast and reliable adoption of the vehicles. One city and one county agency who had begun the process of adopting electric vehicles in their fleets mentioned that a large issue with installing charging stations was the lengthy process of coordinating with the utility and obtaining permits, which led to higher costs and longer project duration. From interviews with state agencies, installation of charging infrastructure can be costly, especially when new electrical service is required. Another state agency representative noted that it can take 12-18 months to install infrastructure at state-owned facilities and can be even longer for leased sites. Other key MHD stakeholders noted reliability issues with utility pilot programs for charging infrastructure.

Procurement and market readiness for MHD ZEVs was another key issue noted by state agencies. Maryland state agency officials noted that for some MHDVs there was low demand and uncertainty from fleet managers around the state. While state agencies and city stakeholders noted that the process of using DBM and DGS to procure vehicles and chargers can be helpful, they also noted that the process can be complex and have long lead times. Adding to infrastructure and procurement concerns, a final common concern heard from both state and city agency officials was the lack of data and fleet management training. Two state agencies mentioned that under the current structure there is a lack of detailed vehicle tracking, especially around dwelling and usage cases for specific vehicles that make transitioning to ZEVs hard. State agency officials from both DBM and DGS that work to procure vehicles and infrastructure said that another concern they hear from fleet managers is the lack of training and familiarity their staff have with electric vehicles. This concern has led to an uneasiness with purchasing new ZEVs for their fleets, though the DBM and DGS officials noted that this concern has begun to lessen.

4.6.3 Opportunities

Through interviews with key stakeholders, many of the challenges provided also come with opportunities to improve. As mentioned in an interview with a key state agency, a new vehicle management system is expected to be put in place at the start of 2026 to help better track the dwell location and usage of state fleet vehicles. This new system will allow for a better understanding of the use case needs for new vehicles, which will assist with the process of determining which ZEV alternatives are best suited for new vehicle purchases. Additionally, this system will allow for more accurate charging infrastructure information as the state can better determine if dwell locations need electrical upgrades or whether new dwell locations need to be identified in order to be more prepared for the large number of ZEVs that the agencies will procure in the future.

An additional focus to help with the adoption of MHDVs in the state fleets can come from reviewing SEIF funding and other incentive programs to help fund the transition. While funding can still focus on having the largest reduction in GHGs/cost, it can also look at which vehicles are least likely to make the transition to BEVs based on the larger cost differential. Funds can also be used to install more charging ports, including Level 2 and DCFC, which are key for the MHDV fleets at state facilities and charging hubs to make the adoption of these vehicle fleets more enticing for other fleet managers.

4.7 Recommendations and Next Steps

For State Government

- Prioritize investment in agencies with high BEV readiness but low charger access
- Address critical data gaps before FY26
- If the state continues to use ZPAC tool for fleet analysis, consider Fleetdash implementation as it is compatible with the ZPAC tool

For Agencies

- Ensure that DBM possesses sufficient staff who are knowledgeable about EVs to engage with agencies about integrating medium- and heavy-duty electric vehicles, including in use-cases which may require operational modifications while simultaneously retaining comparable operational capabilities
- Install EVSE (AC and DC) at strategic locations across the state to provide a backbone network of charging infrastructure so that state-owned vehicles can perform their missions without concern for running out of fuel
- Utilize vehicle telematics to evaluate routes and identify those which are suitable for EVs
- Additional staff at DBM to support EV integration and new fleet management software
- Validate and improve vehicle attribute tracking (in process)
- Prepare infrastructure grant applications for identified charger gaps

Chapter 5: Early Adopters and Industry Trends

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Chapter at a Glance:

- Current adoption of MHD BEVs in Maryland is limited to a small number of vehicle types and is heavily concentrated among large corporate fleets (which often act as "first movers"), and individuals that own BEV pickup trucks which are heavy enough to qualify as MHD.
- Detailed interviews with twenty-two industry stakeholders highlight consistent concerns around the readiness of charging infrastructure and the BEV market but also showed that stakeholders believe there are opportunities to address infrastructure needs as demand for vehicles grows, and that state policies can provide critical support.
- For many vehicle types, there is a significant cost and performance gap between BEVs and internal combustion engine vehicles, with some vehicles lacking a direct BEV replacement.
- Vehicles that run short, fixed, and predictable routes that have regular downtimes are the best fit for early electrification, including Class 8 trash trucks, Class 7 school buses, Class 3-8 straight trucks for regional line-haul, and Class 2b-3 vans used for local delivery.
- Potential first movers that could act as early adopters for certain types of battery-electric vehicles (BEVs) include utility services, large logistics companies, local governments, certain state agencies, school systems, and regional line-haul trucking.

Introduction

In this chapter, we address the opportunities and challenges associated with implementing the Advanced Clean Trucks (ACT) rule for various types of vehicles and fleets, focusing on county- and privately-owned medium and heavy-duty vehicles (MHDV). State-owned vehicles are covered separately in Chapter 4. The primary focus of this chapter is to address the conditions needed for industries to adopt zero emission vehicle (ZEV) technologies within the first five years of ACT implementation (2027-2031), with some additional insights into longer-term deployment trends.

In order to support large-scale deployment of new technologies, Maryland policymakers should consider adopting both "supply push" policies that seek to increase the availability of the technology on the market, and "demand pull" policies that seek to increase consumer appetite for technology adoption. The ACT rule acts as a "supply push" policy that requires manufacturers to make ZEVs an increasing share of their sales over time. For optimal implementation of this policy, coupled actions are therefore needed on the demand side to ensure sufficient uptake of the available ZEV models. A key part of this demand-side approach is identifying "first movers" entities, which are the organizations most motivated and able to adopt new technologies that are still in the early stages of commercialization. First movers are most commonly large corporations or governments, which are more likely to have the deep resources necessary to absorb higher costs and access the necessary technical and operational support needed to implement new technologies. As first movers, these entities can then demonstrate the business case for the technology and share knowledge on effective applications across the industry. First mover adoption is already being seen in commitments by large companies, such as Amazon,[81] Walmart,[82] and IKEA[83] to test and deploy ZEVs within their fleets. There are also networks of corporations that have committed to battery electric vehicle (BEV) deployment, such as EV100 and the Corporate Electric Vehicle Alliance (CEVA), and a network of corporations focused on the infrastructural challenges of BEV charging known as Powering America's Commercial Transportation (PACT).[84–86] These networks of first-movers are particularly important for ZEVs, which combine the challenge of deploying new vehicle technologies with the need for substantial deployment new supportive infrastructure.

To analyze adoption opportunities in Maryland, we first examine the current status of MHD ZEV deployment in Maryland, with a focus on identifying first mover trends and use cases that are most suited for early deployment. We then summarize insights from detailed interviews with a broad set of stakeholders across the MHDV industry, addressing both supply-side and demand-side challenges and opportunities for ZEV deployment. Finally, we provide an overview of projected trends for different types of MHD ZEVs, focusing on when different types of vehicles are expected to reach cost parity with conventional internal combustion engine vehicles, and potential factors that could help accelerate this timeline.

5.1 Profile of Private and County-owned MHDV in Maryland

According to Maryland registration data provided by the Motor Vehicle Administration (MVA), there are 123,810 vehicles owned by businesses (53.8% of total), 85,369 vehicles owned by individuals (37.1%), 20,674 vehicles owned by government entities (9.0%), and 404 vehicles owned by non-profits, trusts, and cooperatives (0.2%) that are subject to the ACT rule. These vehicles are primarily concentrated geographically in central Maryland, with the largest numbers of vehicles in Prince George's County, Baltimore County, Montgomery County, and Anne Arundel County (Figure 5.1).

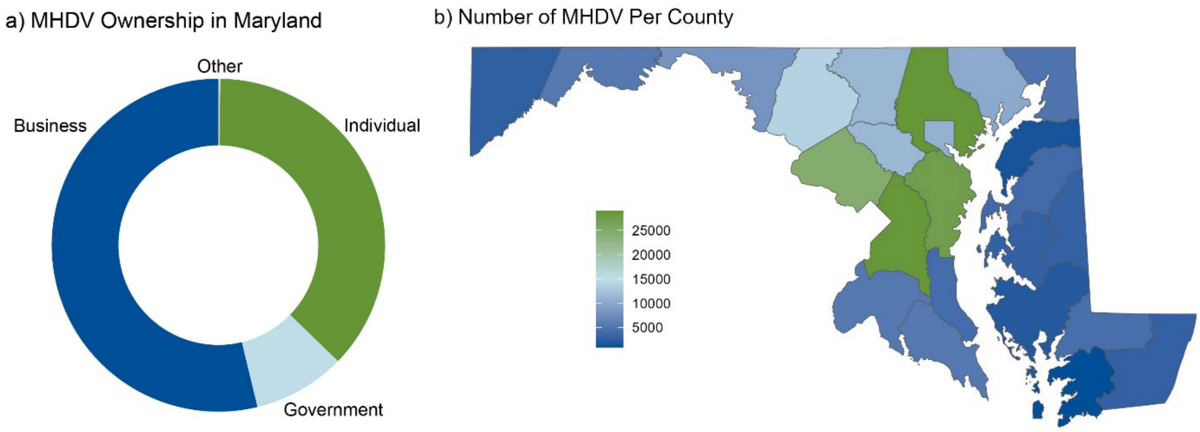


Figure 5.1. Summary of medium- and heavy-duty vehicles (MHDVs) in Maryland with a) breakdown of vehicle ownership by type of entity and b) geographical distribution of vehicles by county.

In Figure 5.2, we show the distribution of vehicles in each ACT category by county to distinguish geographical trends. We find that Class 2b-3 vehicles dominate in most localities, and Class 4-8 tractors only account for at most 1.76% of MHDV in a given county. Only five counties have more than 100 registered Class 4-8 tractors - Anne Arundel, Baltimore, Baltimore City, Howard, and Prince George's. This may be because of the proximity of these counties to the Port of Baltimore and the I-95 corridor.

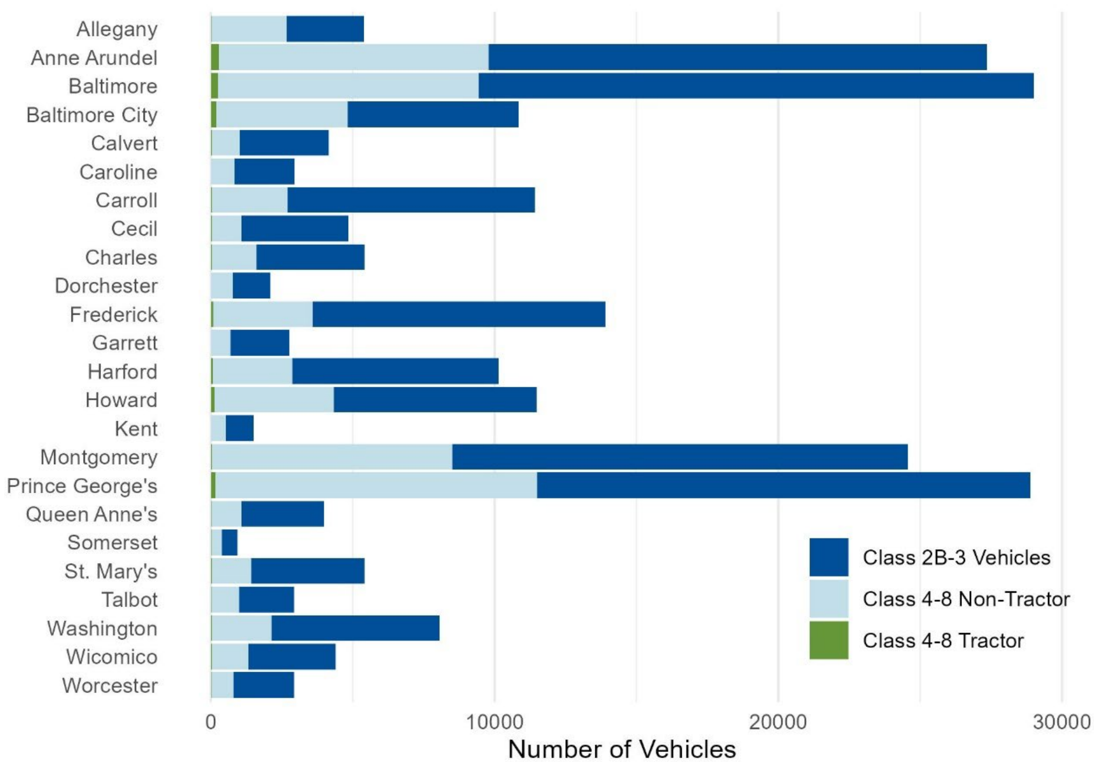


Figure 5.2. Number of medium- and heavy-duty vehicles (MHDVs) in each Maryland county, shown by Advanced Clean Trucks (ACT) category.

When vehicles are broken out by the categories in the ACT rule, we also see that ownership patterns are distinct for Class 2b-3, Class 4-8 trucks, and Class 4-8 tractors (Figure 5.3). Businesses are more likely to own heavy-duty vehicles, while individuals only own a large proportion of vehicles in Classes 2b-3. This means that individuals will be most impacted by the sales targets for smaller vehicles, while the sales targets for heavy-duty vehicles will have comparatively little impact on small-scale owner-operators or those using MHDV as a personal vehicle. The majority of MHDV owned by individuals are pick-up trucks, with many likely used as personal vehicles. Notably, BEVs are usually heavier than internal combustion engine vehicles, so with electrification more pick-up trucks may qualify as medium-duty based on weight. Businesses make up the majority of vehicle ownership across all ACT categories, but there can be large differences in ability to adopt electric vehicles between small businesses and large corporations. To capture these dynamics, we also examine vehicle ownership broken out by fleet size in the following section.

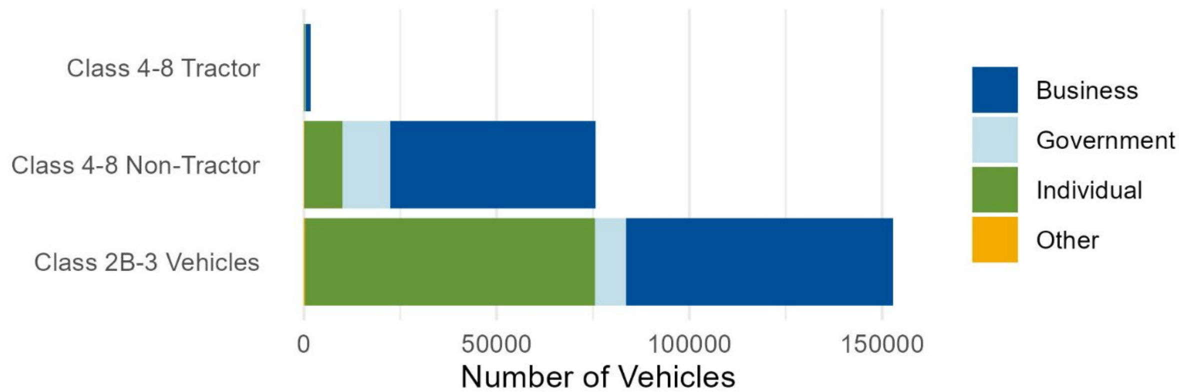
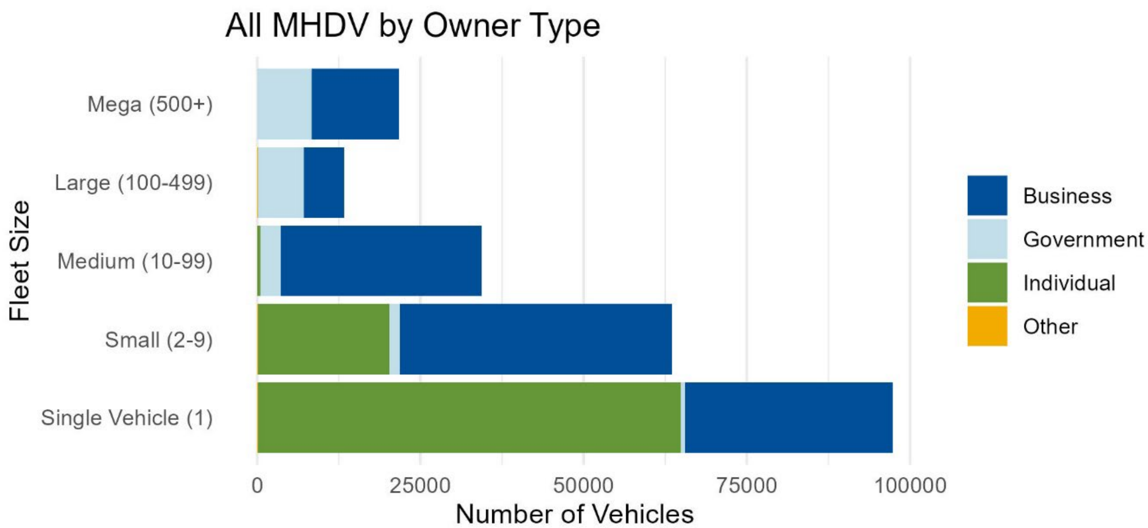


Figure 5.3. Ownership of medium- and heavy-duty vehicles (MHDVs) in Maryland shown by Advanced Clean Trucks (ACT) category and owner type.

5.1.1 Current Deployment of BEVs in Maryland

We divide owners into categories based on the size of their fleets, with entities that only own one MHDV in a "single vehicle" category, while others are grouped into small (2-9 vehicles), medium (10-99 vehicles), large (100-499 vehicles), and "mega" (500+ vehicles) fleets. Figure 5.4 shows that while individuals and small fleets dominate the overall number of MHDV in Maryland (Figure 5.4a), it is Mega fleets of more than 500 vehicles that are driving the majority of current BEV adoption (Figure 5.4b), led by businesses and counties. Individuals account for a large share of BEV adoption among owners of single vehicles. These trends match closely with the "first mover" dynamics described above. Governments and large corporations are the entities most likely to have the resources necessary to adopt new technologies before they reach cost parity. Public pressure or alignment with other strategic priorities may also provide the motivation for both to do so despite any additional costs.

a)



b)

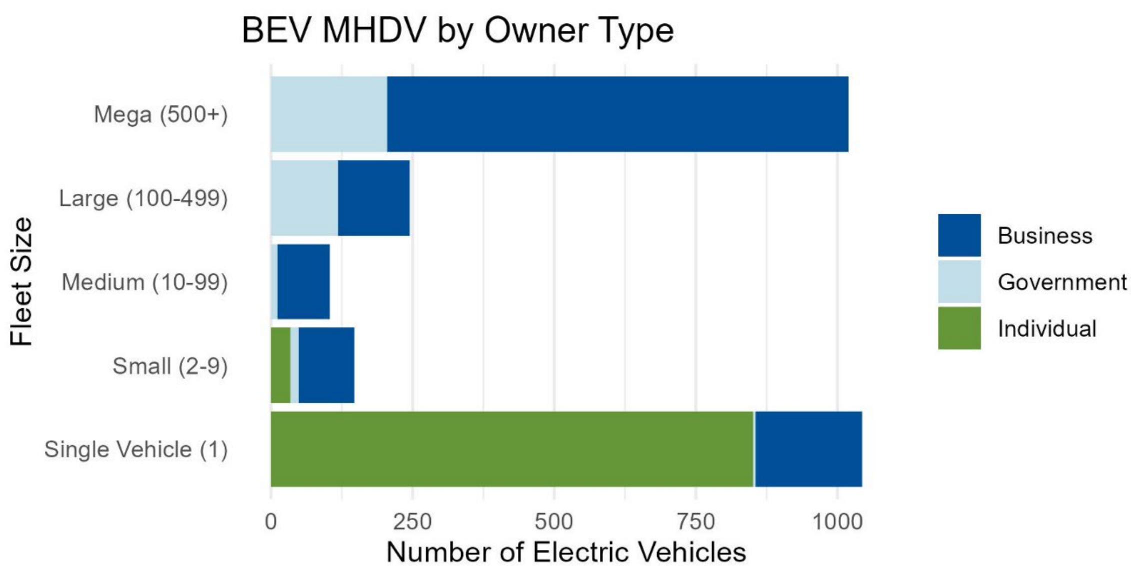


Figure 5.4. Medium- and heavy-duty vehicles (MHDVs) in Maryland shown by the size of the fleet owned by different types of entities. a) shows all MHDV in Maryland, and b) shows only MHD battery electric vehicle (BEV).

Table 5.1 summarizes the 2,560 MHD BEVs currently operating in Maryland by class and owner type. Class 2b BEVs include vans, pick-ups, and straight trucks, with notable adoption across all three owner categories of governments, businesses, and individuals. Class 3 BEVs include pick-ups, straight trucks, and other trucks. The only Class 6 BEV in Maryland is a trash truck procured by the City of Hyattsville in 2021. Class 7 BEVs are primarily school buses owned by Montgomery County, Prince George's County, Baltimore County, Baltimore

City, and Frederick County. The Class 8 BEVs are tractors. There are currently no known MHD fuel cell electric vehicles (FCEVs) registered in Maryland.

	Local Governments	State Government	Businesses	Individuals
Class 2b	92	28	1309	859
Class 3	0	0	10	26
Class 6	1	0	0	0
Class 7	232	0	0	0
Class 8	0	0	3	0
Total	**325**	**28**	**1322**	**885**

Table 5.1. Number of deployed medium- and heavy-duty battery electric vehicles (MHD BEVs) in Maryland, shown by type of owner and vehicle class.

Notably, all but 10 of currently in-use BEVs are model years 2020 or later (Figure 5.5). The large increase in deployed BEVs seen in recent years was primarily due to large purchases by Montgomery County, the University of Maryland, a Mega (>500) corporate fleet, and 3 Large (100-499) corporate fleets. This again demonstrates the importance of engaging with these large fleets as key drivers of early adoption.

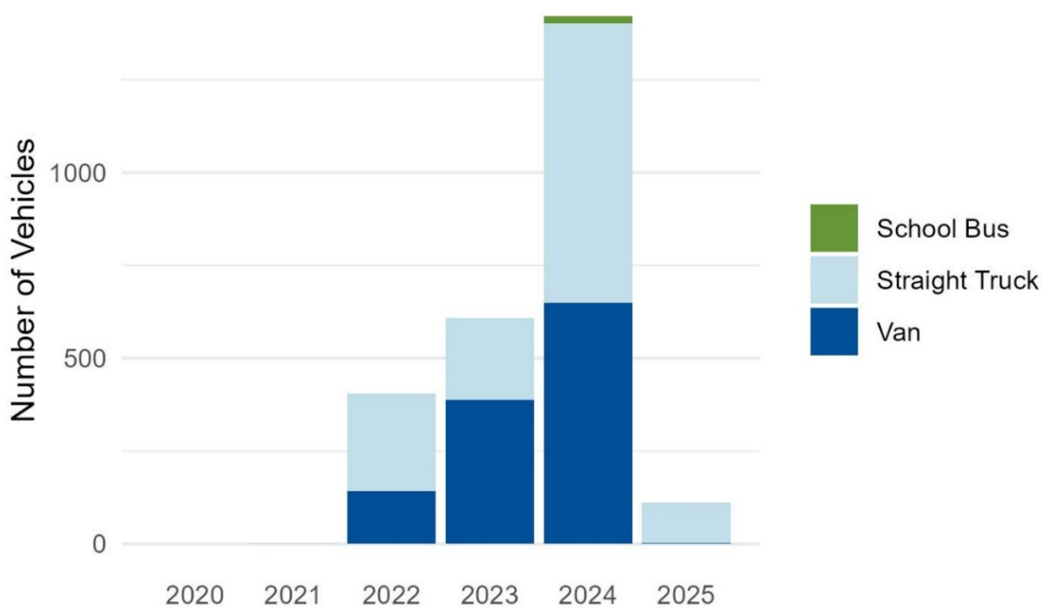


Figure 5.5. Medium- and heavy-duty battery electric vehicles (MHD BEVs) registered in Maryland by model year. Ten BEV vehicles from the 1990s are not shown. Data for 2025 is shown through April 10th.

With this understanding of the current trends in vehicle deployment in Maryland, in the next sections we discuss opportunities and challenges for further deployment of ZEVs in the state.

5.2 Opportunities and Challenges for Early Adopters

5.2.1 Methodology we use to define best cases for early adoption

We adopted a five-dimensional framework (Figure 5.6), supported by detailed sub-dimensions (Table 5.2), to give a full scope of considerations for early adopters in the MHD BEV market under the ACT scope. These five dimensions are:

- ACT/Policy Support: examining the role of state-level policies and incentives in facilitating or hindering the ACT implementation and BEV adoption.
- MHD BEV market: describing market readiness and assessing future intentions of companies and sectors that have begun adopting BEVs.
- BEVs: covering topics related to vehicle cost, available models, technical features, weight limitations, driving range, and salvage value.
- Supporting Infrastructure: including both on-site and enroute charging infrastructure, as well as coordination with utility providers and other stakeholders for installation and grid access.
- Human Capital: focusing on workforce-related challenges such as driver awareness and readiness, training needs, and the availability of qualified maintenance technicians.

This framework helps ensure a structured and comprehensive understanding of the multifaceted barriers to ACT implementation and broader BEV deployment across the MHDV segments. Building on this framework, we further map potential opportunities and strategies to address these challenges, ranging from targeted policy interventions and workforce development initiatives to infrastructure investment and tailored support for fleet operators and manufacturers. Using this framework, we conducted in-depth interviews with stakeholders in key roles such as BEV suppliers, infrastructure providers, and end-users, to capture diverse perspectives and insights across the industry.

A series of interviews was conducted with twenty-two stakeholders between February and July 2025. Each interview began with a set of standardized questions, followed by open-ended prompts to gather nuanced, on-the-ground perspectives and practical insights into the barriers and potential solutions associated with the implementation of the ACT. By capturing views across the value chain, from vehicle suppliers and fleet operators to local policymakers and distribution grid managers, this effort aimed to build a comprehensive understanding of the key challenges facing the MHDV sector in transitioning to ZEVs. The stakeholders were categorized into eight types: local government (city/county) (4), consultants (3), dealerships (1), OEMs (2), corporate stakeholders (3), state agencies (5), trucking industry associations (1), and utilities (2).

For each of the dimensions in our framework, the interviews revealed key topics that were mentioned consistently across different stakeholders. These topics are summarized in Table 5.2 and discussed in detail in section 5.2.2 below.

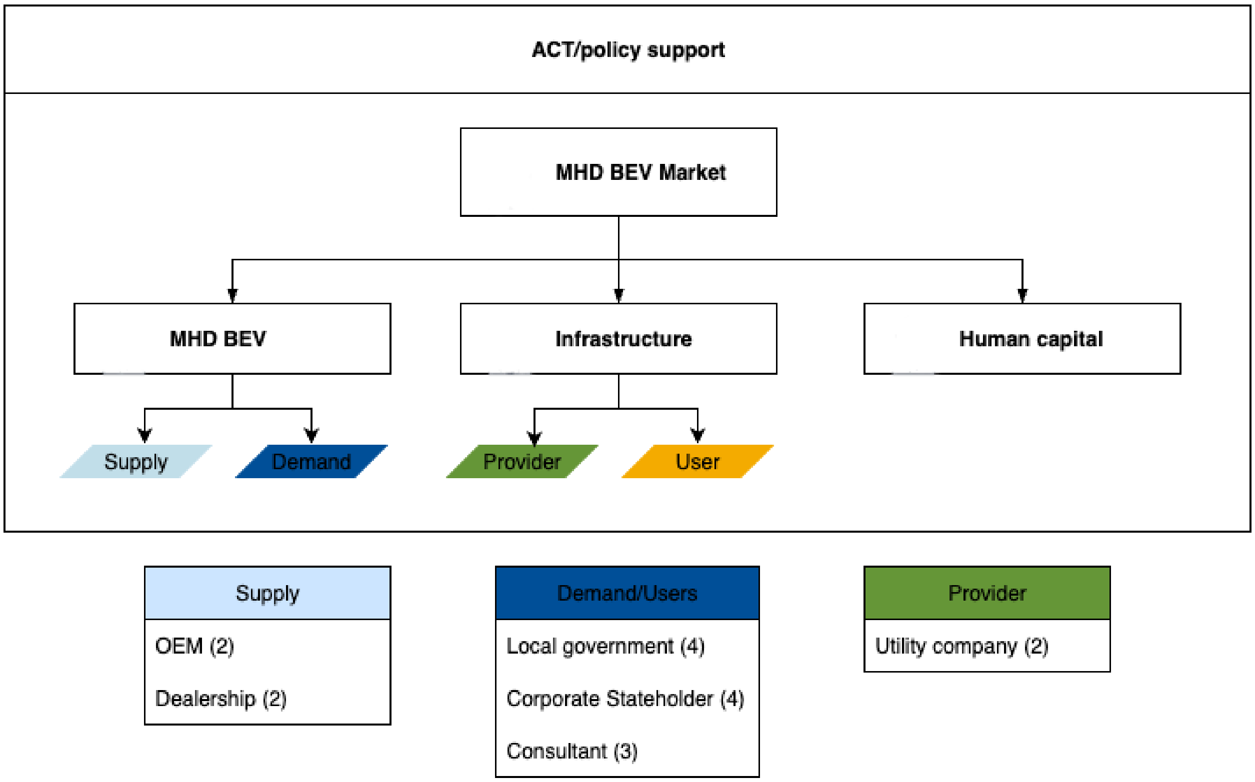


Figure 5.6. The five-dimensional framework used by the authors to capture challenges and opportunities associated with implementing the Advanced Clean Trucks (ACT) rule.

Main Dimension	Key Topics
MHD BEV	Cost, Models, Features, Range, Used Market & Resale Value
Infrastructure	On-site, En route, Cost, Utility Coordination
MHD BEV market	Market Readiness, Intention/Goal, Parking
Human capital	Drivers, Maintenance
ACT/Policy Support	ACT, State Incentive

Table 5.2. Key topics derived from the interviews with stakeholders, organized according to the framework shown in Figure 5.6.

5.2.2 Results of this methodology

Overall mapping results on challenges and opportunities

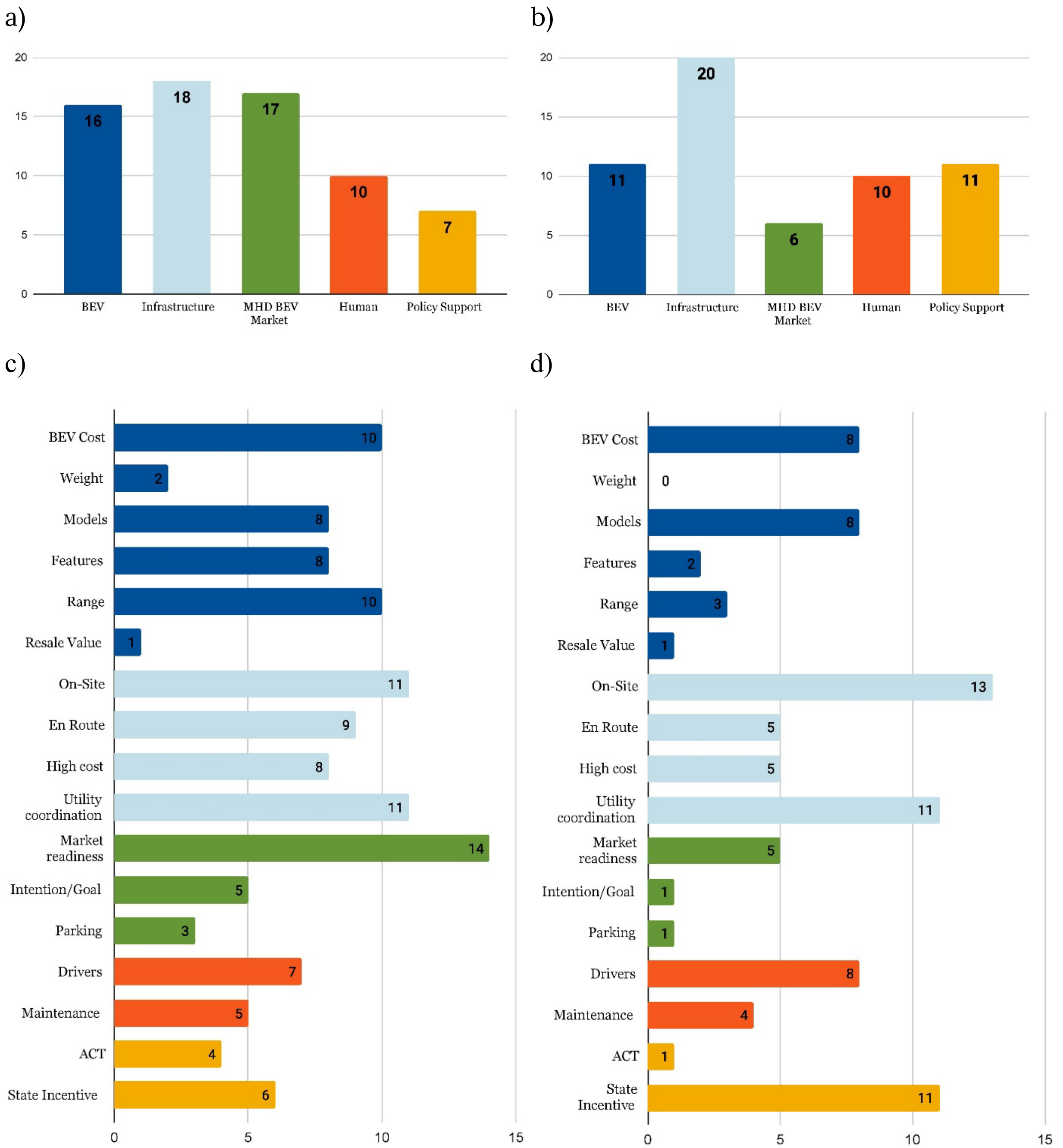


Figure 5.7. The number of times that one of the main dimensions in our framework were mentioned by stakeholders as a challenge (a) or opportunity (b). These are further broken down by key topics in (c) challenges and (d) opportunities by number of stakeholders.

Challenges

Figure 5.7 panels a and b highlight the challenges (left) and opportunities (right) most frequently discussed by stakeholders in interviews. On the challenges side, infrastructure emerges as the most frequently cited topic (18 mentions), followed by MHD EV market (17) and BEV-related issues (16).

Within infrastructure, six stakeholders raised concerns about the lack of access to reliable BEV infrastructure, five highlighted the high costs associated with installation and operation, and three mentioned technical challenges in installing chargers. When examining infrastructure accessibility in more detail (Figure 5.7 panel c), on-site infrastructure emerged as a key barrier (mentioned by 11 stakeholders) compared to enroute infrastructure (9 mentions). Currently, stakeholders face limited access to suitable charging infrastructure, and existing charging speeds are often inadequate for MHD BEV trucks. For on-site infrastructure, coordination with utilities was identified as a major challenge (11 mentions), followed by the high cost of installation (8 mentions), particularly when significant new electrical service was needed to support sufficient chargers. Regarding utility coordination, stakeholders expressed significant uncertainty surrounding the development of BEV infrastructure, including estimating usage demand, forecasting project timelines, understanding charging technologies, and determining optimal charger locations. Due to these uncertainties, they are also unsure about the overall costs and the physical space required to install and operate BEV infrastructure effectively. While a charger installation that does not require new service might proceed relatively cheaply in a few weeks to months, larger projects might require multiple years of lead time and be subject to high costs.

For the MHD BEV market, market readiness is the predominant challenge noted by stakeholders (14). Stakeholders imply that the current ACT market in Maryland is not mature with three main challenges: long lead times for vehicles, low demand in the market, and lack of financial incentives. Five pointed out that long lead times and ongoing delivery delays for receiving vehicles significantly hinder their ability to make strategic decisions, and a typical lead time ranges from two to ten years. Additionally, two expressed difficulties in setting concrete BEV adoption goals due to a lack of experience and confidence in the technology.

In the BEV dimension, cost and range were the two primary topics of discussion among nine stakeholders. Many frequently compared BEV costs to those of their internal combustion engine vehicle fleets, noting that BEV purchase costs are reported to be three to five times higher than traditional internal combustion engine models. Regarding range, current MHD BEVs typically offer 100–250 miles per charge, which often does not meet the operational needs of stakeholders, particularly for those who require vehicles capable of covering 200 miles or more per day. The second key topic raised was the functional capabilities of BEVs, as many stakeholders emphasized the need for current BEV models to include specific features required for their daily or seasonal operations such as power take-off for snowplows that many local governments need during the wintertime.

In the human dimension, stakeholders primarily discussed the adjustments drivers must make to use EVs, with particular emphasis on the training needed to operate and maintain BEVs. Stakeholders have used intern or retraining programs to help familiarize drivers with the new systems. While most of the trucking industry is not unionized, an interviewee noted that aligning training with union discussions is important as it can affect route completion. An interviewee that had already tested or operated BEVs said that their in-house maintenance teams were unfamiliar with the BEVs, and vehicles had to be maintained by the manufacturer. Dealerships are also capable of BEV maintenance, but one indicated that training staff for BEV maintenance can be a significant cost. Many also observed that the acceptance of BEVs varies among employees, often influenced by age and familiarity with new technologies. A key challenge for ACT's workforce is the current shortage of both trained drivers and adequate training resources.

Finally, the policy support dimension revealed a divide in stakeholder perspectives on financial incentives and infrastructure readiness. While most stakeholders focused on state-level grants, there was also acknowledgment of funding from federal programs and private-sector incentives. Stakeholders identified more challenges with state incentives (6 mentions) compared to ACT regulations (4 mentions). However, there was no single dominant theme among these challenges, as they varied based on stakeholders' roles in the market. Many stakeholders expressed the need for the state to introduce additional incentives to support overall market demand, infrastructure development, and BEV technology innovation. More detailed challenges will be outlined in the next section. On the ACT regulation side, the four stakeholders who raised concerns primarily pointed to a lack of confidence in the current market's ability to meet the regulatory goals.

Opportunities

On the opportunity side, Figure 5.7b shows that among the main dimensions, Infrastructure is associated with the most opportunities identified by stakeholders (20), followed by Policy Support (11), and BEVs (11).

In the infrastructure dimension, eight stakeholders identified financial opportunities, including reducing installation costs, lowering electricity rates, and accelerating the market adoption of BEVs. When examining this dimension in more detail (Figure 5.7, Panel d), on-site infrastructure (13 mentions) and utility coordination (11 mentions) emerged as the areas with the greatest opportunities, aligning closely with the key challenges previously identified. For on-site infrastructure, stakeholders noted that increased state-level support and investment in infrastructure would help them transition to BEVs more quickly. Programs like the Climate Pollution Reduction Grants (CPRG) can serve as promising tools to expand MHD BEV charging infrastructure, especially along the I95 corridor, helping to alleviate En route charging concerns for regional trucking operations. Several stakeholders also suggested strategies to enhance the efficiency of charging infrastructure, such as incentivizing user demand and improving charger design. Regarding utility coordination, four stakeholders emphasized that a faster and more consistent permitting process would create additional opportunities for infrastructure development. They also stressed the importance of maintaining long-term relationships with utility companies and other infrastructure-related government agencies.

In the policy support dimension, five stakeholders highlighted financial opportunities, particularly the need for increased state-level financial incentives for both infrastructure development and fleet expansion. A notable number of stakeholders (11) recognized existing opportunities in state incentives but emphasized the need for additional state-level policies and consistent financial support to accelerate the deployment of charging infrastructure. Additionally, they suggested that the state establish a centralized database to map charger locations, which would help stakeholders better assess and address their infrastructure needs.

In the BEV dimension, stakeholders identified the greatest opportunities in cost (8 mentions) and vehicle models (8 mentions). To reduce the purchasing cost of ACTs, three stakeholders suggested that financial incentives from the private sector could be a viable approach. Regarding vehicle models, stakeholders noted that certain types—such as load packers with stable, short weekly routes—are particularly well-suited for replacement with BEVs, given the current limitations in range.

In the human dimension, drivers (8 mentions) emerged as the key topics with the greatest opportunities. Three stakeholders highlighted the success of implementing BEV training programs, which not only helped drivers adopt BEVs more easily but also reduced initial resistance by improving their confidence and familiarity with the technology. Additionally, three stakeholders whose drivers demonstrated strongly positive responses to BEVs attributed this to tangible benefits such as a quieter and smoother driving experience with less fumes.

Finally, within the MHD BEV market dimension, market readiness was identified as the area with the most opportunities (5 mentions). These four stakeholders emphasized that fostering a well-developed BEV market, supported by strong networks among various market participants, is essential for sustaining and accelerating the growth of the BEV market. They stated that while MHD BEV adoption is currently slow, the market is moving in that direction and that as more stakeholders become involved and proactive, it will make each component of BEV adoption more accessible.

Challenges and Opportunities Alignment and Divergence

From these interview results, it is evident that challenges and opportunities are closely aligned in certain dimensions, while they diverge in others. Examining these patterns helps us identify common trends shared by stakeholders, while also revealing new barriers that may have been overlooked. At the same time, this analysis provides fresh perspectives and actionable insights to better support the ACT transition.

On the alignment, stakeholders shared similar levels of challenges and opportunities on the BEV infrastructure dimension, human capital dimension and some sub-categories of the BEV dimension, such as cost and models. In the human capital dimension, stakeholders found that most challenges come from the lack of familiarity and training for vehicle operators, but this can be addressed by providing workforce training programs from the state or individual company on operating and maintaining BEVs.

On the divergence side, the MHD BEV market emerged as the area with the most challenging discussions, while offering only limited opportunities based on stakeholder input (17 mentions of challenges vs. 6 mentions of opportunities), primarily driven by the market readiness sub-dimension. This reflects the market's current immaturity for the MHD BEVs, characterized by very limited demand, hesitancy to invest, a lack of available vehicle models, long lead times, and uncertainties surrounding cost and operational performance. The limited opportunities identified mainly relate to potential market readiness improvements through stronger collaboration among manufacturers, fleet operators, and policymakers. Overall, the barriers in this dimension continue to outweigh the opportunities, underscoring the need to accelerate efforts to prepare the MHD BEV market for broader adoption.

Another divergence emerges within the policy support and BEV key topics, particularly regarding vehicle range and features. A common challenge highlighted by stakeholders is that current BEVs lack certain features and cannot meet the range requirement necessary for many market applications. Given the limited availability of technological solutions to fully address these gaps, our suggestion is that efforts should focus on identifying and prioritizing suitable models that can operate effectively as early adoption use-cases. Particular use-cases that were mentioned as opportunities in interviews include trash trucks, school buses, line-haul trucks, and local delivery vans. These examples are discussed in more detail in Section 5.2.3.

Challenges and Opportunities by Market Role: MHD BEV Supply, Demand, and Infrastructure

We further analyzed the challenges and opportunities based on the stakeholders' roles in the market. For example, OEMs and dealerships function as the primary suppliers of MHD BEVs, while private-sector companies, trucking firms, and local governments represent the demand side for these vehicles. In addition, utility companies act as the primary providers of electrical grid infrastructure, while various companies provide chargers or charging services. Most other stakeholders primarily function as infrastructure users. Since the challenges and opportunities vary across these distinct market roles, summarizing them by stakeholder type offers a clearer understanding of the specific barriers and opportunities each group faces, as well as potential areas for improvement tailored to their specific needs.

Supply and Demand Role in the MHD BEV Market

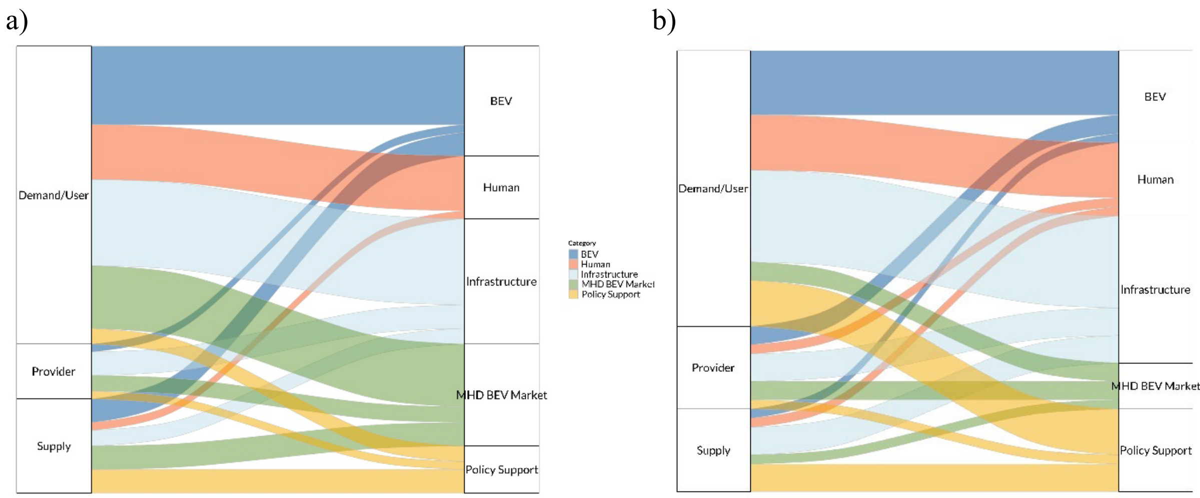


Figure 5.8. Main dimensions identified as challenges (a) and opportunities (b), broken out by the market role of stakeholders.

For Supply, Figure 5.8a highlights several challenges related to BEVs (3 mentions), the MHD BEV Market (3 mentions), and policy support (3 mentions) dimensions. Suppliers expressed sensitivity to the cost of BEVs, noting that they have greater familiarity and pricing transparency with internal combustion engine vehicles for their customers. A key challenge cited in the MHD BEV market is the lack of local demand, as one supplier noted while they had delivered 800 electric trucks across North America, only one was deployed in Maryland. Regarding policy support, suppliers voiced concern over the ACT regulation emphasizing that they expect the regulatory burden to fall disproportionately on them, potentially straining their operations and market strategies.

On the demand side, Figure 5.8a indicates that the primary challenges lie in infrastructure (11 mentions), BEV-related issues (10 mentions), and the MHD BEV market (8 mentions). As noted in the supply-side analysis, current demand for BEVs remains low, largely due to the absence of reliable and flexible charging infrastructure. Without adequate infrastructure in place, users find it difficult to integrate BEVs into their daily operations. In addition, the MHD BEV market is still underdeveloped as stakeholders cited long lead times and a lack of dependable OEM partners. This lack of supplier engagement further complicates the ability of demand-side actors to identify and procure models suited to their specific operational needs. Taken together, these interrelated barriers have contributed to the overall sluggish demand in the MHD BEV market.

Opportunities on the supply side (Figure 5.8b) are primarily concentrated in infrastructure (3 mentions) and policy support (3 mentions). Suppliers believe that demand could be significantly increased through expanded infrastructure development. However, they emphasized that the State must take a leading role by starting with investments in public charging infrastructure. In addition, suppliers noted the need for enhanced state-level financial support for the MHD BEV market, including vehicle purchase rebates and infrastructure grants. Greater public investment would not only provide market certainty but also help alleviate the burden on suppliers by driving demand.

On the demand side, opportunities are more widely distributed across several dimensions: infrastructure (10 mentions), human capital (6 mentions), policy support (5 mentions), and BEV availability and performance (7 mentions). Like suppliers, users emphasized the urgent need for expanded charging infrastructure, with two stakeholders explicitly calling for state leadership in this area. What distinguishes demand-side perspectives is a greater focus on the importance of fast-charging solutions as three users identified the widespread deployment of DC fast chargers as critical to meeting operational needs. Additionally, three stakeholders suggested that BEV adoption could accelerate if the state streamlined the permitting process for charging infrastructure projects.

One critique of the ACT in states without a corresponding mandate on buyers is a lack of demand for the BEVs that manufacturers are required to sell. The rule compels manufacturers to produce and deliver an increasing percentage of zero-emission trucks, but without a purchase mandate on fleets and operators there is no guaranteed market. This can create an imbalance in supply and demand, leading to manufacturers struggling to meet sales quotas and a potential shift in liability to Maryland truck dealers. If Maryland truck dealers are effectively required to turn down business because customers do not want ZEVs, those dealers could lose business as truck sales shift to neighboring states which do not have the ACT.

Provider and User Roles for MHD BEV Infrastructure

Two primary challenges face both providers and users of charging infrastructure: location and power levels. Providers (i.e., electric utilities) do not know, in advance of a request from a customer, precisely where new BEV infrastructure will be installed or the amount of power that will be requested. As one provider noted, they "won't proactively build infrastructure until requests [from customers] come in." As a result, distribution system upgrades are not generally made ahead of need other than based on generalized load forecasting, and the result can be lengthy lead times for power to be provided to a site. A trucking industry user emphasized, "Charging needs to be in the right place and right time."

Despite the obstacles to building ahead of need, as discussed in more detail in Chapter 1, opportunities also exist. All three providers we interviewed identified specific locations, such as near delivery company warehouses or on state-owned land, where actions can be taken to be responsive to expected high user demand. On the user side, state-level support was seen as crucial to accelerating utility permitting processes and enabling faster infrastructure deployment. In the absence of ubiquitous charging infrastructure, one user also highlighted the potential of fuel optimizers, logistical tools that can guide BEVs along routes with efficient energy use and access to charging, helping reduce both range anxiety and unnecessary downtime.

5.2.3 Case Studies

We summarize four case studies below that represent perspectives from different market roles. On the demand side, we share insights from a trucking company that tested a BEV in its fleet operation and encountered some common adoption challenges such as vehicle range and limited on-site charging infrastructure. From the government side, we focus on a city government that manages the largest fleet among those interviewed, with more than 4000 vehicles and heavy-duty equipment, and was one of the earliest to test electrification. On the supply-side, an OEM (original equipment manufacturer) provides detailed insights into the challenges of BEV production and the tension with dealers. Drawing from similar experiences in California, the OEM was able to highlight potential implications for Maryland's ACT regulation. Finally, an infrastructure provider case study focuses on a utility in Maryland, chosen for its perspective on weak market demand and equipment shortages.

Case study 1 – Trucking companies as BEV users

The trucking company's BEV experience began when an OEM approached it to test an electric truck over five years. Cost quickly emerged as the biggest challenge: even after allocating vehicle costs three ways with the OEM and dealer, the truck remained far more expensive than a diesel (roughly $350,000 vs. $130,000), with total five-year costs, including insurance, charging infrastructure, and electricity costs, projected to be over $550,000. The truck's limited 130-mile range also failed to meet operational needs of 200–450 miles per day. Attempts to maximize usage through slip seating (the practice of having multiple drivers rotate through using the same vehicle) proved impractical because of the downtime needed for charging. Additional concerns included poor performance in adverse weather, lack of salvage or resale value, and dependence on the OEM for maintenance due to limited on-site expertise. Charging infrastructure further compounded challenges. Public chargers were unsuitable for unpredictable trucking routes and quick "drop and hook" operations, forcing reliance on the company's own facility. Charging costs reached nearly five times higher than expected, adding $1,100–$1,200 monthly in extra expenses. While the OEM temporarily covers this differential, attempts to "work with the utility" or adjust charging schedules have not reduced costs. On the human side, driver acceptance varied by age group, with younger drivers more open to BEV adoption than older ones. The stakeholder is currently implementing AI route planning software to optimize efficiency and minimize miles traveled by their trucks, thereby improving future battery utilization. The stakeholder called for greater state investment in charging stations and emphasized the need for incentives to supplement vehicle purchase cost and fuel cost differentials.

Case study 2 – Local governments as BEV users

Baltimore City operates 1,500 light-duty (LD) vehicles and 4,000 MHD vehicles and heavy-duty equipment, with a goal of achieving carbon neutrality by 2045 and 100% LD ZEV purchases by 2030. Progress has been slowed by four key challenges: high BEV costs (with MHDV purchases feasible only through federal, state, and OEM grants), limited model availability with long lead times (e.g., an electric bookmobile had a two-year lead time), vehicle design gaps such as missing worker-safety features and regenerative braking, and infrastructure barriers including lengthy procurement and utility permitting timelines (review processes ranged from eighteen to twenty-four months, with higher-power chargers taking even longer). While LDV electrification is advancing, Baltimore has not yet set a timeline for MHDV electrification beyond preliminary feasibility studies. On the opportunity side, Baltimore identified load packers as a strong candidate to be their first MHD electric vehicles, provided that future models incorporate the essential features outlined in their feasibility study. They are currently working to procure an electric load packer and an electric street sweeper (for bike lanes) for which they received grant funding. For infrastructure, they have found that installation moves faster when using their own employees, and they are working to streamline the permitting process by establishing a single point of contact for all permits, with the goal of reducing approval times to less than a month. They are also investing in training programs for both maintenance staff and drivers to better prepare for BEV deployment. In addition, they suggested that the state could help ensure procurement and permitting processes are more streamlined, while still being flexible so that local jurisdictions can meet their needs and preferences.

Cast study 3 – Manufacturers as BEV suppliers

This manufacturer, whose primary ZEV market is in other states (California), currently offers a limited lineup of electric vocational trucks, with plans to eventually expand their portfolio into all product segments. However, they emphasized that no ZEV has been sold without incentives, and with the reduction in federal support, they anticipate a steep market decline within the next two to three years. Customers remain hesitant due to limited range and payload capacity, particularly in heavy vocational segments where payload directly affects revenue and total cost of ownership. Supply chain constraints, with most batteries sourced from China and subject to restrictions and tariffs, add further challenges. On the policy side, the stakeholder noted that even in California, shifting environmental justice requirements have excluded some large fleets from incentives, while in Maryland, delayed implementation of the ACT regulation would mandate that the first compliance year would require 40% of truck sales be ZEVs in 2029, a target they view as unmanageable. They stressed that the burden of compliance would fall primarily on OEMs and dealers, not consumers, creating significant tensions in the market. On the opportunities side, the stakeholder emphasized the importance of allowing natural market growth in the MHD BEV sector, noting that pushing products prematurely into the market is unlikely to succeed. To address long-term supply constraints, greater support is needed for domestic battery production, though current North American production still falls short of market demand. At the state level, they suggested that increasing BEV incentives and investing in charging infrastructure would help build certainty and confidence among companies, offsetting concerns about cuts to federal incentives and encouraging greater private-sector investment.

Case study 4 – Utilities

This utility emphasized the nature of supporting BEV infrastructure development in Maryland is different from other customers, and noted that while they recognize rising BEV demand, they are not proactively investing in additional distribution infrastructure until clear market growth and specific customer requests emerge. They explained that no forecasting analysis has yet been conducted for MHD BEVs, as dedicating engineering resources at this stage are not seen as cost-effective. Other utilities we interviewed echoed this perspective and stressed that it is not standard practice to preemptively build infrastructure for chargers without predictable customers. This stakeholder also highlighted the location-dependent and potentially high costs of infrastructure development, compounded by long equipment lead times: a 1 MW transformer typically requires 12–18 months, while a 10 MW transformer can take up to five years due to manufacturer shortages. On the positive side, the stakeholder noted that areas where new warehouse facilities like Amazon are driving higher demand for BEVs will act as hubs for the build-out of BEV infrastructure. Regarding long lead times, the stakeholder explained that overall project timelines could be shortened if customers were allowed to provide their own transformers, though they emphasized that this would not resolve the fundamental challenge of lengthy transformer acquisition times.

5.2.4 Early Adoption Use Case Analysis

Use Case Analysis: trash trucks, school buses, line-haul trucks, and local delivery vans

From the interviews, we identified several specific use cases that were frequently mentioned during discussions of opportunities, particularly as potential cases for early adoption by our interviewees. These use cases represent sectors where early adoption of BEVs is considered feasible and strategically advantageous and include Class 8 trash trucks, Class 7 school buses, Class 3-8 straight trucks for regional line haul, and Class 2b-3 vans used for local delivery. We discuss these cases separately below, focusing on the key challenges they face and the potential strategies to address these challenges, in order to make them more viable and scalable in the short term.

The most common characteristic of these vehicles are that many of them run shorter fixed and predictable routes that can help address BEV range concerns and be a better fit for introducing charging periods. Several of these use cases are already available as BEV models, one indicator of first-mover success,[87] and many have already been piloted or used in Maryland. These types of vehicles also tend to be on the lighter class size for the range of MHD BEVs and may not need power take-off.

While these types of vehicles are more likely to electrify in the early years of the ACT, stakeholders that had tested or piloted these vehicles still cited considerations that would help wider adoption of these use cases. For example, while regional line haul trucks can have predictable routes, some routes are more unpredictable and many drivers may be independent contractors, who tend to hold onto their vehicles longer and may switch frequently between carriers. Therefore, larger line haul companies that own their own fleet are in better positions to adopt BEVs. Considerations for each use case are listed in Table 5.3.

Vehicle	Mentioned by	Characteristics	Considerations
Trash Trucks	City government, truck company	Stable, predictable weekly routes	• Cost recovery within lease terms • Driver training for regenerative braking • Route completion time and coordination with unions • Size features for driving down alleyways
School Buses	Truck company, OEM, local government	Fixed, predictable routes	• Number of routes that must be completed morning and afternoon • Longer field trips and charging enroute • Driver shortages
Regional Line-haul Trucks	OEM, Trucking Association	Fixed route, often between distribution centers or terminals	• Logistics to maximize use of truck and number of trips (e.g. slip seating or drop and hook) • Independent contractors vs. larger companies
Local Delivery Vans	Corporate stakeholder, Trucking Association	Shorter routes, stopped for loading and unloading or frequent down time	• May not get the fuel savings benefits in this segment to justify the higher cost of vehicles

Table 5.3. MHDV electrification use cases mentioned by interviewed stakeholders and their characteristics and considerations.

First Movers

Therefore, we are now able to identify the potential first movers, those organizations or fleets that have both the motivation and capacity to advance MHD BEV deployment within the early stages of the ACT in Maryland. These first movers are typically characterized by well-established operational routes, early engagement in infrastructure deployment planning or strong potential access to charging infrastructure, and a compelling business case for electrification.

First, utility service providers, local governments, and other corporations that already operate MHD BEVs at the lower weight classes, such as pickup trucks (Class 2b to Class 3). Cost differences between BEV and internal combustion engine vehicles are relatively small in this group, and the significantly lower maintenance costs make BEV ownership more economically attractive. In this segment, the cost difference between BEVs and internal combustion engine vehicles is relatively small, often within 8–10%, and the significantly lower maintenance costs further enhance the economic case for electrification. Some stakeholders reported operating BEVs for over 120,000 miles without major repairs, highlighting their durability and cost-effectiveness. However, these first movers still face notable challenges, particularly related to charging infrastructure and workforce readiness. A key barrier is the lack of sufficient DC fast charging, which limits the operational flexibility and scheduling of BEVs.

Second, large logistics corporations, either those that own substantial fleets or work closely with fleet operators. Companies such as Amazon, FedEx, and UPS, large private firms specializing in logistics and package delivery, have strong potential to become early adopters of MHD BEVs. Their demand for such vehicles is substantial, and both major private stakeholders we interviewed indicated ambitious goals to transition 100% of a specific segment of their fleets to electric by 2030 and 2040, respectively. Delivery and logistics vehicles, particularly those in Class 3 and 4, and in some cases Class 5, often have less demanding range and feature requirements compared to other vehicle types. This is especially true for last-mile delivery fleets, which are ideal candidates for electrification due to their predictable routes and frequent return-to-base operations. In addition, the high concentration of vehicle demand in certain areas makes these companies valuable partners for utility providers, who can strategically build charging infrastructure around these "hotspots" to achieve greater cost-efficiency, an approach confirmed by one utility stakeholder during interviews. Furthermore, a range of public and private incentives, including rebates from utilities and government programs, can help large companies offset the high upfront costs of BEV adoption. However, key challenges remain, particularly related to vehicle cost and range. While logistics BEVs are well-suited for shorter routes, their purchase prices remain higher than comparable internal combustion engine vehicles, making financial incentives crucial for adoption. Additionally, while range may not be a significant concern under normal conditions, one stakeholder pointed out that BEVs can experience a 10–30% reduction in range during cold weather, which poses operational challenges for consistent delivery performance.

Third, local governments operating in the waste management sector, particularly those using lighter-duty refuse vehicles such as load packers in Classes 4, 5, and 6 and trash trucks in Class 8, are also strong candidates for early adoption of MHD BEVs. These vehicles typically have modest range requirements and predictable daily routes, making them well-suited for electrification. Because of these operational characteristics, local governments can deploy charging infrastructure without disrupting service schedules. One city-level stakeholder shared that their load packers typically travel 40 to 60 miles per day, and they have already established a central garage equipped with sufficient Level 2 chargers to meet future charging needs. However, key barriers remain, particularly vehicle cost and lead time. According to stakeholders, studies of electric load packers dating back to 2014 have consistently found that the cost premium over internal combustion engine vehicles remains prohibitively high. In addition, procurement challenges persist as stakeholders noted that vehicle orders can take several years to fulfill, with frequent delays from vendors.

Fourth, county school systems represent another group with high potential for electrification, given their defined routes, regular schedules, and potential access to state and federal funding support. The average daily route driven by the ~7,000 school buses owned or contracted by county school systems in Maryland is 90 miles, with dense counties generally having shorter routes and rural counties generally having longer routes. Today's electric school buses are available in various configurations, with driving ranges for full-size buses generally varying from 150 to 200 miles per charge, which means the buses can serve typical routes particularly if they charge mid-day. However, the stakeholder noted that other external constraints, like a bus driver shortage, have limited the transition because buses have had to run constantly without the down times needed for charging. In terms of funding, stakeholders mentioned that state grants are often structured as reimbursable cost-share programs, which makes chief financial officers (CFOs) more comfortable with the investment.

Universities also offer strong examples of fleet electrification. For instance, the University of Maryland College Park has set a goal of fully electrifying its shuttle bus fleet by 2035. It currently operates 19 routes with 50 buses, serving over 1.1 million riders in 2023. These vehicles run on fixed, low-mileage routes, and the university has already installed accessible charging infrastructure to support future EV expansion. Despite this potential, key challenges remain for both school districts and universities. The cost of electric school buses is still high, with one stakeholder reporting a $100,000–$250,000 premium over comparable internal combustion engine models. Infrastructure reliability is another concern: several stakeholders shared experiences of charging equipment failures, such as chargers not functioning properly. One stakeholder noted that many counties are facing similar issues with reliability and support from infrastructure providers. Finally, workforce readiness poses a barrier. A stakeholder noted that new BEV drivers require extensive documentation and in-person training, adding administrative and logistical burdens to the transition process.

Fifth, regional line-haul trucking companies are emerging as potential first movers, particularly those with fixed regional routes and centralized depot operations, which make them better suited for near-term BEV deployment. There are business cases in other states demonstrating successful deployment of electric Class 7 and 8 trucks, for example, along the Phoenix–Los Angeles corridor, where operations are being supported by the development of multi-billion-dollar charging facilities. Further strengthening the outlook, several new electric line-haul models from manufacturers such as Tesla and Windrose are expected to enter the market within the next 12 months. However, significant challenges persist, particularly in the area of charging infrastructure. Limited availability of charging stations and high electricity costs present operational and financial constraints. With regard to energy costs, when charging spikes and is not spread relatively evenly throughout the day, demand charges can significantly increase the per-kWh price, intensifying the pressure on fleet operators.

Finally, state and local fleets of transit buses are another potential first mover, although they are not currently covered under the ACT. Given their predictable routes and opportunity to reduce GHG emissions, transit buses represent a strong candidate for early adoption. They also enable Maryland to lead by example and bring air quality improvements to neighborhoods in which depots are located, while helping grow the vehicle and battery manufacturing market and generate valuable learning experiences for fleet owners. This would contribute additional electrification benefits for the state, as these deployments would go beyond ACT compliance. Additionally, although transit buses are not currently eligible to generate credits under the ACT, there may be other credit opportunities available through Maryland or MDOT programs outside of the ACT framework.

5.3 Cost Trajectories

Significant cost decreases for BEVs and FCEVs are projected from 2020 to 2030 based on technological improvements and increasing market maturity, with slower but continued decreases from 2030 to 2040 and beyond.[88–90] Based on holistic lifetime cost measures such as total cost of ownership (TCO) and total cost of driving (TCD), smaller BEV and FCEV trucks and larger, short-haul trucks are expected to achieve parity with conventional vehicles between 2025 and 2035, with many reaching parity before 2030.[88,90,91] This positions these vehicles well to contribute to early adoption under the ACT. Large, longer-haul trucks (which are projected to require >500 miles of range and may require power levels reaching or exceeding 1 MW for rapid charging) are expected to achieve parity later, between 2035 and 2050. Several estimates predict parity before 2035 or within the earlier part of the 2035-2050 range.[88,91] Some projections also suggest that FCEVs rather than BEVs will be dominant in this long-haul market.

Importantly, holistic measures such as TCO and TCD are expected to reach parity between ZEVs and internal combustion engine vehicles before upfront purchase costs due to lower maintenance costs, more efficient energy usage, and lower electricity costs. On an upfront cost basis, BEV trucks are not expected to achieve parity with diesel trucks until the late 2020s through mid-2030s for most classes; long-haul tractor BEVs take longer.[88,89] FCEV trucks are expected to become upfront price competitive between 2030 and 2040, but estimates vary widely. This means that while early adopters may be able to achieve a savings over the lifetime of some ZEVs, a larger initial outlay of capital will still be needed for many years, which could be prohibitive without substantial subsidies for entities without large capital reserves such as small businesses.

It can be difficult to track and verify pricing data for commercial vehicles because such data is not readily publicized, and even when prices are known there is often a wide variability in prices for similar models. However, a recent publication by the International Council on Clean Transportation (ICCT) found that price trends from 2020-2025 show decreases in upfront costs for Class 5 and lower BEVs, but price increases for most heavier vehicles.[92]

School buses are the exception to this trend, with modest price declines seen in recent years. This preliminary data emphasizes the difficulties of achieving price declines for the heaviest vehicle classes.

5.3.1 Total Cost of Driving Projections

We highlight specific cost projections below for vehicles with particularly important implications for meeting ACT requirements in Maryland. This includes Class 2 Vans as one of the most common MHDV types in Maryland and one of the only categories with significant current BEV adoption, Class 6 Straight Trucks as the most common type of vehicle in the Class 4-8 category, Class 7 school buses which are primarily owned by local governments who are leaders in current BEV adoption, and Class 8 drayage and long-haul trucks that are important for freight moved through the Port of Baltimore and trucked through the state along the I95 corridor. All cost projections shown here are taken from the 2024 Annual Technology Baseline (ATB) published by the National Renewable Energy Laboratory (NREL).[93] NREL developed three vehicle scenarios: conservative, mid and advanced. Each scenario has different assumptions about powertrain technology advancement and future costs for assumed technologies.[94] We show levelized TCD estimates, which include capital costs for the vehicle and charger, maintenance costs over the lifetime of the vehicle, and fuel costs based on an assumed usage pattern.

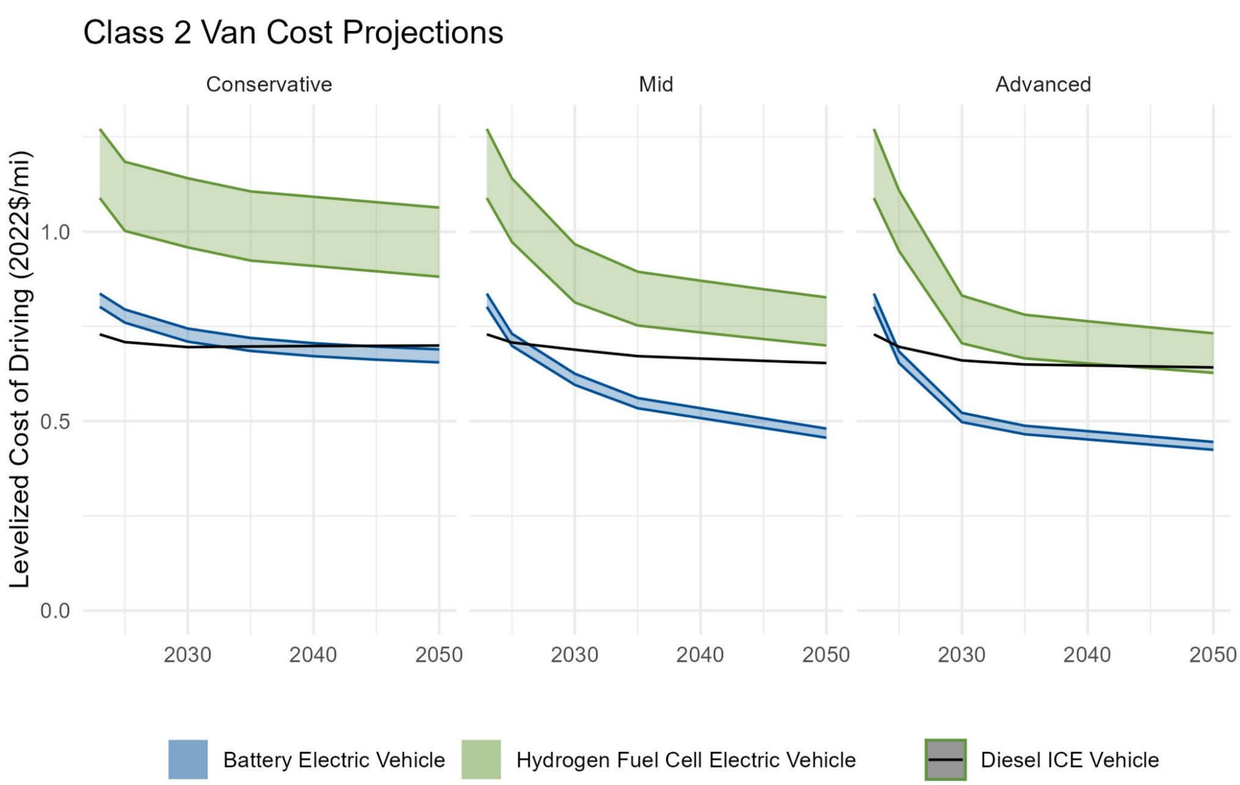


Figure 5.9. Levelized cost of driving projections from NREL's 2024 ATB for Class 2 Vans. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges

are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

The light payload and short range for Class 2 vans increases the economic feasibility of fleet electrification, with mid-range estimates from NREL suggesting these vehicles are already competitive on a TCD basis today.[93] This is reflected in significant deployment of this class of vehicles by major fleets, including Amazon.[95] More stable chassis prices compared to heavier vehicle classes help keep projected future costs low, but the main driver of cost decreases between 2025 and 2050 for Class 2 vans are significant projected reductions in the cost of fuel cells and batteries.[90]

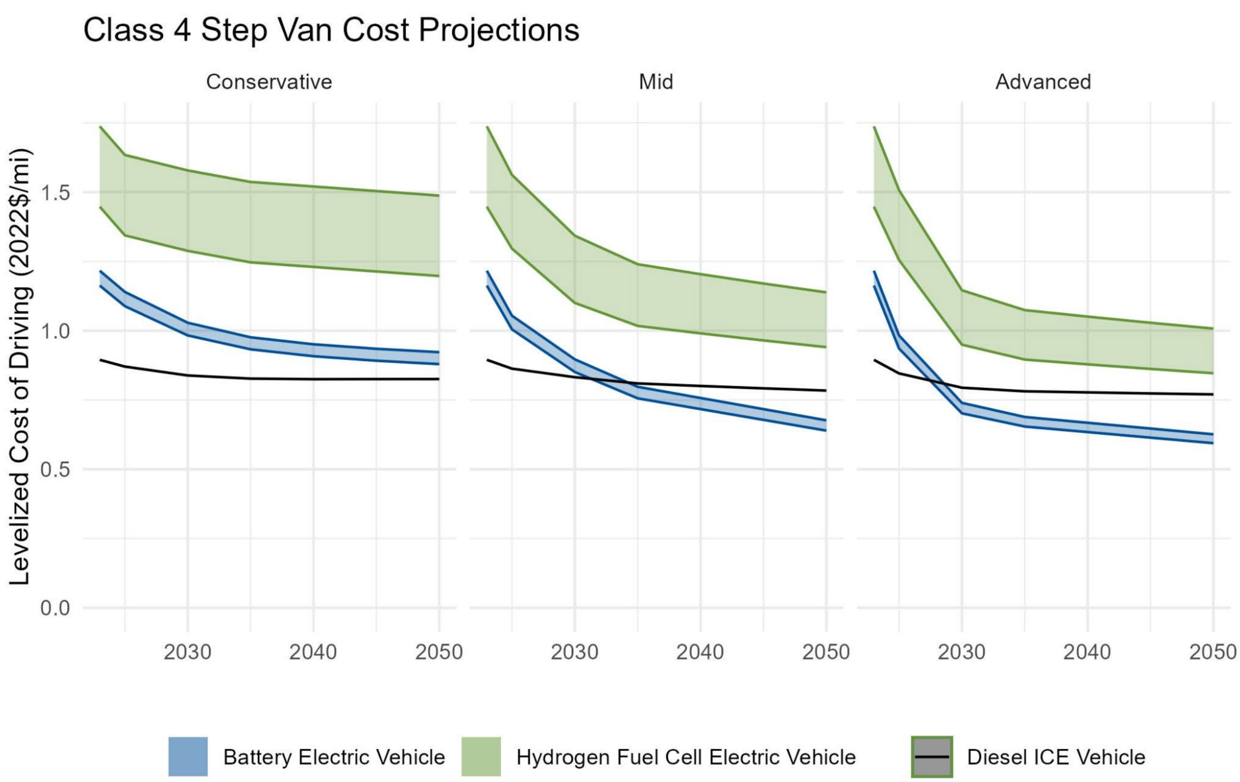


Figure 5.10. Levelized cost of driving projections from NREL's 2024 ATB for Class 4 Step Vans. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

Similar to Class 2, Class 4 Step Vans are primarily used for local and regional deliveries which may be suitable for electrification, but heavier loads and greater use at the regional scale raise additional challenges. This results in a longer timeline to cost parity, with NREL's "Mid" and "Advanced" projections suggesting BEVs could reach TCD parity with internal combustion engine vehicles in the late 2020s to early 2030s. In the most conservative case, cost parity is not reached even by 2050. As with Class 2 vans, the primary driver of reduced costs is the expected reduction in the cost of batteries and fuel cells.[90]

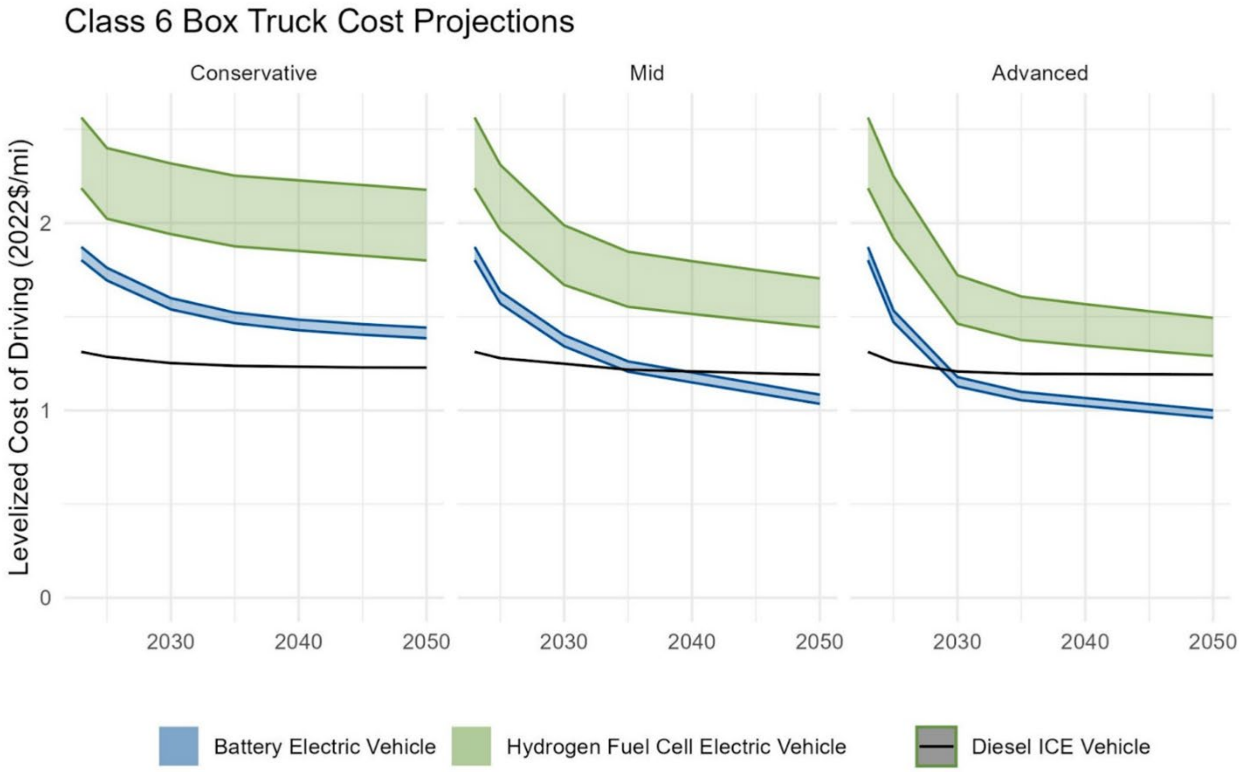


Figure 5.11. Levelized cost of driving projections from NREL's 2024 ATB for Class 6 Box Trucks. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

Upfront capital costs are the largest TCD cost component for Class 6 box trucks, followed by fuel costs, and to a lesser extent, maintenance.[91] Projected decreases in battery and fuel cell prices are the primary driver for projected retail price reductions.[89,90] Class 6 box trucks also have more stable chassis prices compared to heavier vehicle classes, which will help keep costs low into the future.[90]

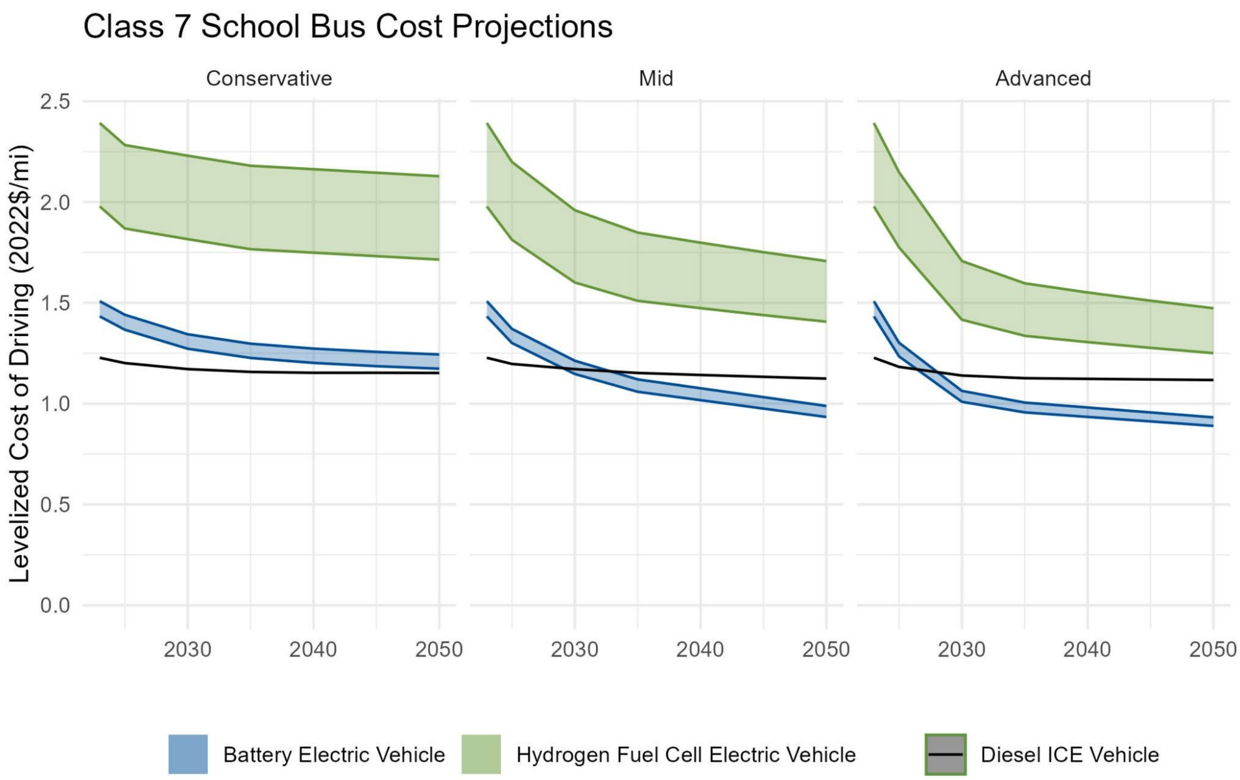


Figure 5.12. Levelized cost of driving projections from NREL's 2024 ATB for Class 7 School Buses. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

School buses have set routes, frequent access to charging, and low to moderate daily mileage, which requires proportionally smaller batteries and less fuel storage capacity compared to other vehicles in the same weight class. Projected decreases in battery and fuel cell prices are still the primary driver for projected retail price reductions, although these technologies represent a lower proportion of retail price than in vans or Class 8 trucks.[90]

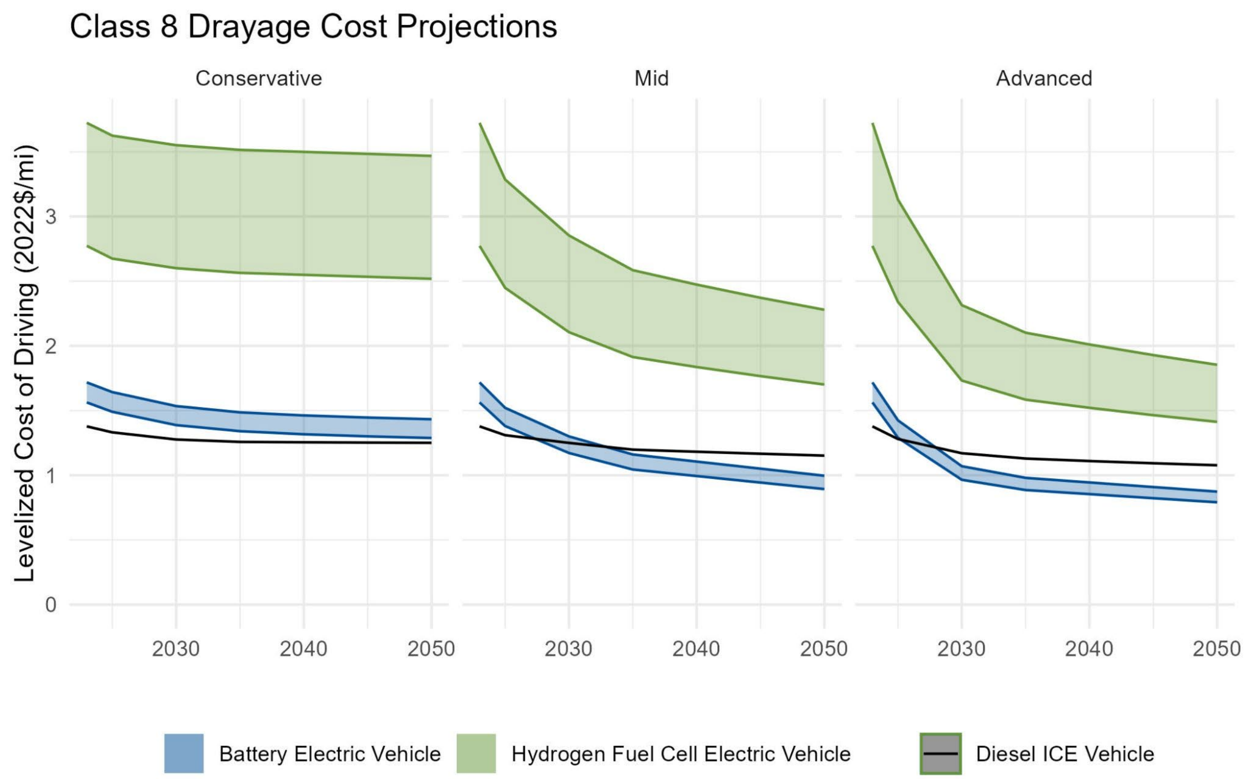


Figure 5.13. Levelized cost of driving projections from NREL's 2024 ATB for Class 8 Drayage Day cabs. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

Upfront capital costs are projected to be the largest TCD cost component for Class 7-8 vehicles with low annual mileage (<10,000 miles/year), including drayage trucks.[91] Drayage trucks require large batteries and fuel cells, which contribute to a significant portion of the cost of these trucks.[89] Thus, reductions in retail prices will largely be driven by reductions in battery and fuel cell prices.[89,90] On the other hand, fuel and maintenance costs are relatively minor components of TCD for low-mileage Class 7-8 vehicles when compared to the same vehicles used for long-haul routes.[91]

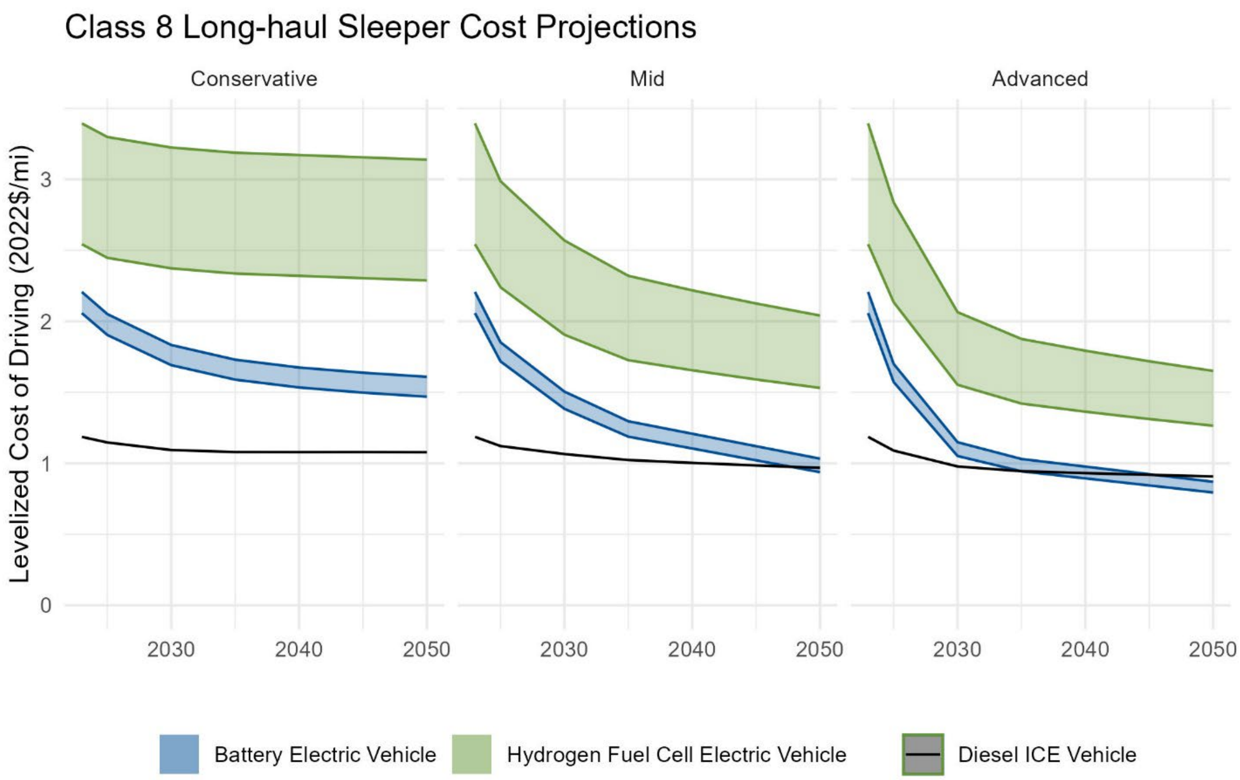


Figure 5.14. Levelized cost of driving projections from NREL's 2024 ATB for Class 8 Long-haul Sleeper Cabs. Projections are shown for conservative, mid, and advanced technology assumptions. Ranges are given for battery and hydrogen fuel cell electric vehicles. All projections assume national electric grid mix and the use of dedicated renewables to produce green hydrogen.

Class 8 long-haul sleeper tractors will be one of the most difficult categories to electrify because they have significantly higher energy and mileage demands than drayage trucks. Since vehicle mileage can significantly increase TCD, even the mid-range estimates from NREL's ATB suggest BEVs in this category may not reach cost parity until at least 2050, and the most optimistic scenarios show cost parity will not be reached within the 2035 timeline set in the ACT (Figure 5.14). Greater mileage demands denote a greater share of fuel costs as a portion of TCD.[91] This higher share of fuel costs makes the economics of larger vehicles with higher mileage more subject to fuel price volatility, which is true for both internal combustion engine vehicles and ZEVs. Electricity prices in the future may represent a more stable fuel cost compared to global oil prices which are subject to external shocks. Maintenance costs also represent an elevated share of TCD for these vehicles. Reductions in retail prices will largely be driven by reductions in battery and fuel cell prices.[89,90]

5.3.2 Impacts of Cost Uncertainties and Federal Policies on ZEV Adoption

While the cost projections shown here represent the best information currently available, it is important to note that they still contain many sources of uncertainty that could impact early adoption decisions. If electricity prices decline with greater deployment of renewable energy, this could further reduce operational costs for BEVs. Global market trends and price shocks could impact the cost of diesel for internal combustion engine vehicles. Additionally, MHDV costs could be significantly impacted by ongoing increases to tariffs, although it is not clear what the final amount and coverage of these tariffs will be, making it difficult to estimate their impact. Preliminary estimates suggest that tariffs could impact key parts of the supply chain necessary for MHDV electrification, such as a proposed 93.5% tariff on Chinese refined graphite, an essential component for batteries.[96–98]

The projections shown here do not rely on federal government incentives;[94] however, the recent shifts in federal government policy will still have critical impacts on the likelihood of achieving faster cost reductions and the ability of some actors to deploy technologies on earlier timelines. The second Trump administration's executive orders, agency actions, and legislation remove several federal funding sources, vehicle standards, and tax incentives encouraging MHDV vehicle electrification. Significant portions of funding for states to develop charging networks through the National Electric Vehicle Infrastructure Program (NEVI) and the Charging and Fueling Infrastructure Discretionary Grant Program (CFI) were also under funding freezes.[99,100] A federal judge ordered the NEVI funds be released in June 2025 and the Federal Highway Administration published new guidance for the NEVI funds in August 2025, starting the process of unfreezing the funds.[101]

Agencies are also rolling back key emissions and fuel economy regulations. The Environmental Protection Agency (EPA) is reconsidering emissions standards for MHDVs and the 2022 Heavy-Duty Nitrous Oxide (NO_x) rule, part of the Biden-era Clean Trucks Plan.[38] In May, Congress revoked California's right to set its own tailpipe emissions standards under the Clean Air Act (CAA), which is the foundation for the ACT rule.[4] This revocation is currently being challenged in the courts.[5] The Department of Transportation recently announced the National Highway Traffic Safety Administration's (NHTSA) authority to reset Corporate Average Fuel Economy (CAFE) standards, claiming that previous CAFE standards and commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency program standards unfairly favored BEVs.[102]

The reconciliation bill passed in July, 2025 also eliminated nearly all federal MHD ZEV incentives. Credits for commercial BEVs were repealed for vehicles acquired after September 30, 2025, while credits for alternative fuel installations will be eliminated in mid-2026. EPA funds for MHD ZEV transitions through the Advanced Technology Vehicle Manufacturing Loans Program and Section 132 of the CAA were also rescinded. Combined, these actions will make it more difficult to achieve rapid scaling and cost declines for MHD ZEVs.

5.3.3 A Collaborative Approach to Reducing ZEV Costs

Manufacturers, fleet operators, and other stakeholders all have a crucial role to play in lowering costs and achieving cost parity sooner. Prior analysis by McKinsey suggests steps these actors can take.[103]

Manufacturers

BEV manufacturers can create cost reduction pathways through changes to battery pack sourcing and design, manufacturing and engineering optimization, increased production scale, and lower warranty rates as technologies become more reliable. Chinese manufacturers can serve as a model for innovative strategies and a benchmark for reaching global competitiveness.

Fleet Operators

For fleet operators, changing operations to meet the specific strengths and limitations of ZEVs is more cost-effective than a "plug-and-play" model which assumes a seamless transition between internal combustion engine vehicles and ZEVs. Among the parameters in operators' control, specific considerations include the length of a haul, the timing and duration of stops (on vs. off-peak), and route optimization for charging breaks and regenerative braking, among others.

System-wide collaboration

A collaborative model can foster otherwise cost-prohibitive electrified fleet corridors and fleet ownership innovation. An example partnership includes a consortium of truck fleets, charging solution providers, and investors that each contribute components to establish a robust charging corridor. ZEV manufacturers can support fleets without the resources to fully transition through a for-hire service or a lease-like model, switching the focus from ZEV ownership to ZEV deployment.

5.4 Summary and Recommendations

Summary

In this chapter, we examined the opportunities and challenges of implementing the ACT rule for different types of vehicles and fleets, focusing on county- and privately-owned MHDV. From our analysis, we identified vehicle use cases and first movers that have better enabling conditions for electrification. To support these use cases and first movers, we also examined cost projections for vehicles with large populations or important implications for meeting ACT requirements in Maryland.

We find that Class 8 trash trucks, Class 7 school buses, Class 3-8 straight trucks for regional line-haul, and Class 2b-3 vans used for local delivery are most conducive to near-term electrification. These types of vehicles often run short, fixed and predictable routes that can help address battery range concerns and be a better fit for introducing charging periods because they have down times. Some vehicle classes and uses have already reached cost parity in terms of total cost of ownership, such as Class 2b vans, but most vehicle classes currently carry a cost premium for early adopters. First movers that could overcome this cost premium or have a strong use case include utility services, large logistic companies, local governments, school districts, and regional line-haul trucking.

Many of the stakeholders we interviewed have already begun to think about how to electrify their MHDV fleets, with some end users having already completed fleet assessments, pursued grant opportunities, or piloted BEVs in their fleets. However, there are still many challenges to increased adoption of MHD BEVs in Maryland, such as high upfront costs, insufficient charging infrastructure, and lack of vehicle specifications that meet end-user needs. To address these challenges, the state can take actionable steps to foster enabling conditions for the MHD BEV market. We list those recommendations below.

Recommendations

- Large fleet managers such as counties and corporations can be important partners for electrification, and coordinating with these entities can help speed adoption. One effective and accessible strategy is to engage organizations operating in Maryland that are already part of regional and national networks supporting BEV adoption. Coordinating with these entities can help accelerate BEV adoption by leveraging their operational scale, planning capacity, and infrastructure readiness.

- A stable funding source is critical to support build-out of infrastructure and provide funding support for vehicle acquisitions. This could take many forms, with one example being California's Low Carbon Fuel Standard. The CPRG program funding obtained by Maryland in partnership with other states also offers a critical opportunity to fund planning and implementation for MHD BEV infrastructure along the high-demand I95 corridor. More details on funding options can be found in Chapter 3.

- Sustained subsidies may be needed to support higher upfront costs for a longer period, even once total cost of ownership has reached parity. Particularly, grants may be needed with a smaller cost share for some end users with low resources. Alternatively, low-interest loans could be provided through mechanisms such as the state green bank to support entities where the TCO costs are economical but the initial capital costs are prohibitive, such as small businesses. However, any such loan program should be funded separately from other green bank programs to avoid conflicts with other loan priorities.

- Maryland should consider non-financial incentives for electrification such as a dedicated lane for ZEVs at the port to reduce waiting times.

- Coordinated efforts to aggregate demand and users can help make vehicle and charger procurement more cost-effective and logistically feasible, especially for smaller fleets. Aggregation can also improve pricing leverage and increase the likelihood of engaging local or regional vendors. To support this process, the state can play a key role in establishing a centralized “one-stop shop” that compiles resources, technical assistance, and guidance.

- There is a growing need for comprehensive training programs for both drivers and maintenance personnel to support the transition to BEVs. The state government can play a critical role in coordinating these training efforts, ensuring that public agencies and private fleets have access to the resources necessary for upskilling their workforce.

- Broader planning and grid coordination among multiple stakeholders is essential for a successful electrification transition, with the state playing a central role in leading and coordinating the process. Utilities should engage with the PSC and other stakeholders to consider MHDV needs on a 5-to-8-year horizon to align with the broader electrification landscape and ensure infrastructure readiness. Given the growing demand from transportation electrification, there is also a critical need to improve efficiency across all end-uses to manage the rate of total electricity demand growth.

- In addition, utilities and regulators should consider the implications of Vehicle-to-Grid (V2G) guidance, especially the potential for MHDV EV battery storage to enhance grid stability.

Conclusions and Recommendations

This report lays out the challenges and opportunities Maryland may encounter when implementing the Advanced Clean Trucks (ACT) rule. Federal action seeking to rescind the waiver granting regulatory authority to the states has caused significant uncertainty about the future of this policy. Therefore, this report also provides many recommendations that could be pursued even without the ACT in place. These actions therefore enable Maryland to continue making progress toward adoption of zero-emission MHDVs and its greenhouse gas reduction goals.

Maryland will face many challenges associated with reaching the zero-emission vehicle sales targets established in the ACT. Buyers report that ZEVs currently cannot satisfy many MHDV uses economically and operationally. Based on this combination of high cost and perceived reduced usability, many MHDV buyers are hesitant to change. Technological advances are expected to improve the economics and utility of ZEVs, but a significant shift in the market will likely not be seen until sufficient improvement occurs or a legal requirement is imposed. For example, under certain regulatory frameworks the requirement on OEMs to sell ZEVs is accompanied by a requirement on customers to buy ZEVs; that is not the case in Maryland. A lack of charging infrastructure is also perceived as an impediment to transitioning to electric MHDVs, however we conclude that sufficient infrastructure can be built, with the primary difficulties arising from the fact that the timeline for developing charging infrastructure is far longer than that for deploying vehicles, leading to the proverbial chicken and egg problem.

Despite these challenges, significant progress can be realized with appropriate state action to support the nascent zero-emission MHDV industry. Detailed recommendations are provided at the end of each chapter, but we summarize here a few key steps the state can take to accelerate MHDV electrification:

- A stable, dedicated funding source is needed to provide funding for vehicle purchase incentives and charging infrastructure deployment. This funding source could take the form of a Clean Fuels Standard such as those adopted in New Mexico, California, Oregon, and Washington, or other dedicated funding pathways previously proposed in the state's Climate Pollution Reduction Plan.

- Maryland should coordinate with surrounding states and the District of Columbia to mitigate buyers circumventing the ACT requirements by buying vehicles out-of-state, and to enable integrated charging networks that can support interstate travel.

- The state can lead by example through electrification of government-owned vehicles. This could include updating procurement procedures to always consider a BEV option when a vehicle is to be replaced, similar to the current state process for LDVs. It could also include updated fleet management practices to consider adjusting vehicle usage to maximize suitability for electrification and supporting county and local governments that are also seeking to electrify their fleets.

- The state and utilities (the latter with the approval of the Public Service Commission) can support ZEV growth, particularly in the early years, by providing incentives such as payments or tax credits to offset capital costs, outreach and education, and policies which serve to encourage ZEVs as discussed previously in this report.

- Maryland can act as a convener to bring together complementary industry stakeholders. Convening industry partners along the supply chain from OEMs and dealers to logistics companies and corporate shipping clients could help maximize utilization of BEVs and charging infrastructure. This effort could build on Maryland's existing partnership with New Jersey, Connecticut, and Delaware to build charging infrastructure along I-95, which is funded by an EPA Climate Pollution Reduction Grant.

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Maryland
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OCTOBER 2025

ADVANCED CLEAN TRUCKS ACT

NEEDS ASSESSMENT AND DEPLOYMENT PLAN

APPENDICES

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Appendix A: INSITE 2.0 Documentation

Introduction

Investment Needs of State Infrastructure (INSITE) is an integrated technoeconomic modeling framework developed to produce high-level planning estimates of charging infrastructure needs and associated deployment costs for newly adopted electric medium- and heavy-duty vehicles. It combines a physical model of charger energy delivery, an activity-based model of vehicle energy demand, and a simplified economic model for estimating infrastructure costs.

The key input to the model is a projected annual count of new electric vehicles, disaggregated by vehicle class and segment. The tool is configured using a combination of additional scenario inputs and model parameters including: vehicle operational patterns, vehicle efficiency projections, and environmental and technical factors. INSITE is a deterministic modeling tool that produces consistent results for a given set of inputs.

For any given electric vehicle adoption input, the INSITE model produces two key outputs:

- The number of charging ports required, categorized by power level (e.g., 7 kW, 50 kW) and installation context (i.e., depot, home, or enroute).
- The associated costs, including equipment, installation, and utility connection.

Because detailed operational data for individual vehicles are unavailable, INSITE does not directly simulate charger selection at the vehicle level. Instead, it calculates the required mix of charging infrastructure (categorized by power level) across geographically bound populations of vehicles in the same segment and class, using empirically derived distributions of operational parameters as weighting factors. As such, results at the individual level are fractional, reflecting the *expected* charging mix need of the average vehicle. However, at broader scales—such as counties, utility service territories, or vehicle segments—INSITE's aggregated results approximate the charging infrastructure mix (and costs) required to accommodate the diverse operational patterns of projected electric MHDVs in that county, utility, or vehicle segment.

A.1. Inputs

Projected Electric MHDV Adoption	Establishes the number, segment, and class of electric medium- and heavy-duty vehicles requiring charging support.	Atlas turnover model results for Maryland based on Motor Vehicle Administration population data and implementation of ACT through 2035 and then increasing to 100% zero-emission vehicle sales by 2050 for all vehicle classes and types.
Daily Miles Traveled (Trucks and Vans)	Basis for daily energy demand based on typical usage patterns.	U.S. Vehicle In Use Survey (VIUS) annual mileage; converted to daily values using assumed operating days (300 for tractors/vans, 260 for others) and mapped to INSITE segments and classes.
Daily Miles Traveled (School Buses)	Basis for daily energy demand for school bus operations.	National Summary Statistics for Depot-Based Medium- and Heavy-Duty Vehicle Operations; school bus mileage distribution adapted from 10th to 90th percentile estimates.
Vehicle Efficiencies	Provides baseline vehicle energy consumption per mile.	Autonomie Model; efficiency outputs mapped to INSITE vehicle segments and classes and used as-is.
Coldest-Day Temperature	Adjusts vehicle energy demand to account efficiency losses during cold weather.	NOAA historical climate data for Maryland counties; additional analysis performed to quantify cold-weather efficiency penalties.
Charging Location	Determines likely charging context (home, depot, or enroute), affecting how infrastructure need is modeled.	VIUS data on vehicle home base; additional analysis used to classify vehicles into charging location types and estimate location proportions.
Charging Windows	Determines vehicle availability for charging to inform how much energy charging equipment can supply.	National Summary Statistics for Depot-Based Medium- and Heavy-Duty Vehicle Operations; dwell time distribution adapted from 10th to 90th percentile estimates in literature and mapped to INSITE vehicle segments and classes.

Charger Efficiency	Accounts for energy losses between charger and battery.	A comprehensive review on charger technologies, types, and charging station models for electric vehicles; literature-based efficiency factors averaged across charger power levels.
Charger Power Delivery Profile	Simulates how power output changes during a charging session (e.g., tapering curves)	EV Profile Capture: A Next-Gen Profiles Project Report; literature-based power curves used to estimate peak-to-average profiles across charger power levels.

A.2. Model Methodology

Module 1: Depot and Home Charging Infrastructure Need

This module estimates the quantity and power levels of charging infrastructure required for the subset of the projected new electric vehicle population that is expected to regularly recharge at a depot or private residence. This is a critical output of the INSITE model and provides part of the basis for estimating infrastructure costs in Module 4.

The model assigns charger power levels to projected new EV populations in a two-step process that:

- Calculates the thresholds of daily vehicle travel supportable by each charger power level; and
- Assigns vehicles to power levels based on vehicle daily travel distances.

Calculating Power Level Thresholds

This step calculates the maximum vehicle miles traveled (VMT) that can be supported by each depot or home charger power level for a given vehicle, charging window, and geography (e.g., a climate zone).

In essence, the calculation determines the maximum energy (in kWh) that a charger can deliver and divides this by the energy efficiency of the vehicle—measured in miles per kWh—while factoring in charging losses, cold weather impacts, and a reserve margin. The result is the maximum number of miles the charger can support.

This maximum supportable VMT serves as a threshold, guiding the assignment of depot and home chargers to each vehicle in the subsequent step. The VMT threshold calculation can be expressed as the following equation:

Equation 1. Full Threshold Calculation

$$thresholdVMT_{p,s,v,gv,cw,sf,geo,y} = \frac{\frac{P_p * D_{p,gv} * T_{cw}}{SF_p}}{E_{v,gv,y} \cdot Ef_p \cdot Tf_{v,gv,geo} \cdot RM}$$

Where the indices of thresholdVMT are:

- **p** is charger power (7.2 kW, 11 kW, etc.)
- **s** is an indicator of whether the charger is shared or unshared
- **v** is Vehicle Type (van, straight truck, etc.)
- **gv** is GVWR Class (2b, 3, etc.)
- **cw** is charging window in hours (4, 5, 6, etc.)
- **geo** is the geographic basis for low temperatures
- **y** is scenario year

The threshold calculation has two sub-equations. The first calculates the maximum energy delivery capacity of the charger (in kWh) The second calculates the per-mile energy usage of the vehicle.

Charger Capacity

The charger capacity sub-equation calculates the maximum charge (in kWh) a specific charger can deliver within a given charging window. This is done by multiplying the charger's nominal power rating by the number of hours in the charging window, yielding a naïve energy delivery estimate. That result is then adjusted using an efficiency factor that adjusts the wall to battery efficiency of the charging equipment and a derating factor to simulate the effects battery charging curves have on average power delivery. Finally, the adjusted maximum energy is divided by a sharing factor to estimate the energy available when the charger is shared.

Equation 2. Charger Capacity Sub-Equation

$$\frac{P_p \cdot D_{p,gv} \cdot Ef_p \cdot T_{cw}}{SF_p}$$

Where:

- **P** is the power rating of charger type p (in kW)

- **Ef** is the charger's wall-to-battery efficiency rate
- **D** is the power curve derating factor
- **T** is the length of the charging window in hours
- **SF** is 1 if charger is unshared and 2 if shared

Vehicle Energy Needs Per Mile

The vehicle energy calculation sub-equation determines the peak energy consumption per mile during charging. It begins with the vehicle's base efficiency and adjusts for cold weather impacts on efficiency, and a reserve margin to that simulates conservative planning decisions of vehicle operators.

Equation 3. Charger Energy Needs Per Mile

$$E_{v,gv,y} \cdot Tf_{v,gv,geo} \cdot RM$$

Where:

- **E** is the baseline vehicle efficiency in kWh per mile
- **Tf** is the impact of cold winter temperatures on vehicle (and possibly charging) efficiency
- **RM** is the reserve margin

Output

The final output of the charging threshold calculation is a table or array that provides daily VMT thresholds (in miles) for each combination of indices, such as vehicle type, charging power level, charging window, and geography. This is an intermediate output that feeds directly into the depot and home charger assignment algorithm.

Depot and Home Charging Assignment

The depot and home charger assignment algorithm maps charging equipment to populations of newly purchased EVs in year y, based on their expected VMT and the VMT that each charger type (or shared charger) can support. To simplify computations, the algorithm assigns chargers from a predefined set of common power levels:

- Depot Chargers: Seven standard power levels are considered: 7 kW, 11 kW, 19 kW, 50 kW, 150 kW, 350 kW, and 1000 kW.

- Home Chargers: Three typical AC power levels are used: 7 kW, 11 kW, and 19 kW.

This simplification strikes a balance between accurately representing real-world charging equipment options and maintaining computational efficiency. It also ensures that the outputs are clear and easy to interpret.

The algorithm simulates behavior where operators select the lowest-powered charger capable of meeting their daily energy recovery needs within their charging window. This structured approach ensures that chargers are assigned efficiently based on vehicle needs, minimizing over- or under-provisioning while accounting for sharing opportunities with higher-powered chargers.

For an illustrative example, consider a set of thresholds where: a 7 kW charger supports up to 50 miles/day, an 11 kW charger up to 80 miles/day, and a 19 kW charger up to 135 miles/day. Under these constraints, the algorithm would assign:

- a 7 kW charger to a vehicle traveling 40 miles/day
- an 11 kW charger to one traveling 70 miles/day
- A 19 kW charger to one traveling 90 miles/day

Sharing Chargers

The model allows DC fast chargers (DCFC) to be shared between two vehicles if:

- a shared charger can meet a vehicle's energy recovery need
- the energy recovery need cannot be satisfied by a single, lower-powered charger

For example, a vehicle traveling 150 miles/day is assigned a shared 50 kW charger capable of supporting that vehicle up to 180 miles/day (while shared). For that vehicle, a 19 kW charger is insufficient and a dedicated 50 kW charger is excessive. Similarly, the same vehicle traveling more than 180 miles (but less than 360 miles) would use a dedicated 50 kW charger but not a shared 150 kW charger. This method allows sharing within the assignment algorithm framework—which requires each charging option to satisfy a continuous, non-overlapping range of VMT. By limiting sharing potential, it also avoids potential impractical over-optimization of shared charging. Level 2 chargers are not allowed to be shared between vehicles in this model.

Assigning Chargers to Projected Vehicle Populations

The algorithm employs precalculated VMT thresholds to create mileage intervals for each charger type, ordered from lowest to highest. It then combines those intervals with vehicle mileage distributions calculated from VIUS data to determine the percentage of vehicles within each charger type interval. These percentages are applied to the total vehicle population to estimate the number of chargers required for each type. Recalling the example given above, if 50% of vehicles travel under 50 miles/day, 30% travel 50–80 miles/day, and 20% travel 80–135 miles/day, and there are 100 vehicles in the population, then the model will project need for:

- 50 chargers at 7 kW
- 30 chargers at 11 kW
- 20 chargers at 19 kW

Output

The assignment algorithm outputs the number and type of home and depot chargers needed to support the number of EVs projected to be adopted in each year. This is both a final output of the model, and an input into Module 2's estimation of energy need and Module 4's estimation of infrastructure costs.

Equations 4a & 4b. Number of chargers needed

a. $$CW\_downscaled\_Population = Existing\ population\ (v_{gv}) * charging\_window\_share$$

b. $$No.of\ chargers = CW\_downscaled\_Population * Proportion\_per\_kW$$

Module 2: Energy Need Metrics

This module estimates the total amount of daily energy required by the projected new electric vehicle population. These metrics are both an output of the model and an input to Module 3's estimate of enroute charging need.

Energy Use Coefficients

Energy use coefficients represent the average energy requirements of vehicles grouped by a distinct set of index variables. This calculation is represented by Equation 5.

Equation 5. Energy use coefficient

$$EnergyUse_{v,gv,y,p,l} = E_{v,gv,y} \cdot avgVMT_{v,gv,p,l}$$

where:

- **v** is vehicle type
- **gv** is GVWR class

- **p** is charger power
- **y** is scenario year
- **l** is charger location

and:

- **E** is the baseline vehicle efficiency in kWh per mile
- **avgVMT** is the average daily VMT per index values (weighted by survey weights)

To calculate low-temperature peak energy use, the energy use coefficient is adjusted using a temperature factor, which accounts for the increased energy demand caused by low-temperature conditions. This adjustment reflects the temperature-driven peak daily energy requirements for a vehicle group in a specific area with the same temperature factor. This calculation is represented by equation

Equation 6. Peak Energy Use

$$PeakEnergyUse_{geo,v,gv,y,p,l} = EnergyUse_{v,gv,y,p,l} \cdot Tf_{geo}$$

Where:

- **Geo** is a specific geography

And:

- **Tf** is the impact of cold winter temperatures on vehicle efficiency

To estimate the energy consumed by chargers to recharge vehicle batteries, energy use coefficients are adjusted by the wall-to-battery efficiency of the applicable charging power level. This adjustment accounts for energy losses during the charging process, providing an accurate calculation of the total energy required for recharging the vehicles.

Equations 7a and 7b. Peak Charging Energy Use

a. $ChargingUse_{v,gv,y,p,l} = EnergyUse_{v,gv,y,p,l} \cdot Ef_p$

b. $PeakChargingUse_{geo,v,gv,y,p,l} = PeakEnergyUse_{geo,v,gv,y,p,l} \cdot Ef_p$

Where:

- **Ef** is the charger's wall-to-battery efficiency rate

Total Energy Use

Matching each of the charging coefficients calculated above to the corresponding vehicle populations by their respective indices, and then multiplying the coefficients by the population sizes, yields the total energy use for those vehicles.

Output

The average and peak total energy use and charging energy use tables are key outputs of the INSITE model. These tables provide detailed estimates of charging energy consumption across geographic and temporal domains. Energy consumption metrics also inform enroute infrastructure need modeled in Module 3.

Module 3: Enroute Charging Infrastructure Need

This module estimates the quantity and power levels of charging infrastructure required for enroute charging. Enroute charging refers to charging that occurs away from a home base, where vehicles typically charge quickly at high-powered chargers. Enroute charging is categorized into three categories that serve the following types:

- Class 2b-3
- Class 4-8 Non-Long-Haul
- Long-Haul Tractors

These categories are based on the physical characteristics of charging locations needed to serve these vehicle types and classes.

Unlike the depot and home charging module, this module does not match chargers to vehicles. Instead, it determines how many shared high-power chargers are needed to meet a given energy demand. Enroute charging infrastructure needs are determined by three factors: the total energy requirements of vehicles without home bases, a fraction of the energy requirements of vehicles that primarily charge at depots or residences, and the energy output of a single charger.

Enroute charging for long-haul vehicles is treated as a special case. These vehicles are assumed to rely entirely on enroute charging, and because they frequently cross geographic boundaries their charging demand is not limited to vehicle adoption projections within the model's geographic domain.

Aggregate Enroute Energy Recovery Need

This calculation determines the total energy that must be recovered from enroute chargers in a given day. The daily energy recovery requirement is adjusted by an energy share factor, which defines the fraction of energy vehicles recover from enroute chargers. For vehicles without a home base, this factor is always 1, as they rely entirely on enroute chargers for their energy needs. Vehicles that charge at a depot or home are assigned a share between 0 and 1 to represent the portion of charging that occurs at enroute charger. The calculation to estimate that energy need is shown in equation 8.

Equation 8. Aggregate Enroute Energy

$$AggregateEnrouteEnergy_{v,gv,l} = \sum DailyEnergyUse_{v,gv,l} \cdot Es_l$$

Where:

- **DailyEnergyUse** is the total energy used by vehicles as calculated in Module 2
- **Es** is the share of total energy vehicles recover from enroute chargers (instead of a depot or home charger)

Output

The output of this calculation provides the total energy required from enroute chargers, taking into account both vehicles without a home base and vehicles that charge at depots or residences. This output is interacted with the dispensing factor of the enroute equipment to estimate charger need.

Dispensing Factor

The dispensing factor of a piece of charging equipment is a measure of the energy it can deliver in a day, based on its power, derating factor, efficiency, and expected utilization.

Equation 9. Dispensing Factor for Public Chargers

$$DispensingFactor_{p,v,gv} = \frac{1}{P_p \cdot \frac{1}{Ef_p} \cdot D_p \cdot U_{p,v,gv} \cdot 24}$$

Where indexing is:

- **p** is the selected enroute charging infrastructure power level

- **v** is Vehicle Type (long haul vs non-long haul)
- **gv** is GVWR class (split here into Class 2b-3, and Class 4-8)

and

- **P** is the nominal capacity of charger p
- **Ef** is the efficiency factor of charger p
- **D** is the derating factor for charger p
- **U** decimal indicating the percentage of time (within 24 hours) a charging station is used

Compute Enroute Infrastructure Need

Enroute charging equipment demand is calculated by multiplying the required energy recovery by the dispensing factor. Essentially, it is the total energy needed by all enroute charging vehicles divided by the energy capacity that enroute charging equipment can provide.

Equation 10. Infrastructure Count

$$EnrouteChargerCount_{v,gv,p} = AggregateEnrouteEnergy_{v,gv} \cdot DispensingFactor_{p,v,gv}$$

Output

The output of this step provides statewide aggregate enroute charger counts, categorized by power level, vehicle type, GVWR, and year.

Enroute Downscaler

We first estimate enroute equipment needs at the statewide level. Because registration location poorly predicts where vehicles actually charge in transit, we allocate that need using travel-based spatial proxies: average daily traffic (ADT) at the road-segment level for non-long-haul activity, and long-haul truck-parking locations for long-haul activity. For each county and utility service territory, we compute its share of statewide ADT and/or truck-parking capacity, then allocate chargers to those geographies in proportion to their share of the state's total traffic or truck-parking.

Module 4: Cost calculation

The INSITE model applies a deterministic, bottom-up framework to estimate total infrastructure costs associated with electric vehicle charger deployment. Cost estimates are based on the projected number of chargers installed over time, combined with average per-port unit costs indexed by charger power and deployment location.

Each charger installation is characterized by three principal cost components:

1. Charging equipment cost, reflecting the capital expense of the hardware;
2. Installation cost, encompassing labor, materials, site preparation, and related construction activities on the customer side of the meter; and
3. Utility-side infrastructure cost, including distribution system upgrades required to support charger operation, such as transformer replacements, line extensions, and service connections.

Unit costs are defined by power level p and location type l (home, depot, or enroute). For each combination, the model applies a single representative cost value based on the best available data. Cost data sources are derived and compiled from both public and confidential sources. Final cost figures are presented in Table A.1.

Location	Charging Port Nameplate Capacity (kW)	Per port Equipment Cost	Per port Installation Cost	Per port Utility Cost	Total Per Port Cost
Depot	7	$1,197	$2,950	$1,400	$5,547
	11	$1,835	$2,950	$2,200	$6,985
	19	$2,602	$2,950	$3,800	$9,352
	50	$28,401	$10,000	$11,650	$50,051
	150	$75,000	$18,750	$34,950	$128,700
	350	$140,000	$48,000	$105,000	$293,000
	500	$200,000	$68,571	$150,000	$418,571
Enroute	350	$140,000	$57,000	$140,000	$337,000
	1,000	$350,000	$87,500	$450,000	$887,500
Home	7	$1,197	$900	$1,400	$3,497
	11	$1,835	$1,270	$2,200	$5,305
	19	$2,602	$2,010	$3,800	$8,412

Table A.1. Cost Values

Total infrastructure cost is computed as the sum of charger-specific costs across all power levels and locations, weighted by the number of chargers deployed of each type.

Formally, this is given by:

Equation 11. Total Infrastructure Cost

$$TotalChargerCost_{p,l} = \sum ChargerCount_{p,l} \times (C_{p,l}^{equipment} + C_{p,l}^{install} + C_{p,l}^{utility})$$

where:

- $ChargerCount_{p,l}$ is the projected number of chargers needed for power level p and location l.
- $C_{p,l}$ are the equipment, installation and utility-side costs for chargers of power level p and location l.

All costs are expressed in real 2025 dollars, assuming stable real prices over the analysis period. Because expenditures are incurred at the time of installation and coincide with the delivery of charging infrastructure value, no temporal adjustment is applied. The resulting cost—whether evaluated at a specific point in time or aggregated across the full deployment period—represents the economic resources required to implement modeled deployment, consistently expressed in 2025 dollars and independent of financing structure or investment timing.

Costs are also reported separately by cost component to support analysis of the expected cost burden for different actors, such as installers and utilities.

Appendix B: Chapter 4

B.1. Data Sources and Preprocessing

B.1.1. Data sources and ZPAC compatibility

- MVA CTA Study Data 04/10/25 - serves as our core dataset.
    - Details omitted included assembly plant, production sequence number, check digit validation, and full vehicle descriptor section (VDS) data, all of which impacted the information that could be extracted about the vehicle and required further processing (more on this topic can be found in Section 4.3)
    - Three types of identifiers were associated with the vehicle-owner relationship, including flngOwnerCustomerKey, flngAccountKey, and flngCustomerKey, all of which were represented by a string of numbers. Of these, only the flngAccountKey served as a unique identifier.

- Details on vehicle ownership were provided using the customer type columns, registration type and duration, and owner name. All this data was categorical and helped to segment data according to relevant customer types and provided agency names. Many of these names were not standardized, and there could be several variations of the same agency name in the owner name column.
- Vehicle information provided included vehicle type, vehicle class attributes which were extracted from registration used in business processes to determine requirements and fees, the vehicle's make, model, model year, body style, fuel type, unladen weight, weight rating, GVW and registration weight. Weight rating was given as a code starting with V and followed by a letter and additional digit, while the rating description was given as a range of digits. The data also included information on the plate type, provided in coded and decoded format.

- FY24 Rate Bulletin for Customers CONUS (3) - serves as a SIN (Standard Item Number) category for MHD vehicles.
  - Geographic information about the vehicles included a county code, county description, and zipcode. Notably, there was no specific dwell location more granular than zipcode, which again presented barriers that had to be appropriately managed to successfully deliver the ZPAC tool.
  - Each row in the dataset corresponds to a vehicle class grouping rather than a unique VIN or unit, meaning that the data operates at an aggregated vehicle type level rather than an individual vehicle level. Columns include rate classification codes, monthly lease cost, mileage rate (cents per mile), fuel type, and maintenance inclusion status. The data is fully structured and numeric, with values formatted for integration into rate calculations and projections.
  - Because these classifications are generalized, a major task in applying this dataset involved mapping individual vehicles with partial VINs from external datasets to the correct bulletin category. This required interpretation and conversion of coded rate classes, including classification logic based on body style, GVWR ranges, and fuel types, as detailed in section 4.4.
  - However, it proved especially valuable for identifying medium- and heavy-duty vehicle configurations due to its comprehensive inclusion of commercial vehicle types, something that was notably lacking in other reference datasets. Compared to the AFV Configuration dataset, which focused primarily on light-duty vehicles and alternative fuel types, the FY24 Rate Bulletin provided a broader, more detailed reference set for matching MHD vehicles to

appropriate SINs, a critical step in achieving accurate vehicle classification in ZPAC.

  - The bulletin did not include emissions, operational use case, or geographic deployment details, which were supplemented using other sources in the ZPAC methodology.

- FY24 GSA Alternative Fuel Vehicle Configurations (As Awarded) - serves as SIN catalog for vehicles where an alternative fuel model exists.

  - While some MHD vehicles are listed, the guide relies on outdated FY23 pricing for those categories, limiting its utility for MHD cost planning. However, this dataset proved especially valuable for matching vehicles from the MVA dataset, as it includes explicit make and model columns. These identifiers were often present in the MVA records alongside partial VINs, making it possible to create accurate linkages between customer-reported vehicles and SIN-classified vehicle types. This level of specificity was absent from the FY24 Rate Bulletin, which used only abstracted classification codes and lacked manufacturer or model detail, requiring additional logic to bridge the gap.

  - Importantly, the AFV Guide is not a full listing of all GSA-leased vehicle SINs—it only includes vehicles with an available AFV or ZEV alternative. As a result, SINs that do not have a clean fuel equivalent are completely excluded from this dataset. This limitation made it unsuitable as a primary reference when building a comprehensive SIN-matching workflow, particularly for fleets with a high proportion of conventional MHD vehicles or specialized internal combustion models. Instead, the AFV Guide served as a complementary reference for confirming SIN assignments where alternative fuel configurations existed and for supporting emissions-related analysis tied to specific makes and models.

- Alternative Fuels Data Center (AFDC) Station Locator - serves as a master list for all charging stations in Maryland as well as other states:

  - Each record contains detailed station-level attributes such as fuel type, access type (public/private), operational status (existing or planned), and vehicle weight accessibility (e.g., light-duty vs. medium- and heavy-duty vehicle compatibility).

  - In contrast to the MVA dataset, which included thousands of individual vehicles tied to partial VINs and customer types, the AFDC Station Locator operates at the infrastructure level and provides granular geospatial information on each fueling station. Location data can be filtered and parsed by country, state, county, city, ZIP code, or even by specific street address, with an additional option to limit the results using a radius-based search. This high level of geographic specificity offers stronger locational precision than was possible with the MVA dataset, which only included ZIP code-level data and no pinpoint dwell locations.

- Another key feature of the AFDC data is its ability to differentiate between station access types and target users. Fields include public/private accessibility, availability of 24/7 access, presence of fleet-only stations, and whether the station supports MHD vehicle fueling, which was especially useful when cross-referencing against fleet datasets like MVA. While MVA provided internal attributes such as fuel type and gross vehicle weight, AFDC's weight class access feature helped bridge vehicle-level data with infrastructure availability by revealing the operational compatibility of specific stations with various vehicle sizes and use cases.

- Additionally, the AFDC tool enables the export of data by either individual station location or aggregate port count—useful for mapping regional infrastructure density or modeling charger availability across geographies. This capacity to retrieve detailed, structured infrastructure data allowed a better understanding of public refueling support systems for zero-emission vehicles and helped to contextualize the vehicle-level findings from the MVA dataset with the realities of alternative fuel availability on the ground.

B.1.2. Charging Levels: Adjustments Made

A key item to note is the use of Level 1 and Level 2 chargers in the ZPAC tool. All calculations are based on these two types of chargers, including ratios calculated for ZEVs to electric vehicle supply equipment (EVSE) ports. However, with nearly 9 out of 10 vehicles in the state-owned fleet being MHD vehicles, we made the decision to drop Level 1 chargers due to the excessive charging time required to fully charge MHD vehicles with such equipment. Level 1 charging, using a standard 120 V outlet, typically delivers only three to five miles of range per hour (≈1.2–1.9 kW), which is insufficient for MHD EVs, whose batteries typically store between 100 and 600 kWh, and therefore generally require at least a 10 kW (Level 2) charger.

Solution scenario	Needed data	Output description	Feasibility
General DCFC port ratio calculated for all BEVs	DCFC to BEV port ratio	This would provide an estimate of DCFC ports needed to support a given BEV ratio; however, because there is no distinguishing category between BEVs in each ratio scenario, these values are not mutually exclusive and therefore do not tailor recommendations to the composition of the fleet	High
Separate DCFC ratio for MHD vehicles	Medium-Duty BEV to DCFC ratio; Heavy-Duty BEV to DCFC ratio	Calculating separate ratios for each weight class of BEVs would more accurately reflect charging port needs by fleet composition. However, since there are only two charging port scenario inputs, Level 2 chargers would have to be dropped completely or medium-duty BEVs assigned to Level 2 chargers. Additionally, a new formula would need to be built that uses total MHD vehicles per site to generate a usable value for the ratio.	Medium
Use case dependent ratio + MHD specification	Specialized ratio based on how vehicle chargers and size	How a vehicle is used determines a lot about its charging needs; for example, a school bus has a long dwell time and fixed routes while a transit bus has high-utilization and medium hauls, which may require enroute charging depending on strategy. All of these factors can alter the suggested vehicle to charging port ratio.	Low

Table B.1. Solution scenarios and output descriptions

The ZPAC tool calculates total charging needed at a site using a BEV to Level 2 port ratio and PHEV to Level 1 port ratio and subtracting from existing infrastructure at the site. For example, if there are 35 BEVs planned at a site, the BEV to Level 2 port ratio would call for 18 ports (rounding up) at the site. However, because six ports already exist, the final suggested Level 2 port count is 12. This is calculated by dividing the number of planned BEVs at the site by the BEV to Level 2 ratio - which is 17.5 in this case - and subtracting the count of existing Level 2 ports at the site (6) to get the suggested count. The formula rounds up the value to the nearest whole number. The same process works for PHEVs and Level 1 chargers except the ratio is one PHEV to one Level 1 port.

However, there is no ratio set in the formula for BEVs to DCFC, and due to the relatively low PHEV availability for MHD vehicles, this is not a useful ratio to calculate. Instead, a BEV to DCFC ratio should be calculated alongside the existing BEV to Level 2 ratio, and perhaps even include a category for heavy-duty BEVs to DCFC to differentiate the charging needs between medium-duty and heavy-duty vehicles. We continue to work on this issue to find the best solution to accurately depict charging needs at the sites that best reflect the composition of the agency's fleets.

B.2. ZEV Models by Class

Qualifying Models for CARB ZEV Incentives
Class 2b: $7,500
Step & Panel Van • Chevrolet BrightDrop 400 Battery Electric Vehicle • Chevrolet BrightDrop 600 Battery Electric Vehicle • Ford Transit T350 Chassis Cab 2WD BEV Battery Electric Vehicle • Ford Transit T350 Cutaway 2WD BEV Battery Electric Vehicle • Ford Transit T350 Van 2WD BEV Battery Electric Vehicle • Rivian Commercial Van 500 Battery Electric Vehicle • Rivian Commercial Van 700 Battery Electric Vehicle
Class 3: $15,000
Step & Panel Van • Chevrolet BrightDrop 400 Battery Electric Vehicle • Chevrolet BrightDrop 600 Battery Electric Vehicle
Class 4: $108,000; Type A
School Bus • Micro Bird G5 Electric School Bus Battery Electric Bus
Class 4: $60,000
Medium-Duty Bus • Motiv EPIC 4 Battery Electric Bus Refuse; Straight Truck • Bollinger Motors B4 Battery Electric Vehicle • Rizon e16L Battery Electric Vehicle • Rizon e16M Battery Electric Vehicle • Step & Panel Van • Blue Arc BA4L-1000 Battery Electric Vehicle • Blue Arc BA4L-600 Battery Electric Vehicle • Blue Arc BA4L-700 Battery Electric Vehicle • Blue Arc BA4L-800 Battery Electric Vehicle • Motiv EPIC 4 Battery Electric Van Step & Panel Van;Straight Truck • Harbinger HBG-04 Battery Electric Vehicle Straight Truck • Motiv EPIC 4 Battery Electric Box Truck • Motiv EPIC 4 Battery Electric Utility Truck

Class 4: $78,000

Medium-Duty Bus

- Micro Bird G5 Electric Bus Battery Electric Bus

Class 5: $60,000

Refuse; Straight Truck

- Isuzu NRR EV Battery Electric Vehicle
- Rizon e18Lx Battery Electric Vehicle
- Rizon e18Mx Battery Electric Vehicle

Step & Panel Van

- Motiv EPIC S Battery Electric Step Van (Class 5)

Step & Panel Van;Straight Truck

- Harbinger HBG-05 Battery Electric Vehicle

Class 6: $110,500; Class 7: $110,500

School Bus

- Blue Bird All American Activity Bus Battery Electric Bus
- Blue Bird Vision Activity Bus Battery Electric Bus

Class 6: $153,000; Class 7: $153,000; Type C

School Bus

- Blue Bird Vision Activity Bus Battery Electric School Bus
- Blue Bird Vision School Bus Battery Electric School Bus

Class 6: $153,000; Class 7: $153,000; Type D

School Bus

- Blue Bird All American School Bus Battery Electric School Bus

Class 6: $153,000; Type A

School Bus

- RIDE Achiever Battery Electric School Bus

Class 6: $85,000

Conversion

- UES UEVCC-CS6 Class 6 Battery Electric Vehicle
- UES UEVCC-CS6 Class 6 Hydrogen Fuel-Cell Vehicle

Step & Panel Van

- FCCC MT50e Chassis Battery Electric Vehicle
- Motiv EPIC S Battery Electric Step Van (Class 6)
- Motiv EPIC SL Battery Electric Step Van
- Workhorse W56 Battery Electric Vehicle
- Xos SV Battery Electric Vehicle

Step & Panel Van; Straight Truck

- Harbinger HBG-06 Battery Electric Vehicle

Straight Truck

- Kenworth K270E Battery Electric Truck
- Peterbilt Model 220EV Battery Electric Vehicle
- Xos MDXT Battery Electric Vehicle

Class 6: $85,000; Class 7: $85,000

Straight Truck

- Freightliner eM2 (106, 112) Battery Electric Truck
- International eMV Truck Battery Electric Truck
- Mack MD Electric Battery Electric Truck

Class 7: $110,500

Heavy-Duty Bus

- RIDE K7M Battery Electric Bus

School Bus

- Thomas Built Buses Saf-T-Liner C2 Commercial Bus Battery Electric Bus

Class 7: $153,000; Type C

School Bus

- IC School Bus (CE) Electric Battery Electric School Bus
- Thomas Built Buses Saf-T-Liner C2 School Bus Battery Electric Bus

Class 7: $85,000

Conversion

- UES UEVCC-CS7 Class 7 Battery Electric Vehicle
- UES UEVCC-CS7 Class 7 Hydrogen Fuel-Cell Vehicle

Step & Panel Van

- FCCC MT50e Chassis Battery Electric Vehicle

Straight Truck

- Kenworth K370E Battery Electric Truck
- Peterbilt Model 220EV Battery Electric Vehicle
- Volvo VNRe Battery Electric Truck

Class 8 Fuel Cell: $240,000

Tractor

- Hyundai Xcient Fuel Cell

Class 8 Fuel Cell: $312,000

Heavy-Duty Bus

- New Flyer XHE40 Fuel Cell Electric Bus
- New Flyer XHE60 Fuel Cell Electric Bus

Class 8: $120,000
Heavy-Duty Bus ● Temsa TS 45E Battery Electric Bus Refuse ● Kenworth L770E Battery Electric Truck ● Mack LR Electric Battery Electric Truck ● Peterbilt Model 520EV Battery Electric Vehicle Straight Truck ● Volvo VNRe Battery Electric Truck Straight Truck; Tractor ● Kenworth T680E Battery Electric Truck Tractor ● Freightliner eCascadia (116, 126) Battery Electric Tractor ● Peterbilt 579EV Battery Electric Vehicle ● Tern RC8 Battery Electric Vehicle ● Volvo VNRe Battery Electric Truck
Class 8: $156,000
Heavy-Duty Bus ● Gillig Low Floor Battery Electric Bus ● Motor Coach Industries D45CRT Charge Battery Electric Bus ● Motor Coach Industries D45CRTLE Charge Battery Electric Bus ● New Flyer XE35 Battery Electric Bus ● New Flyer XE40 Battery Electric Bus ● New Flyer XE60 Battery Electric Bus ● RIDE K11M Battery Electric Bus ● RIDE K7M-ER Battery Electric Bus ● RIDE K8M Battery Electric Bus ● RIDE K9MD Battery Electric Bus School Bus ● Blue Bird All American Activity Bus Battery Electric Bus ● Blue Bird Vision Activity Bus Battery Electric Bus ● Thomas Built Buses Saf-T-Liner C2 Commercial Bus Battery Electric Bus
Class 8: $216,000; Type C
School Bus ● IC School Bus (CE) Electric Battery Electric School Bus ● RIDE Creator Battery Electric School Bus ● Thomas Built Buses Saf-T-Liner C2 School Bus Battery Electric Bus
Class 8: $216,000; Type D
School Bus ● Blue Bird All American School Bus Battery Electric School Bus

• RIDE Dreamer Battery Electric School Bus

Table B.2. ZEV models that qualify for the California Air Resources Board's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, with the incentive amounts listed.

B.3. ZPAC Model Components and Usage

Table B.3. ZPAC Component Breakdown - Active Tabs

Tab name	Type	Components	Use
1. Identify locations	Input	A column for site number, an input column for site name, address information columns, Real Property ID for parking lots, and comments box.	Site names are defined in this tab and need to have as much granularity as possible for predicting EVSE needs as well as current EVSE at each site.
2. ZEV Selection	Output	There are two sections that contain output columns called BEV considerations and PHEV considerations. Columns R and W are filled in using a formula that crosschecks columns O and Q against the ZEV availability tab; this is also true of quality of BEV candidate (column V) and quality of PHEV candidate (column Y). The quality of BEV/PHEV candidate checks the manual inputs described in the "inputs" section across four different columns - BEV/PHEV availability, modeled range concerns, BEV range concerns, and GHG reduction potential for BEV/PHEVs - to produce six total options on the quality of the BEV candidate and four for the PHEV candidate.	The BEV availability and PHEV availability columns use VLOOKUP to concatenate the vehicle type and SIN, which correspond to the ZEV availability tab in the column Segment SIN Key. This reference column tells what - if any - BEVs or ZEVs exist for that particular combination of vehicle type and SIN. This output is calculated with three other inputs to generate the quality of the BEV or PHEV candidate.
	Input	Columns A-G all specify information on the agency fleet's details, including BOACs. Column G is an input column where site names defined in tab 1 are selected and is prepopulated. Columns H-Q contain vehicle information such as VIN, fuel type, model year, and vehicle age. Importantly, columns O and Q are combined into a Segment SIN key that is used to populate the BEV and PHEV availability columns. Key inputs include	Aggregates each agency by vehicle and scrapes particular information such as Existing Vehicle Type and Existing SIN to generate BEV/PHEV availability outputs. The aggregated value corresponds to the status of a BEV/PHEV replacement (identical, similar, consider other

		Modeled BEV range concerns (column S), BEV concerns (column T) and the BEV/PHEV GHG emission reduction potential (Column U and X respectively). Columns AA-AC are decision points which are required input for the ZEV adoption plan but not required for general replacement analysis. Columns AD-AF are further detailed input columns that help explain unsuitable BEV replacement decisions with a dropdown list of reasons. Of all the columns, only Column S is needed to generate outputs.	option, reassess). Inputs under the range concerns section and decision points alter the final adoption decision, timeline of adoption, and reasoning for forgoing adoption to provide extra context.
3. EVSE Needs and Prioritization	Inputs	Columns D and J cover existing Level 2 and DCFC charging points at each site that is auto-populated in column C. These are required inputs to generate the suggested additional charging infrastructure columns. Columns E and K cover planned Level 2/DCFC ports (if known) at the site, but are not required to generate additional charging port recommendations.	These fields are required to generate projected EVSE needs that take into account what already exists at the site and that which is planned to exist at the site in terms of charging ports.
	Outputs	Existing numbers of BEVs and PHEVs (columns F and L) are pulled from Tab 2 to account for any existing EVs before replacement. Columns H and N are particularly important because they aggregate the number of each vehicle type at each site according to the ZEV availability tab. Suggested additional Level 2 and DCFC charging is calculated based on the suggested BEV/PHEV to Level 2/DCFC port ratio subtracted by the number of existing ports for that charging type.	The outputs section helps fleet managers and site owners plan for the number of chargers - by type - they will need to install at their location to support the EV uptake potential identified in Tab 2. It also aggregates the number of light-duty and MHD vehicles per site.
4. EVSE Site Summary	Outputs	This tab consists of only outputs that summarize the findings related to charging at each site. Column A, site name, auto-populates from Tab 1. The table then combines summary information from Tab 2 on the current number of Level 2/DCFC charging ports at the location, the suggested number	The table in this tab aggregates key information on site planning by summarizing key information on charging and planned ZEV uptake. The data is especially helpful to transform into a bar chart to visualize

		based on potential ZEV uptake, and any planned totals input in Tab 3.	charging needs across all agencies.
5. Annual Plan Summary	Outputs	The annual plan summary takes information from Tab 2 in columns AA-AC that specify decision points that must be input by the user, such as estimated year of replacement and planned year of acquisition. Importantly, this tab relies on accurate vehicle acquisition timelines to produce actionable EVSE insights in Tables 2, 4, and 5. First, Table 1 displays planned acquisition by year according to vehicle type while also leaving a column (column O) for unplanned acquisitions that do not have a specified decision point in Tab 2. Its variation, Table 1a, summarizes these acquisitions by vehicle weight class. Table 2 takes a similar time-based approach to aggregating EVSE acquisition by reflecting total planned ports, distributed across years based on when ZEVs are planned to be acquired. The ZPAC scenario assumes port installation is completed a year prior to vehicle acquisition. Table 3 summarizes the planned fleet inventory, which takes a step backwards and looks at the composition of the entire fleet according to the adoption scenario outlined in Table 1, which highlights how the ratio of ZEV to non-ZEV vehicles changes over time. Table 4 divides the number of EVSE ports per year by the number of planned ZEVs to produce a ratio of vehicles to chargers. Table 5 displays a running total of ports by year, taking the value of added ports in Table 4 and the running total of ZEVs in Table 3 to demonstrate a cumulative timeline view of EVSE and ZEV additions by year, highlighting when acquisitions are made and when.	Tab 5 is an interactive tab that allows viewers to select an agency and view a horizon timeline that breaks down ZEV acquisitions and needed EVSE to support increased uptake. Data insights include the number of ZEVs planned to be acquired by year and includes a percentage that displays the composition of each year's acquisitions. For example, if three BEVs are acquired in 2032 and three non-ZEVs, the total vehicle acquisition is six vehicles and the ZEV share for that year is 50%. Table 2 similarly breaks down EVSE acquisition by charging level across a similar timeline. Insights from Table 3 answer how a fleet's composition changes over time and models the percent of fleet electrified by year. Table 4 answers the question of how well EVSE will meet ZEV uptake needs, helping to identify years where ZEV adoption and EVSE uptake may be unbalanced. Finally, Table 5 combines ZEV uptake and EVSE deployment to demonstrate an overview of total ZEVs and ports ZEVs and ports added on a cumulative, year-over-year view.

Class	BEV Availability	Eligibility/Year								
		2027	2028	2029	2030	2031	2032	2033	2034	2035
Class 2b-3	1 - Identical BEV	56	38	19	8	11	7	49	1	2
	2 - Similar BEV	765	64	125	76	17	48	96	169	39
Class 4-8	1 - Identical BEV	8	0	0	1	0	0	0	0	0
	2 - Similar BEV	220	23	29	21	17	16	7	32	0
Class 7-8 Tractor	1 - Identical BEV	24	4	3	3	3	1	2	2	0
	2 - Similar BEV	0	0	0	0	0	0	0	0	0
Total	1 - Identical BEV	88	42	22	12	14	8	51	3	2
	2 - Similar BEV	985	87	154	97	34	64	103	201	39

Table B.4. Number of 10+ year old BEV-replaceable vehicles by year, including both identical and similar BEVs