MAINE

CLEAN TRANSPORTATION ROADMAP FOR MEDIUM- AND HEAVY-DUTY VEHICLES

GOVERNOR'S OFFICE OF
Policy Innovation
and the Future

MAINE GOVERNOR'S
Energy Office

November 2024

MaineDOT

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Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles

prepared for

MaineDOT

GOVERNOR'S OFFICE OF Policy Innovation and the Future

MAINE GOVERNOR'S Energy Office

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TABLE OF CONTENTS

Appendices

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles (MHDV) ("roadmap") charts a path for Maine to decarbonize the trucks and buses moving people and goods within and through the state. Trucks and buses account for 27 percent of the greenhouse gas (GHG) emissions from the state's transportation system, and 10 percent of the state's total emissions.[1] These shares are projected to increase in the future as light-duty vehicles become more efficient and electrify. Decarbonizing Maine's trucks and buses will be critical to achieving the state's ambitious emissions reductions goals laid out in law—a 45 percent reduction by 2030 and 80 percent by 2050.

This roadmap supports Maine's climate action plan, *Maine Won't Wait*, adopted in 2020 and updated in 2024, which calls for accelerating Maine's transition to electric vehicles (EV).[2] The roadmap also complements the 2021 *Maine Clean Transportation Roadmap* that examines future pathways and infrastructure needs to decarbonize the state's light-duty transportation sector.[3] This *Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles* takes a deeper look at the challenges and opportunities to decarbonize Maine's medium- and heavy-duty vehicles, and establishes policy recommendations and an action plan for decarbonization.

> Decarbonizing Maine's trucks and buses will be critical to achieving the state's ambitious emissions reductions goals laid out in law—a 45% reduction by 2030 and 80% by 2050.

Maine's Medium- and Heavy-Duty Vehicles

MHDVs include trucks used to move goods and provide commercial and public services, and transit, school, intercity, and charter buses (Figure ES.1). These vehicles are currently almost exclusively powered by gasoline or diesel internal combustion engines. Decarbonization will require converting Maine's trucks and buses to zero-emission vehicle

1 Maine Department of Environmental Protection (2024). 10th Report on Progress on Greenhouse Gas Reduction Goals.

2 Maine Climate Council (2020). Maine Won't Wait.

3 Governor's Energy Office, Governor's Office of Policy Innovation and the Future, and Cadmus (2021). Maine Clean Transportation Roadmap.

(ZEV) technologies such as battery electric drivetrains or hydrogen fuel cells.[4] While clean fuels such as biodiesel may also play a role in reducing emissions, this roadmap focuses mainly on ZEV technologies, especially electrification.

FIGURE ES.1 COMMON TYPES OF MHDVS

Weight Class	Typical Vehicles			
3–5 (10,001–19,500 lb.)	City Delivery	Walk In	Mini Bus	Conventional Van
6 (19,501–26,000 lb.)	Beverage	Rack	School Bus	Single Axle Van
7 (26,001–33,000 lb.)	City Transit Bus	Furniture	Refuse	
8 (over 33,000 lb.)	Heavy Semi Tractor	Cement Mixer	Dump	

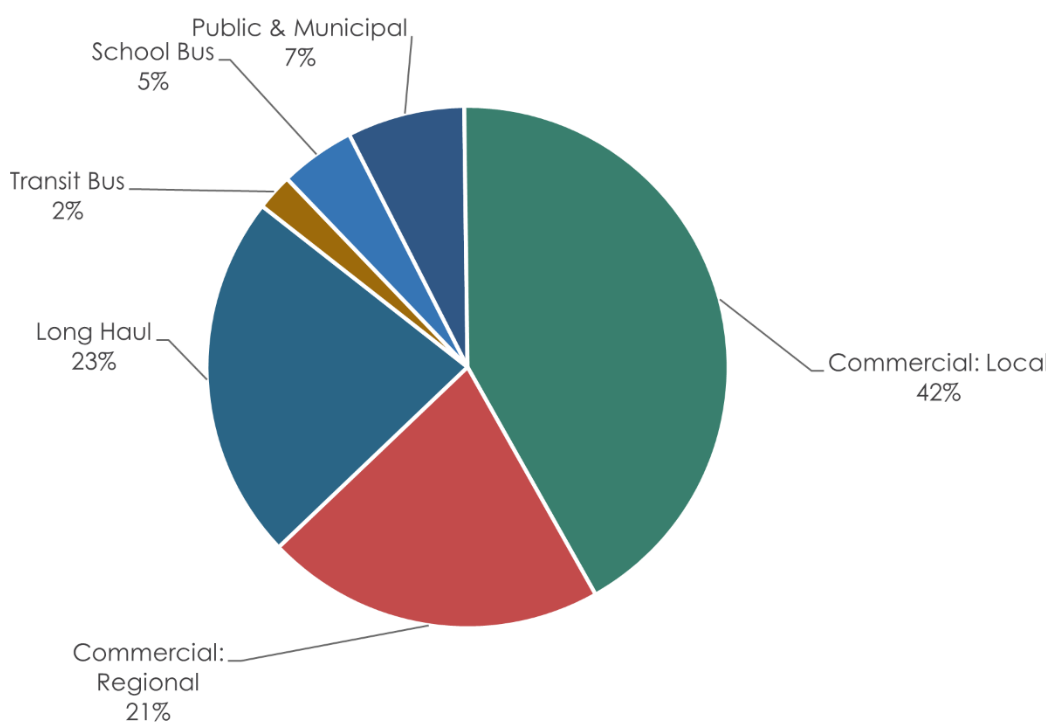
Source: Adapted from Alternative Fuels Data Center, https://afdc.energy.gov/data/10381. Weight class refers to the gross vehicle weight rating (maximum vehicle + load weight).

This roadmap characterizes Maine's trucks and buses based on available data on their weight class, industry, and vocational characteristics—key factors that affect the potential to convert to zero-emissions technology. For example, smaller vehicles driven relatively short distances and returning to a consistent home base (such as delivery trucks) have strong potential to electrify in the near future. Heavy trucks providing long-distance, interstate services will take longer to electrify or may require the use of hydrogen fuel cell technology, due to the large energy capacity required to move heavy vehicles over long distances.

4 This roadmap uses ZEV to refer to both battery and hydrogen fuel cell vehicles, while it uses EV to refer to distinguish just battery EVs.

About 41,000 commercial medium-duty trucks (MDT) and 23,000 heavy-duty trucks (HDT) were registered in Maine as of 2023, along with 4,100 buses.[5] Based on registration data, MDTs in Maine drive an average of 53 miles per day, and HDTs drive an average of 96 miles per day. While these are distances that should easily fall within the range of most future medium- and heavy-duty ZEVs, including electric trucks, daily averages can obscure substantial differences across fleets and vehicles. Figure ES.2 illustrates how different truck and bus market segments contribute to Maine's MHDV GHG emissions of 1.33 million metric tons in 2020. About one-third of these emissions are from medium-duty vehicles with the remaining two-thirds from heavy-duty vehicles.

FIGURE ES.2 CONTRIBUTION OF MARKET SEGMENTS TO MAINE'S MHDV GHG EMISSIONS



Source: Analysis by ERG and Cambridge Systematics.

[5] MDTs are defined for this study as having a gross vehicle weight rating (GVWR, or vehicle weight plus load rating) of 10,001–26,000 lb., including Federal vehicle weight classes 3 through 6. HDTs are defined as having a GWVR of over 26,000 lb., including Federal vehicle weight classes 7 and 8. Vehicles with a weight rating less than 10,000 lb. are characterized as light-duty vehicles (passenger cars, pickups, vans, and sport utility vehicles) or light-medium trucks and are not considered in this roadmap.

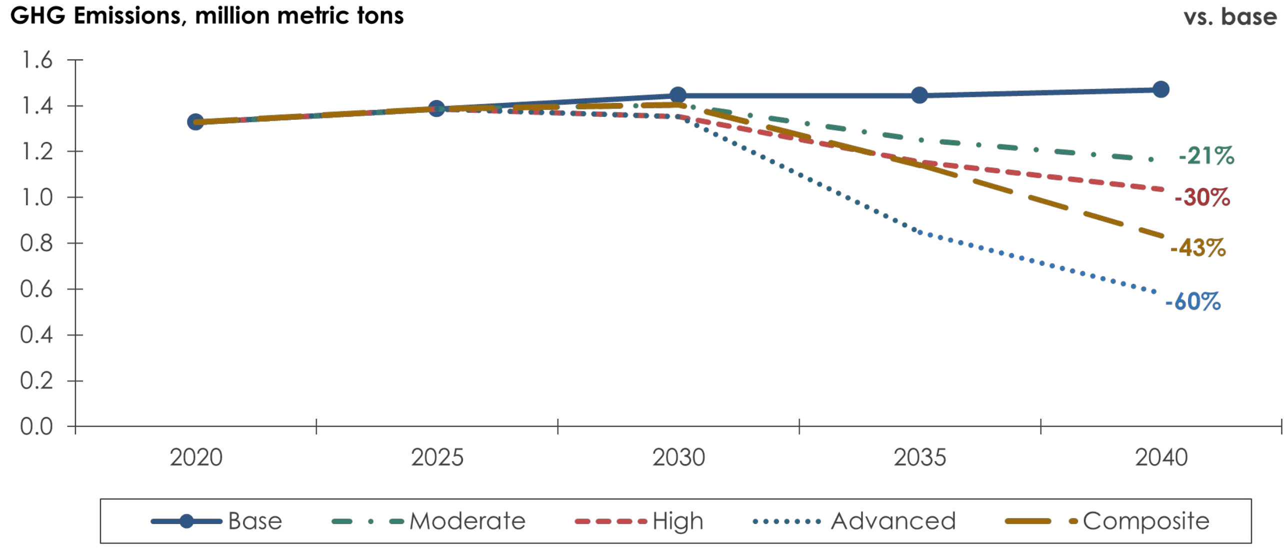
Current and Future Zero-Emission Vehicle Options

While light-duty EVs are becoming common in many parts of the country, MHD ZEV technology is just starting to come to market in many states. Nevertheless, manufacturers are already producing ZEVs across all weight classes. Over 30,000 zero-emission trucks (ZET) were already deployed nationwide by the end of 2023, with over 250 models currently offered by over 40 manufacturers. In Maine and elsewhere throughout the country, electric transit and school buses are already in use in diverse bus fleets. The range of MHD ZEVs on a single charge continues to improve, with the median range of 2023 models being 170 miles and a number of models offering ranges of 200 to 300 miles under favorable conditions. Factors such as cold or hot weather, auxiliary power uses such as refrigeration and power take-offs, and hilly terrain may reduce these ranges. As battery technology continues to improve, ZET and buses should be able to take on longer-range and higher-load capabilities. Manufacturers are also beginning to offer hydrogen fuel cell trucks with ranges of 250 to 500 miles and a 20-minute refueling time, although further coordination and investment by the public and private sector will be needed to bring the infrastructure to fuel these trucks to the northeast.

Benefits of Zero-Emission Vehicles

Three alternative MHD ZEV adoption scenarios were modeled in this roadmap, and compared to a "base" case in which most MHDVs (over 90 percent) remain fueled by gasoline or diesel. These "moderate," "high," and "advanced" scenarios represent increasing levels of policy implementation and market action to achieve higher rates of ZEV market penetration through 2040. The 2040 ZEV share, representing the percentage of all MHDVs registered in Maine which are zero-emissions, increases from 18 percent under the "moderate" scenario to as much as 47 percent under the "advanced" scenario. A "composite" scenario was also developed to represent the potentially feasible market penetration levels in Maine specific to different market segments. These scenarios would reduce MHD GHG emissions by 300,000 to 900,000 metric tons per year, or about 20 to 60 percent, compared to projected emissions with no further action by the state (Figure ES.3).

FIGURE ES.3 MHDV GHG EMISSIONS BY SCENARIO



Source: Analysis by ERG and Cambridge Systematics.

Costs and Savings for Zero-Emission Vehicles

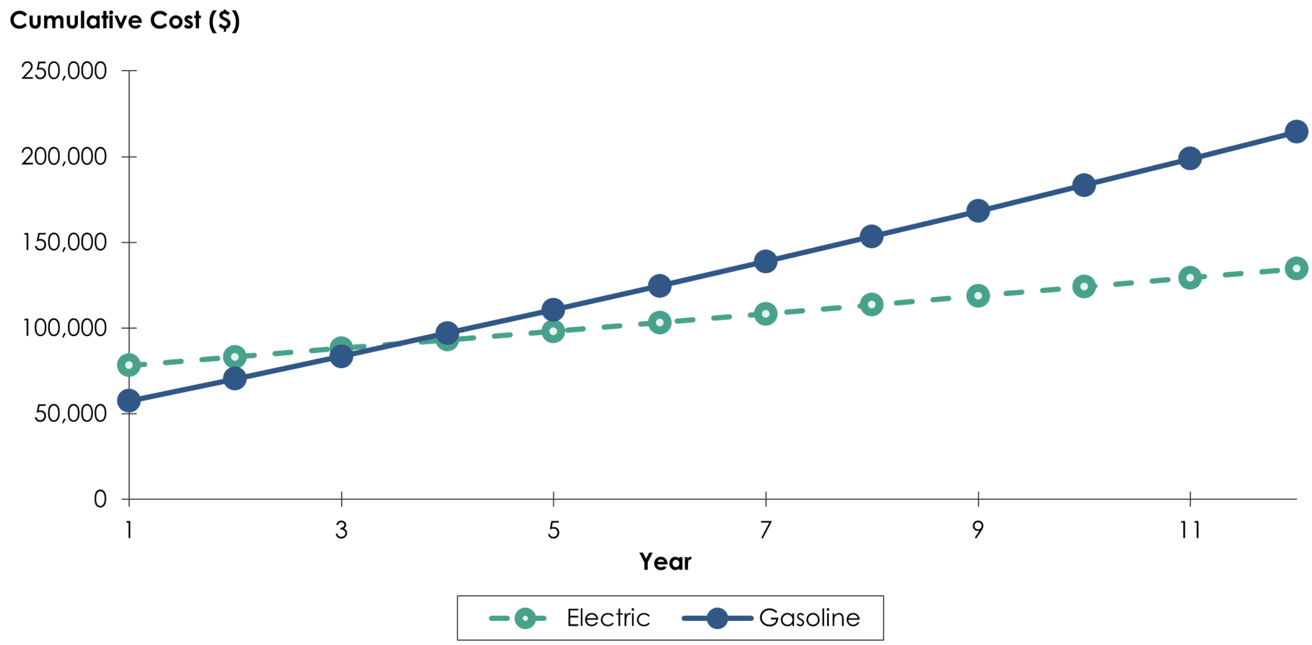
Up-front costs of MHD ZEVs remain higher than gasoline or diesel alternatives, often requiring incentives to "bridge the gap" and contribute to lower overall costs across the lifetime of the vehicle. Investments in charging or refueling infrastructure are also needed to support ZEVs, including charging stations as well as, in many cases, electrical infrastructure upgrades to support higher power demand at the site of charging. Over time, however, MHD ZEVs deliver fuel and maintenance cost savings, which increase with higher vehicle utilization. Federal and state incentives, such as the Federal Clean Commercial Vehicle Tax Credit and Efficiency Maine Trust's (EMT) state vehicle and charging incentives, are currently available to help offset costs; other financial arrangements such as leasing or "trucking as a service" can annualize capital costs, minimizing the need for cash-on-hand at the time of vehicle purchase.

Declining battery costs are expected to dramatically reduce or eliminate the up-front price differential, with some market segments achieving purchase price cost parity between electric and conventional vehicles as soon as 2030.[6] As illustrated in Figure ES.4, smaller and

[6] Bloomberg New Energy Finance with the Smart Freight Centre (2024). Zero-Emission Commercial Vehicles The Time Is Now: A Factbook for Investors.

shorter-range vehicles, such as Class 3 trucks and vans, can already provide rapid payback, with savings exceeding costs within two to three years of purchase in some cases.

FIGURE ES.4 ILLUSTRATIVE CUMULATIVE COST OVER TIME FOR GASOLINE VERSUS BATTERY TRANSIT VAN



Source: CALSTART, based on Maine case study of a Class 3 gasoline transit van driven 25,000 miles a year. Includes costs of charging infrastructure, but does not include any available incentives, which could further reduce the cost of the EV.

While the majority of MHD ZEV charging is expected to be done at private depot and distribution locations, public charging infrastructure will also be necessary to serve some percentage of MHD ZEV charging and refueling. Statewide, across both public and private depot charging, the additional charging demand in 2040 from MHD ZEVs could range from 0.6 to 1.3 million megawatt-hours (mWh), or 5 to 11 percent of 2022 statewide electricity demand, depending upon the ZEV scenario. About 15 to 20 percent of this demand is expected to be met at publicly accessible fast charging sites, requiring an estimated $4 to $16 million per year through 2040 for charging infrastructure and grid upgrades at these sites, depending upon the ZEV scenario and considering a range of potential costs. Additional revenue generated by host sites from vehicle charging—estimated to average between $7 and $17 million annually through 2040—can partially offset these capital costs as well as covering the cost of electricity provided by the charging station and ongoing maintenance costs.

"Smart charging" at depots that minimizes charging during periods of peak demand will help to minimize the need for investments in new generation and grid capacity to meet this increased electricity demand. Challenges related to grid capacity and charging infrastructure are currently being addressed through planning efforts by the Governor's Energy Office (GEO), Maine Department of Transportation (DOT), Maine Public Utilities Commission (PUC), EMT, and the state's two investor-owned utilities, and will require continued attention in the future.

Opportunities and Challenges for Zero-Emission Vehicle Adoption

To better understand the opportunities and challenges for transitioning Maine's trucks and buses to ZEVs, outreach was conducted to stakeholders including fleet owners and operators, vehicle manufacturers, truck and bus dealers, and providers of charging and fueling infrastructure. Some of the key opportunities include:

- **Sustainability goals—**Some companies and municipalities have adopted their own net-zero or low-emissions goals and transitioning to ZEVs will help them achieve emission reductions.
- **Potential long-term cost savings—**Many fleet operators describe themselves as "fuel-agnostic" and are open to ZEV adoption if it makes financial sense.
- **Funding—**Several Federal and state funding sources already exist to support purchases of ZEVs and charging infrastructure.
- **Low-hanging fruit—**Vehicles with relatively short and well-defined routes, which return "home" to a depot at regular intervals, and which have commercially available ZEV alternatives are the best market-segment candidates for early electrification. Examples include buses, short-range delivery and service trucks operating in more densely populated areas, and yard and drayage trucks. While these vehicle types and use cycles may be most suitable for early electrification, individual fleet operational characteristics, and the availability of models meeting performance requirements at a reasonable price point, will determine where electrification is both operationally and financially viable.

The primary barriers that stakeholders perceive to ZEV adoption include:

- Concerns about **limited range** and impacts of cold weather.

- Lack of **maintenance providers** and long lead times for procurement and repair.
- High **upfront costs**, operating cost uncertainty, and uncertain resale potential.
- Lack of **charging infrastructure**, inconsistent electricity pricing, and concerns about grid reliability.

Existing state and Federal programs such as the EMT commercial vehicle incentive, Federal Clean Commercial Vehicle tax credit, federally funded and state-administered EV infrastructure programs, and the state's workforce development initiatives already begin to leverage these opportunities and address barriers. However, additional actions are needed to demonstrate and prove emerging technology, overcome financial barriers, develop a robust public and private network of charging infrastructure, develop a local workforce to service vehicles, and educate vehicle owners about the best approaches for their unique needs.

Policy Recommendations

Accelerating the transition from gasoline- and diesel-powered trucks and buses to zero-emission alternatives requires a suite of supportive policies. While both carrots (incentives) and sticks (regulations/fees) have proven effective in other markets, a coordinated array of policy actions can facilitate a faster, more cost-effective transition to MHD ZEVs in Maine.

Table ES.1 identifies and describes seven types of policies, identifies current or completed Maine policies in that category, and provides recommended additional policies for Maine to consider for adoption and implementation. Maine can build on successful implementation of these recommendations by other states, while tailoring them to the state's unique needs.

TABLE ES.1 CURRENT AND RECOMMENDED MAINE POLICIES AND PROGRAMS TO SUPPORT MHD ZEVS

Policy Type	Justification	Current	Recommended
Target Setting	» Target setting establishes clear vision and sends signal to industry that Maine is open for ZEV business.	» Multi-state NESCAUM-led MHD ZEV memorandum of understanding.[1] » Statutory clean school bus sales target.[2]	» Establish "lead by example" MHD ZEV targets for the state-owned fleet. » Complete a MHD state fleet transition plan.
Planning	» Provides a baseline of knowledge to support cost-effective policies and investments.	» Clean transportation roadmaps, National Electric Vehicle Infrastructure (NEVI) Plan[3], Public Utilities Commission (PUC)-led integrated grid planning.	» Continue stakeholder engagement after this roadmap is published. » Update and expand NEVI Plan guidance for MHD infrastructure. » Monitor and participate in planning for regional hydrogen infrastructure development.

Policy Type	Justification	Current	Recommended
Vehicle Incentives	» Helps to mitigate up-front cost differential for ZEV versus conventional vehicle.	» EMT work van incentives and MHDV pilot. » Federal tax credits.	» Develop a MHD ZEV voucher incentive program. » Assess opportunities for state tax credits.
Infrastructure Support	» Infrastructure costs pose an up-front cost barrier for fleets. » Coordinated planning between utilities, industry, and Government is critical.	» Central Maine Power "make-ready" pilot. » Electric utility EV alternative charging rates.	» Convene MHD ZEV infrastructure stakeholder forum. » Develop MHD ZEV charging and fueling voucher incentive program. » Explore development of utility-run MHD infrastructure incentives. » Build on PUC proceedings requiring EV charging rates.
Fleet Advisory Support	» Fleet electrification can be challenging; support programs make transition more widely accessible.	» Central Maine Power electric school bus support.	» Launch no-cost MHD ZEV fleet advisory program.
Regulations	» Complement incentives to drive faster adoption of MHD ZEVs; may be necessary to meet emissions targets.	» None.	» Track MHD ZEV deployment in states Maine and other states with clean truck regulations and their impact on MHDVs traveling to Maine.
Economic Development	» Train a new generation of workers and transition existing workers to service ZEVs and infrastructure.	» Workforce initiatives through community colleges, Maine Won't Wait, Clean Energy Partnership, Federal grants.	» Explore offering manufacturing tax credit for green investments. » Expand EV job training programs. » Expand Clean Energy Partnership clearinghouse to increase focus on the ZEV industry.
Innovative Policies	» Expand beyond what might be achieved through other actions.	» Regional Greenhouse Gas Initiative (RGGI). » Weight exemption for auxiliary power units (400 lb.).	» Evaluate potential allocation of RGGI funds to support strategic investment in MHD ZEV programs. » Plan for heavier MHD ZEVs on the road.

1 Northeast States for Coordinated Air Use Management (NESCAUM) Multi-State Medium- and Heavy-Duty Zero-Emission Vehicle Memorandum of Understanding.

2 Maine Revised Statutes Title 20-A S5401.

3 Maine DOT (2023). Maine's Updated Plan for Electric Vehicle (EV) Infrastructure Deployment (Maine's NEVI Plan).

Table ES.2 proposes responsibilities and timeframes for implementing each recommended policy.

TABLE ES.2 ACTION PLAN

Policy Recommendation	Responsibility	Timeframe
1. Lead by example MHD ZEV targets for public fleet	Lead By Example Initiative	July 1, 2025
2. MHD state fleet transition plan	Governor's Office of Policy Innovation and the Future (GOPIF); Department of Administrative and Financial Services; and Maine DOT	December 31, 2026
3. Continue MHDV stakeholder engagement	GOPIF and Maine DOT	Ongoing
4. Update and expand NEVI Plan guidance for MHD infrastructure	Maine DOT	2025 NEVI planning cycle and ongoing
5. Develop MHD ZEV voucher incentive program	EMT	July 1, 2025; launch as soon as funding is available
6. Assess state tax credit options	GOPIF and Bureau of Tax and Finance	December 31, 2025
7. Develop MHD ZEV charging and fueling voucher incentive program	EMT, Maine DOT	July 1, 2025; launch as soon as funding is available
8. Explore development of utility-run MHD infrastructure incentives	PUC, GEO	2025
9. Build on regulatory proceedings requiring EV charging rates	PUC, GEO	Ongoing, in rate cases
10. Launch no-cost fleet advisory program	Various	By 2026
11. Track MHD ZEV deployment in Maine and other states with clean truck regulations	GOPIF, Maine Department of Environmental Protection (DEP)	Ongoing
12. Explore offering manufacturing tax credit	GOPIF, Maine Department of Economic and Community Development	2025
13. Expand EV job training programs	GEO, through the Maine Clean Energy Partnership	Ongoing to meet demand
14. Expand Clean Energy Partnership clearinghouse to increase focus on the ZEV industry	GEO	July 1, 2026
15. Evaluate use of RGGI funds to support ZEVs	GOPIF, Maine DEP, GEO, EMT	December 31, 2025
16. Plan for heavier MHD ZEVs on the road	Maine DOT	December 31, 2026

Implementation of many of the above recommendations will require varying degrees of funding. Existing programs offered through the U.S. Department of Transportation, U.S. Environmental Protection Agency, and U.S. Department of Energy could support many of these recommended initiatives. Maine program budgets may be able to support activities that require modest costs, such as planning and regulatory proceedings.

1

INTRODUCTION

1.1 Objectives

This *Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles* (MHDV) ("roadmap") charts a path for Maine to decarbonize the trucks and buses moving people and goods within and through the state. Currently, trucks and buses account for 27 percent of the greenhouse gas (GHG) emissions from the state's transportation system, and 10 percent of the state's total emissions.[7] These shares are projected to increase in the future as light-duty vehicles become more efficient and electrify. Decarbonizing Maine's trucks and buses will be critical to achieving the state's ambitious emissions reductions goals laid out in law—a 45 percent reduction by 2030 and 80 percent by 2050.

This Clean Transportation Roadmap takes a deeper look at the challenges and opportunities to decarbonize Maine's medium and heavy duty vehicles in particular, and establishes policy recommendations and an action plan for decarbonization.

The roadmap supports Maine's climate action plan, *Maine Won't Wait*, adopted in 2020 and updated in 2024, which calls for accelerating Maine's transition to electric vehicles (EV).[8] The roadmap also complements the 2021 *Maine Clean Transportation Roadmap* that examines future pathways and infrastructure needs to decarbonize the state's light-duty transportation

[7] Maine Department of Environmental Protection (2024). Tenth Biennial Report on Progress Toward Greenhouse Gas Reduction Goals.

[8] Maine Climate Council. *Maine Won't Wait*.

sector.[9] This *Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles* takes a deeper look at the challenges and opportunities to decarbonize Maine's medium- and heavy-duty vehicles, and establishes policy recommendations and an action plan for decarbonization.

1.2 Audience

This roadmap is intended for a broad audience to understand the opportunities and challenges to decarbonizing Maine's trucks and buses. In particular:

» Those involved in **policy and program development** (elected officials, state agency staff, and other interests) should use the roadmap to consider implementing policies and programs that support Maine's medium- and heavy-duty (MHD) zero-emission vehicle (ZEV) transition.

» **Fleet owners, dealers, manufacturers, and other private-sector interests** can use the roadmap to better understand the potential benefits and costs of transitioning to ZEVs, to identify potential funding and other resources available to them, and to help shape corporate policies that align business interests with the state's clean energy objectives.

» Other **members of the public** can use the roadmap to understand how Maine's trucks and buses contribute to air pollution including carbon emissions, and how the state is working to reduce emissions from these vehicles and support a healthier environment.

1.3 Development Process

This roadmap was developed by the Governor's Office of Policy Innovation and the Future (GOPIF) in close collaboration with Maine Department of Transportation (DOT) and Governor's Energy Office (GEO). An Advisory Group representing project partners and Efficiency Maine Trust (EMT), as well as the private sector and nonprofit organizations, guided the effort.

Roadmap development included extensive stakeholder outreach to better understand the opportunities and challenges for transitioning Maine's trucks and buses to ZEVs, and to help identify and shape policies and programs to leverage those opportunities and address the challenges. Outreach included eight focus group discussions and interviews with another

[9] Governor's Energy Office, Governor's Office of Policy Innovation and the Future, and Cadmus (2021). Maine Clean Transportation Roadmap.

20 individuals representing Maine's truck and bus fleet owners and operators, dealers, vehicle manufacturers, charging and fueling infrastructure providers, and other interested parties. Conversations were held with Maine's two investor-owned utilities, Versant and Central Maine Power, on an ongoing basis. Case studies were also conducted with four fleet owners to look at operational and site-specific opportunities for EVs and charging infrastructure in a variety of Maine contexts. Appendix B provides information from the case studies and Appendix C provides more detail on stakeholder engagement.

The roadmap also analyzed data on Maine's MHDV sector to explore potential for ZEV adoption. Data sources included Maine Bureau of Motor Vehicles (BMV) registration records, national truck surveys, and anonymized telematics data on truck activity patterns. Together with this data and modeling methods, this roadmap developed forecasts of potential future MHDVs including ZEVs, emissions, vehicle-related costs, charging infrastructure requirements, and the costs of providing this infrastructure.

MHD ZEVS—BATTERY ELECTRIC, HYDROGEN FUEL CELL, OR BOTH?

The primary focus of this roadmap is on battery electric trucks and buses, and the associated needs for charging infrastructure. However, it is likely that hydrogen fuel cells will be an important ZEV technology for some subsets of the MHD sector, especially for long-haul uses including interstate trucking and intercity coach service. The forecasts of ZEV adoption and benefits presented in this roadmap assume that most, but not all, MHD ZEVs are battery electric. The development of hydrogen infrastructure in Maine will require a separate planning effort; the roadmap recommends that Maine monitor the development of regional hydrogen infrastructure and collaborate with other states on efforts to plan for this infrastructure.

1.4 Organization of This Roadmap

The roadmap is organized as follows:

» **Chapter 2—Maine's Medium- and Heavy-Duty Vehicle Landscape:** Provides an overview of the MHDVs currently operating in Maine, including numbers of vehicles, weight classes, ages, vocations, distances traveled, and activity patterns. Also describes current and future options for MHD ZEVs and their performance and cost characteristics.

» **Chapter 3—Benefits of Medium- and Heavy-Duty Zero Emission Vehicles:** Describes emissions from Maine's MHDVs and the expected emission reduction benefits from adopting ZEVs. Includes different scenarios for MHD ZEV adoption, which may be influenced by any supporting policies and programs Maine implements.

» **Chapter 4—Costs of a Zero-Emission Vehicle Transition:** Estimates the costs and cost savings to transition to MHD ZEVs, including costs for vehicles and supporting charging and refueling infrastructure, as well as potential fuel and operational cost savings.

» **Chapter 5—Policies and Programs Needed to Achieve a Transition to Zero-Emission Vehicles:** Identifies policies and programs already in place in Maine to support MHD ZEVs and additional policies and programs available to help accelerate the ZEV transition and achieve emission reduction goals.

» **Chapter 6—Roadmap for Action:** Identifies specific actions, responsibilities, and timeframes to support the ZEV transition, along with funding requirements and potential sources of funding.

» **Appendix A—Examples of Other State Programs:** Provides examples of programs in other states similar to those recommended in this roadmap.

» **Appendix B—Case Studies:** Summarizes case studies of four sites in Maine with truck and bus fleets, looking at infrastructure needs to support electrification of these fleets. Also identifies a longer list of potentially significant MHDV charging sites across the state.

» **Appendix C—Stakeholder Outreach:** Identifies the specific outreach methods and participants engaged in this study and provides additional detail on findings.

» **Appendix D—Vehicle Landscape:** Describes the data and assumptions behind the description of the current MHDV fleet in Maine.

» **Appendix E—Scenarios:** Describes the data and assumptions behind the scenarios for MHD ZEV adoption.

» **Appendix F—Emissions Analysis:** Describes the modeling methods and key assumptions for estimating emissions from MHDVs and the MHD ZEV scenarios.

» **Appendix G—Charging Demand and Cost Analysis:** Describes the modeling methods and key assumptions for estimating charging demand and associated costs needed to support MHD ZEVs.

2

MAINE'S MEDIUM- AND HEAVY-DUTY VEHICLE LANDSCAPE

This chapter provides a description of the current MHDV sector in Maine and options for future MHD ZEVs. The section uses available data sources to characterize Maine's MHDV fleets in terms of vehicle types, vocations, age distributions, and annual miles traveled per vehicle by market segment and geography. Through this analysis, we can (1) better understand the potential for ZEV adoption in different MHDV market segments; and (2) support quantitative estimates of emissions benefits and charging demand from vehicle electrification. Additional details on the data underlying this analysis are provided in Appendix D.

2.1 Maine Vehicle Fleet and Operating Characteristics

Maine's current MHDVs were characterized based on three data sources:

» The **Maine Registration Information vehicle registration database**, provided by Maine Department of Environmental Protection (DEP). The database includes individual vehicle registrations statewide from Maine's BMV as of July 1, 2023, with 64,045 identified as Class 3–8 trucks and 4,083 identified as buses. This database was used to identify weight class, industry categories, ages, and miles per year for MHDVs registered in Maine.

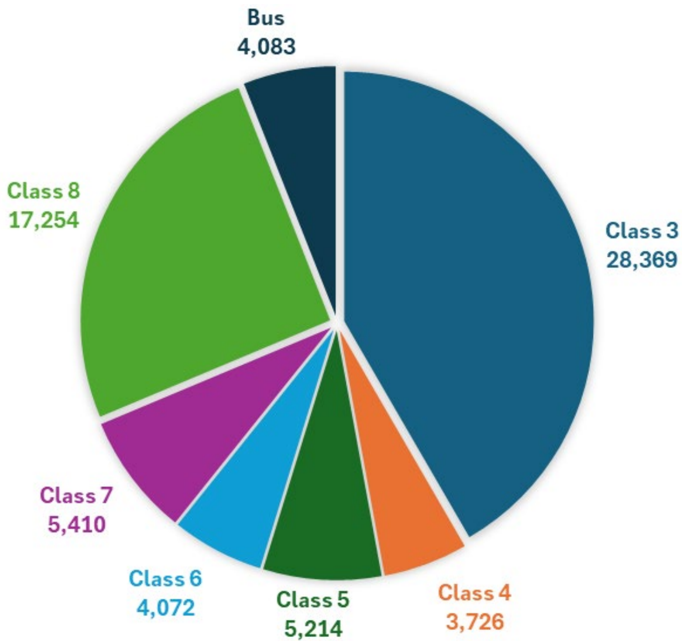
» The U.S. DOT **Vehicle Inventory and Use Survey (VIUS)**, a 2021 survey providing information on truck characteristics and activity from a sample of 150,000 trucks nationwide. Statistics were examined based on approximately 800 trucks with their primary base in Maine.

» **LOCUS Truck**, provided by Cambridge Systematics based on Geotab telematics data, for year 2023. LOCUS Truck provides truck activity information, including trips, vehicle-miles traveled (VMT) associated with those trips, dwell time, trip lengths, and time of day for three weight classes and five vocational categories, at the Census Tract geographic level. The LOCUS sample data includes trips taken by about 11,600 trucks (18 percent of Maine's truck population) with an estimated 5 percent of total trips sampled.

Key findings about MHDVs currently operating in Maine include:

- About 41,000 commercial medium-duty trucks (MDT) and 23,000 heavy-duty trucks (HDT) were registered in Maine as of 2023. About 44 percent of these are in the Class 3 weight class, the lowest weight class considered in this study (Figure 2.1).[10] As might be expected, most MHDV registrations and vehicle trips are concentrated in Maine's population centers—especially the Portland region, Kittery, Lewiston-Auburn, Brunswick, Augusta, Waterville, and the Bangor area (Figure 2.2). Smaller nodes can be seen in other coastal, inland, and border communities.

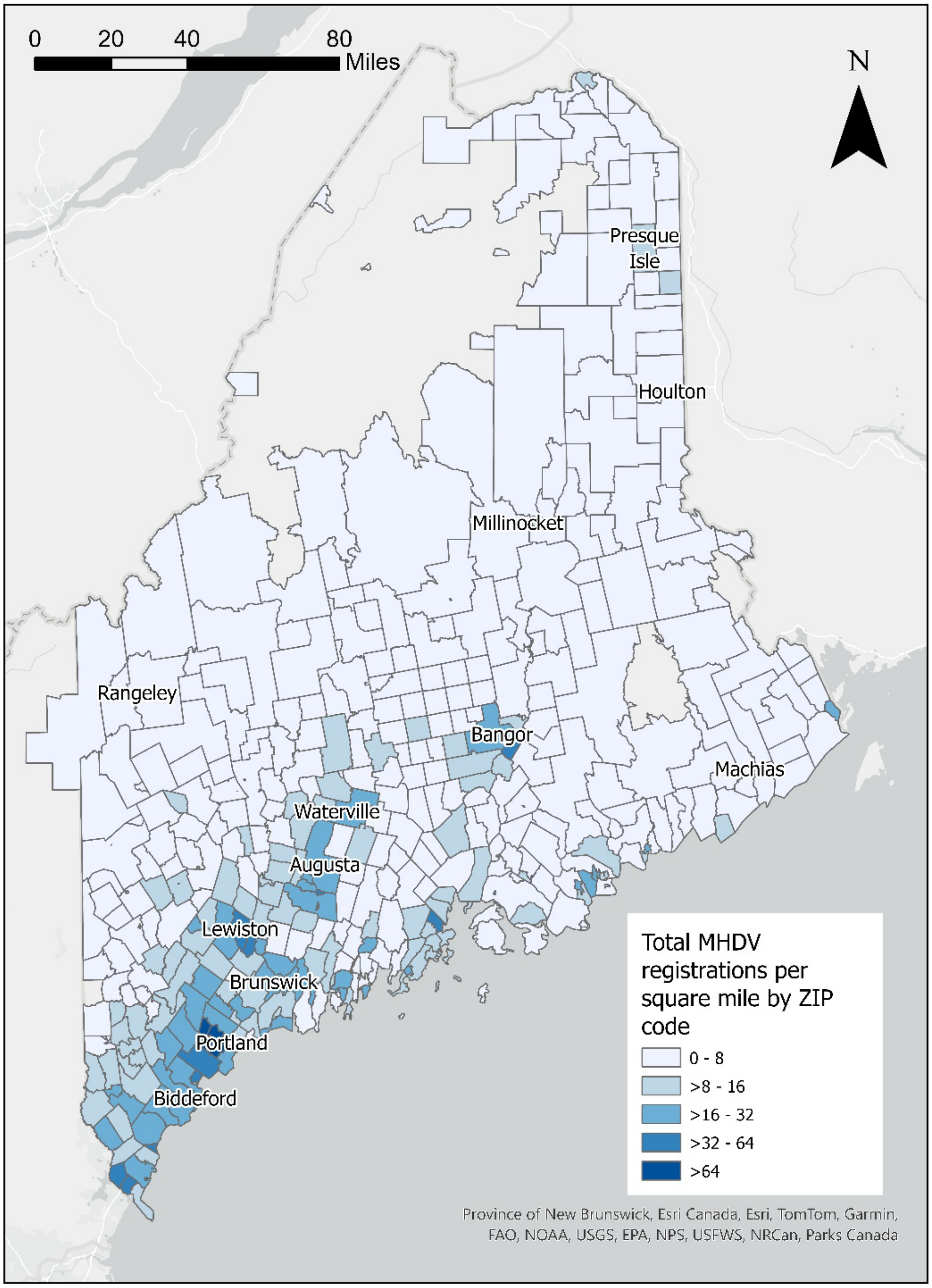
FIGURE 2.1 NUMBER OF REGISTERED MAINE MHDV BY WEIGHT CLASS



Source: Analysis of Maine BMV registration data by Maine DEP and ERG.

[10] Medium-duty vehicles are defined for this study as having a gross vehicle weight rating (GVWR, or vehicle weight plus load rating) of 10,001–26,000 lb. This includes Federal vehicle weight classes 3 through 6. Heavy-duty vehicles are defined as having a GWVR of over 26,000 lb. This includes Federal vehicle weight classes 7 and 8. Vehicles with a weight rating less than 10,000 lb. are characterized as light-duty vehicles (passenger cars, pickups, vans, and sport utility vehicles) or light-medium trucks and are not considered in this roadmap. Other studies and data sources may include weight class 2b vehicles (8,501–10,000 lb. GVWR) in the "medium-duty vehicle" category.

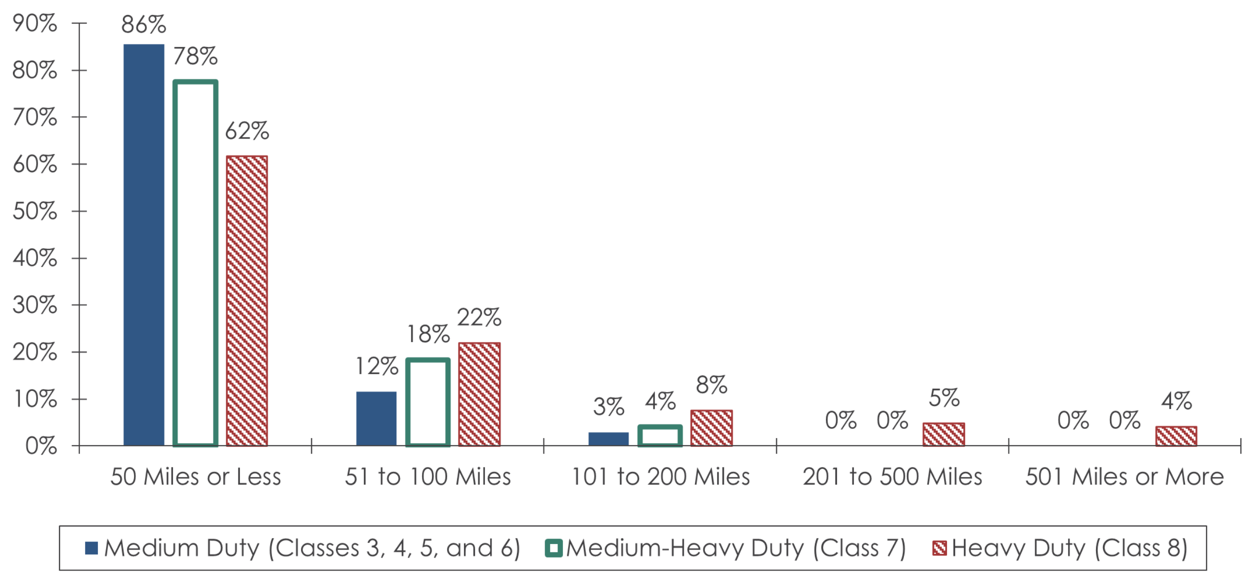
FIGURE 2.2 TOTAL TRUCK AND BUS REGISTRATIONS PER SQUARE MILE BY ZIP CODE



Source: Analysis of Maine BMV registration data by Maine DEP and ERG.

» Based on odometer readings collected at the time of registration, MDTs in Maine drive an average of 53 miles per day, and HDTs drive an average of 96 miles per day. National survey data also confirms that most Maine-based MDTs (85 percent) have a typical operating range of less than 50 miles and most HDTs (over 80 percent) have a typical operating range of less than 100 miles (Figure 2.3). These distances are expected to easily fall within the range of most future MHDV ZEVs, including electric trucks. That said, daily averages obscure differences across vocational classes, age groups, and also day-to-day differences in some vehicles' usage patterns. For example, new vehicles are typically driven more miles than average, with annual miles per vehicle declining as the vehicle ages.

FIGURE 2.3 DAILY OPERATING RANGE OF MAINE-REGISTERED TRUCKS



Source: U.S. DOT Bureau of Transportation Statistics, 2021 Vehicle Inventory and Use Survey.

- MDTs in Maine have an average age of just under 10 years compared to nearly 15 years for HDTs, suggesting that the MDT fleet is likely to turnover more quickly and therefore transition to ZEVs more quickly. However, this also highlights the importance of beginning a transition of the HDT fleet to ZEVs as soon as practical. Maine's MHDV fleet appears slightly older (10–12 percent) than the national average for MHDVs. Forty percent of registered vehicles are model year 2009 or older while an additional 10 percent are model years 2010–2014. These older vehicles were subject to less stringent air pollution emission standards; replacing them with ZEVs will reduce criteria air pollutants as well as GHG emissions.
- The LOCUS Truck database provides information on trips and VMT for truck trips that start or end in Maine.[11] Activity is categorized in three vocational categories: local, regional,

[11] A LOCUS Truck "trip" is defined as ending (a) when the vehicle's engine is turned off; OR (b) when the vehicle has been idle (no movement) for longer than 15 minutes (MDT) or 30 minutes (HDT).

and long-haul operations. As shown in Table 2.1, about two-thirds of trips and 40 percent of VMT are made by vehicles in the "local" category, which have higher electrification potential based on operating relatively close to home. About 28 percent of trips and 40 percent of VMT are in "regional" use which may be somewhat harder to electrify, due to longer trip lengths and potentially shorter overnight dwell times; and only 8 percent of trips but about 20 percent of VMT are from long-haul travel, which will likely be the hardest segment to electrify but may be suitable to future deployments of hydrogen fuel cell vehicles. Some local operations may also be harder to electrify if the vehicles are in constant use over the course of a day, driving a total combined distance that exceeds the electric range.

TABLE 2.1 SHARE OF DAILY TRUCK TRIPS AND VMT BY MARKET SEGMENT

Market Segment	Share of Trips	Share of VMT
Local	65%	40%
Regional	28%	39%
Long Haul	8%	21%
Total	**100%**	**100%**

Source: Cambridge Systematics/LOCUS Truck; 2023 truck trips starting and/or ending in Maine. "Local" includes three vocational categories—door-to-door (many stops, little time per stop); hub-and-spoke (multiple round trips from a centralized hub), and local (range of activity below 150 miles). "Regional" includes trucks that typically range over 150 miles but rest in the same location often. "Long haul" (or "long distance") includes vehicles with a large range of activity that do not rest in the same location.

» Table 2.2 shows the statewide distribution of trip lengths by vehicle weight class and Table 2.3 shows post-trip stop duration by weight class (cross-tabulations of distance by stop duration were also evaluated, as shown in Appendix D). While this dataset does not provide total daily operating range, it does show that over half of all trips are relatively short (less than 50 miles), with a post-trip stop duration of 15 to 60 minutes. These are trips for which a brief "top-up" charge might be feasible from a charging station available at the destination, and for which a full charge between trips may not be necessary. Only 11 percent of trips have a distance greater than 100 miles and a stop duration less than 2 hours—these are challenging trips to serve with a post-trip recharge unless a fast charging station is available.

TABLE 2.2 TRIP DISTANCE BY WEIGHT CLASS

Trip Distance	Medium Trucks	Heavy Trucks
<50 mi	78%	53%

Trip Distance	Medium Trucks	Heavy Trucks
50—100 mi	14%	13%
100—200 mi	6%	12%
200—300 mi	1%	11%
>300 mi	<1%	5%
Total	**100%**	**100%**

Source: Cambridge Systematics/LOCUS Truck; 2023 truck trips starting and/or ending in Maine.

TABLE 2.3 POST-TRIP STOP DURATION BY WEIGHT CLASS

Trip Distance	Medium Trucks	Heavy Trucks
<15 min	24%	9%
15–30 min	21%	17%
30 min–1 hr	27%	22%
1–2 hr	20%	17%
>2 hr	8%	36%
Total	**100%**	**100%**

Source: Cambridge Systematics/LOCUS Truck; 2023 truck trips starting and/or ending in Maine.

» There are about 4,100 buses registered in Maine. School buses make up over three-quarters of the bus population but drive only one-third of the annual miles per year of a transit or "other" (intercity or charter) bus, meaning that fewer emissions benefits per vehicle will be achieved by transitioning to ZEVs. However, transitioning to ZEV school buses carries other benefits, including decreased student, teacher, and operator exposure to air pollutants and decreased operating costs for schools. Based on a review of bus electrification transition plans for Maine's transit agencies, the majority of transit routes in Maine require less than 200 miles per day, a range that can be served by models currently or anticipated to soon be in production.

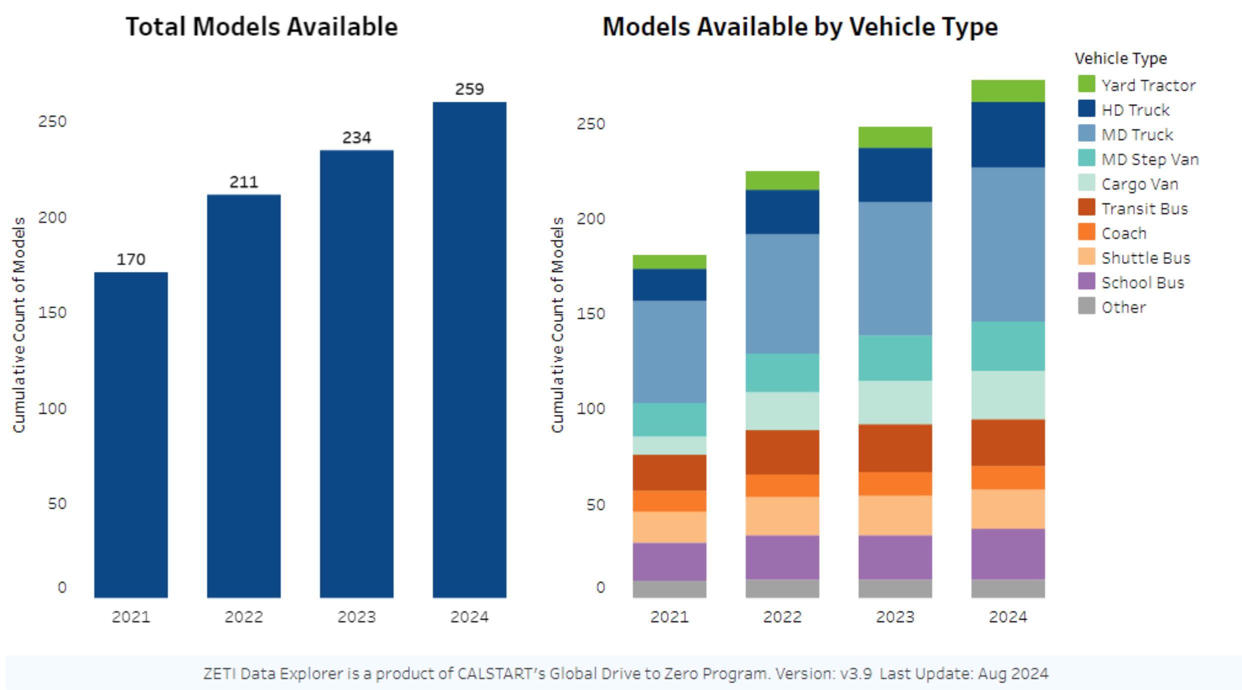
2.2 Current and Future Zero-Emission Vehicle Availability

While light-duty EVs are becoming common in many parts of the country, MHD ZEV technology is just starting to come to market in many states. Manufacturers are offering increasing numbers of ZEV alternatives for each MHDV class; more than 250 MHD ZEV model offerings are currently available in the United States (as of August 2024).[12] Within each

[12] CALSTART ZETI Data Explorer, https://public.tableau.com/app/profile/yin.qiu6767/viz/ZETIDataExplorer/ZETIDataExplorer.

vehicle segment, there are at least 10 zero-emission models currently available, giving fleets an increasingly wide range of non-polluting options. The growth in U.S. MHD ZEV availability is shown in Figure 2.4.

FIGURE 2.4 MHD ZEV MODEL AVAILABILITY



Source: CALSTART, https://public.tableau.com/app/profile/yin.qiu6767/viz/ZETIDataExplorer/ZETIDataExplorer.

For Class 3 pickups, one alternative is the Ford E-Transit Chassis Cab/Cutaway. Class 4 cargo/ passenger vans can be replaced with the Cenntro Logistar 400, the Envirotech Logistics Van, or GreenPower EV Star, available in both Cargo and Passenger Van builds. Though they are Class 2b/3, both the Brightdrop ZEVOC 400/600 and the Rivian Delivery 500/700 have been successfully deployed by fleets such as Ryder[13] and Amazon.[14] Class 5 chassis cabs can be replaced with the Phoenix Motorcars Work Truck or the Rizon e18M/e18L. Class 6–8 trucks can be replaced with options including the Freightliner eM2 or eCascadia, Mack MD Electric, or Volvo, North America, Regional (VNR) Electric. The Freightliner eM2 has been deployed to

[13] Ryder. "Ryder Deploys its First BrightDrop Electric Vehicles into Rental Fleet." September 20, 2023, accessed October 2024.

[14] "Amazon rolls out new Rivian EVs at Cohoes delivery station." Times Union, October 25, 2024.

PITT OHIO,[15] and the Volvo VNR Electric has been deployed by Home Hardware.[16] These examples are just a small sample of MHD ZEVs operating across national fleets.

The range and performance of MHD ZEVs has steadily improved. Most commercially available MHD ZEVs offer sufficient range to meet the average daily mileage of Maine's trucks (53 miles/day for MDTs and 96 miles/day for HDTs). An increasing variety of MD zero-emission trucks (ZET) are now available with 200 miles of range, and there are a few HD ZETs with at least 250 miles of range such as the Hyundai XCIENT Tractor, Kenworth T680, and Nikola Tre FCEV. Similarly, battery and hydrogen buses for school, transit, and commercial uses are available with ample range to meet the vast majority of bus trips. Hydrogen transit buses such as the New Flyer Xcelsior CHARGE FC have been piloted in locations including Philadelphia, PA and Rochester, NY; in the fall of 2024 the San Mateo County Transit District placed an order for 108 hydrogen fuel cell buses.

More than 30,000 ZETs were deployed in the United States at the end of 2023; 25,000 of them were deployed in that year alone.[17] Every segment of the truck market, from Class 2b cargo vans through Class 8 tractors, saw at least 40 percent growth in deployments from the prior year. ZEV cargo vans are the leading ZET segment, accounting for the vast majority of ZET deployments to-date—nearly 26,000 nationwide. The early success in the cargo van segment is due to enabling market characteristics including high production volumes, smaller batteries, ideal duty-cycle capability, a quicker payback period for the vehicle, and strong demand from large fleet operators. Case studies developed for this roadmap

FIGURE 2.5 ELECTRIC REFUSE TRUCK IN PORTLAND, ME

Source: https://www.macktrucks.com/mack-news/2024/mack-delivers-the-lr-electric-to-portland-maine-the-states-first-electric-refuse-vehicle.

[15] "DTNA delivers Freightliner eM2 trucks to PITT OHIO." The Buzz EV News, April 2, 2024, accessed October 2024.

[16] "Home Hardware adds Volvo VNR Electric semi trucks to its fleet." Electrek, September 22, 2024, accessed October 2024.

[17] CALSTART (2024). Zeroing in on Zero-Emission Trucks: Market Update.

suggest that electric cargo vans in Maine can start saving fleets money as soon as one to three years after purchase. HDTs were the second leading segment for ZEV growth in 2023, seeing a 369 percent increase to 1,162 total vehicles deployed nationwide. A significant number of deployments have been in cold-weather states, with Wisconsin adding over 800 ZETs and New Jersey, New York, and Pennsylvania adding over 3,700 ZETs collectively in 2023; over 100 ZEV step vans have been deployed to-date in New Hampshire.

Mirroring national trends, most of the MHD ZET deployments in Maine have been electric cargo vans and electric school and transit buses. One notable exception is the state's first battery electric refuse truck, the Mack LR Electric, serving the City of Portland (Figure 2.5).

While MHD ZEV deployments are still in the early stages in Maine, the state's truck and bus dealers are getting ready to meet consumer demand. Dealers and original equipment manufacturers (OEM) interviewed for this roadmap shared that they are already prepared to sell MHD ZEVs from their locations in Maine. A selection of current options is highlighted in Table 2.4. In addition to selling the vehicles, all of the dealers and OEMs listed below offer a range of support to customers to help them navigate the transition, including driver training, specialized charger recommendations, local maintenance plans, and support securing both Federal and state incentives.

TABLE 2.4 ANTICIPATED NEAR-TERM MHD ZEVS AVAILABLE IN MAINE

Vehicle	Vehicle Class	Dealership/OEM Availability
VNR Electric Box Truck	Class 7	Volvo
VNR Tractor	Class 8	Volvo
Kenworth 270E	Class 6	Kenworth (four dealerships)
Kenworth K370E	Class 7	Kenworth (four dealerships)
Kenworth T680E	Class 8	Kenworth (four dealerships)
Mack 22'	Class 6/7	Mack Portland
Mack Refuse Truck	Class 8	Mack Portland
IC Type C School Bus	Class 6/7	Devivo Bus
Collins Type A School Bus	2b/3	Devivo Bus

Source: Interviews with Maine dealers and OEMs.

Experts generally agree that battery electric technology will be the dominant technology for ZET and buses serving local and regional markets, and is the best (and only viable) ZEV option in the northeast at this time (2024). The electrical grid infrastructure largely exists to support charging, though local upgrades may be required; whereas a clean hydrogen production and distribution infrastructure would need to be built from scratch. Battery electric technology is also more energy-efficient than hydrogen fuel-cell technology, meaning that operating costs will be lower per mile. The relatively low energy density (with batteries cutting into payload) and long recharging times of batteries, however, make them less suitable for long-haul travel, including interstate trucking and intercity coaches. While energy densities are improving and megawatt (MW) chargers will greatly shorten recharge times, it is still possible that hydrogen-fuel cell technology will become important for long-haul ZEV markets. Some states have begun to plan for and support hydrogen infrastructure on the east coast, for example through Connecticut's Clean Hydrogen Roadmap[18] and New York's Hydrogen and Clean Fuel Program.[19]

2.3 Zero-Emission Vehicle Scenarios

The future of MHD ZEVs in Maine will depend on actions taken by a variety of actors, including the state and Federal agencies, partners and regulators; and on market factors such as energy costs, technological progress, and model availability.

To inform this roadmap, a baseline projection of MHD ZEVs in Maine was developed through 2040. The baseline considers available Federal vehicle and charging incentives, but no further existing state and Federal policies. Three alternative scenarios were developed to illustrate how a portfolio of more supportive and ambitious state policies and programs, along with other supportive factors, could increase the number of MHD ZEVs in Maine over time.

These scenarios are important to:

» Help the state understand what it needs to do to meet its GHG reduction goals.

» Help the state's utilities plan for increases in electricity demand and corresponding needs to upgrade, expand, or strengthen the electricity grid.

» Quantify and communicate other benefits of investing in ZEVs, including reductions in hazardous air pollution emissions.

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[18] Engie Impact (2024). Draft 2024 Connecticut Clean Hydrogen Roadmap. Prepared for Connecticut Department of Energy and Environmental Protection.

[19] NYSERDA (2024). More Than $16 Million Now Available to Advance Innovation in Clean Hydrogen.

Three alternative scenarios were initially developed for this roadmap:

- **"Moderate"**(National adopted policies). Manufacturers sell ZEVs to meet recently adopted national GHG emissions rules,[20] and Maine policies encourage some of those ZEVs to come to Maine. This differs from the baseline policy by adding in proportional effects of OEMs placing ZEVs in service to comply with Federal emissions rules.
- **"High"** (Advanced states). Maine's supporting policies are sufficiently strong to achieve the benefits of the Advanced Clean Trucks (ACT) rule adopted to-date (2024) in 11 states (including Massachusetts, New York, and Vermont), without adopting the rule in Maine. This differs from the moderate scenario by adding sales share percentages aligned with ACT to previously-discussed compliance with Federal policies.
- **"Advanced"** (*Maine Won't Wait* targets). Maine implements even more ambitious funding, technical support, and/or rules to achieve market shares needed to meet emission reduction targets from the 2020 *Maine Won't Wait* climate action plan. While these targets are not the same as those included in the state's 2024 climate action plan, this scenario illustrates the level of change that would need to occur in the MHDV sector to meet aggressive emission reduction goals. While achieving these levels of ZEV penetration in this sector will be highly challenging due to economic, political, and readiness factors, this scenario serves as an upper bound to guide the state's ambition.[21]

Each scenario included separate estimates of ZEV market shares for six vocation-based market segments, each further segmented into medium- and heavy-duty segments. This was done to account for the different electrification potential of different market segments. For example, vehicles in local use that return to a regular home base will be easier to electrify than vehicles that travel long distances and/or do not return to the same home base every night. Similarly, medium trucks are likely to be easier to electrify than heavy trucks since a smaller battery pack is needed and charging can be accomplished more quickly or at a lower power level. The six vocational segments are:

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[20] In 2024, the U.S. Environmental Protection Agency adopted "Phase 3" Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles, setting declining limits on tailpipe pollution from trucks and buses through model year 2032. EPA has modeled scenarios in which manufacturers sell ZEVs to help comply with those emission reductions; this Maine scenario is based on the EPA national scenarios.

[21] This roadmap was developed concurrently with the state's 2024 climate action plan. This roadmap and the 2024 climate plan rely on the same data sources for this sector, and make similar assumptions about adoption and allocation of ZEVs in later years. This Advanced scenario is based on the state's 2020 climate action plan to model ambitious goals.

» Commercial—Local (typically operate within a 150-mile range and return to base daily).

» Commercial—Regional (typically operate within a range greater than 150 miles and return to base daily).

» Commercial—Long-haul (typically has a large range of activity and does not rest in the same location).

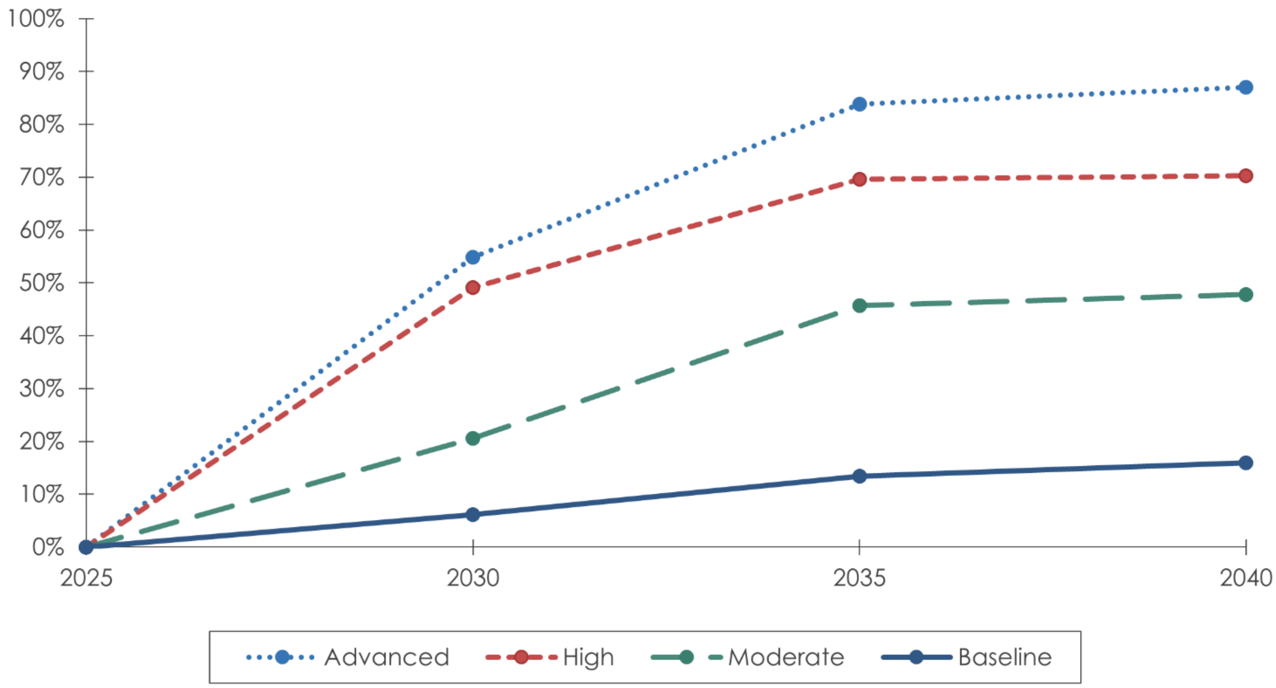
» Public and municipal services, including state and municipal vehicles as well as utilities, emergency services, and refuse trucks.

» Transit bus, including those operated by urban and rural public transportation providers.

» School bus.

Sales shares for the baseline and alternative scenarios are shown in Figure 2.6. Without any further action (baseline), 6 percent of MHDV sales in 2030 are projected to be ZEVs, increasing to 13 percent in 2035 and 16 percent in 2040. This growth from today's near-zero level will be driven by Federal incentives such as the Commercial Clean Vehicle Tax Credit, as well as decreasing ZEV costs and improved performance that make them increasingly competitive in some market segments. Over three-fifths of these vehicles through 2040 are likely to be commercial vehicles serving local markets, with two-thirds of those local vehicles being medium-duty (Class 3–6), with the performance and operating characteristics most likely to support electrification. Under the Moderate scenario, ZEV sales shares would rise to 20 percent by 2030 and over 40 percent by 2035. Under the High and Advanced scenarios, over 50 percent of new MHDV sales would be ZEVs by 2030.

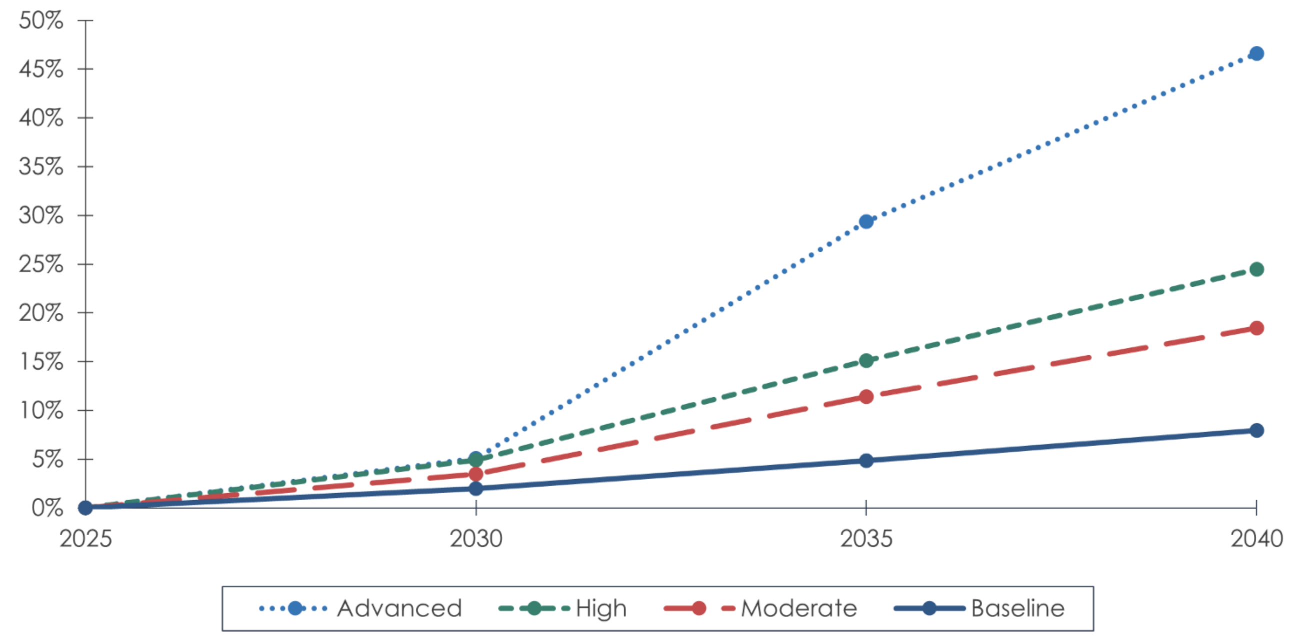
FIGURE 2.6 SCENARIOS FOR ZEV SHARE OF NEW MHDV SALES AND PROCUREMENTS IN MAINE



Source: Analysis by ERG and Cambridge Systematics.

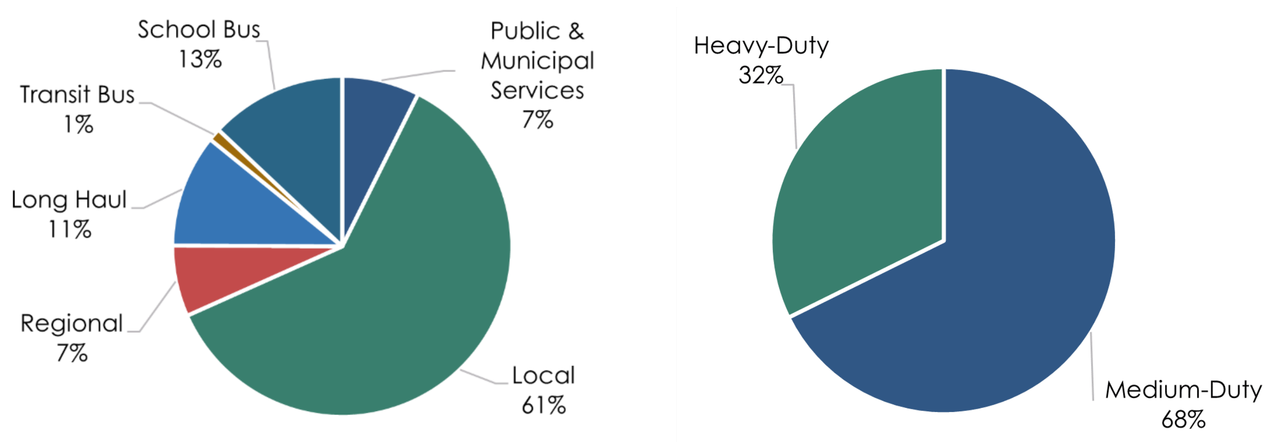
The resulting shares of vehicle stock (percent of vehicles on the road) are shown in Figure 2.7. Without any further action (baseline), about 2 percent of MHDVs on the road in 2030 and 8 percent in 2040 would be ZEVs. The Moderate scenario would increase MHD ZEV stock to about 20 percent in 2040, with the High scenario increasing to 25 percent and the Advanced scenario to nearly 50 percent. Figure 2.8 shows the projected breakdown of 2040 ZEVs by most likely market segment and weight class in 2040, under the Moderate scenario.

FIGURE 2.7 SCENARIOS FOR MAINE MHD ZEV STOCK



Source: Analysis by ERG and Cambridge Systematics.

FIGURE 2.8 SHARE OF 2040 MHD ZEVS BY MARKET SEGMENT (MODERATE SCENARIO)



Source: Analysis by ERG and Cambridge Systematics.

While some market segments may be ready to evolve along the High to Advanced scenario projections more quickly, it may be ambitious for other market segments (such as long-haul trucks) to achieve new sales percentages aligned with even the Moderate scenario. It is also likely that Maine's adoption of new technologies starts off slow and the ramps up as technology improves and is deployed and proven elsewhere.

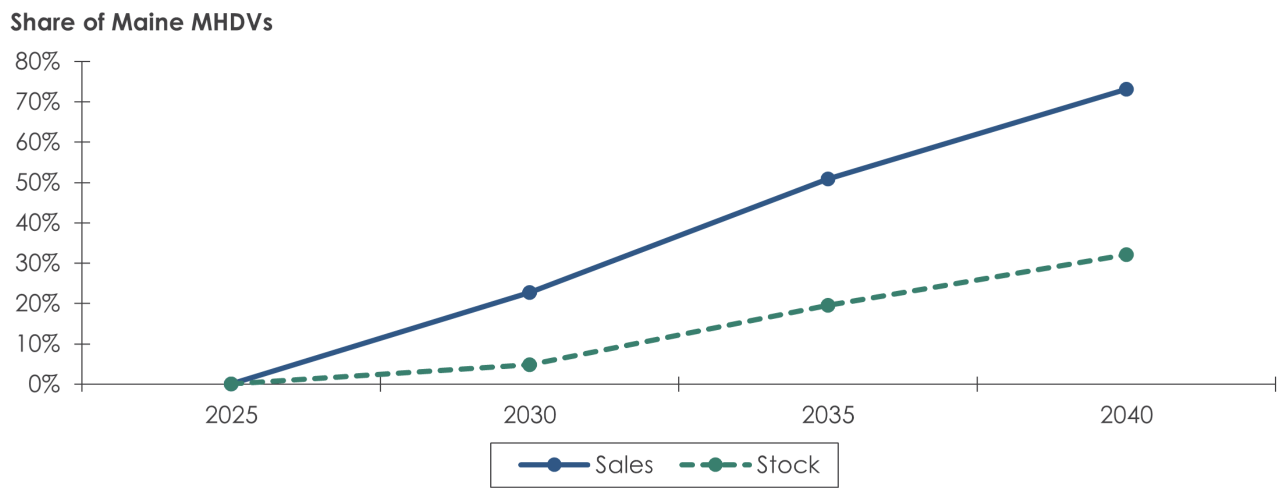
Finally, sales curves driven by regulation (state or Federal) flatten out after 2035, as today's regulations do not extend after that time; however, technology is likely to continue to advance through 2040, leading to a continued increase in ZEV market shares.

With these considerations in mind, a **"composite" scenario** was developed which mixed different levels of ZEV adoption across different years, depending on market segments and operational cycles. In this scenario, the statewide average ZEV sales share increases from almost one-quarter of new MHDVs in 2030 to nearly three-quarters in 2040 (Figure 2.9), increasing the ZEV share of MHDV stock from 5 percent in 2030 to 32 percent in 2040. The guidelines for this composite scenario are:

» Public and municipal service vehicles (transit and school buses, state and municipal fleets, utilities, and refuse trucks)—aligned with High scenario in 2030, increasing to the Advanced scenario by 2040. These vehicles tend to operate locally under conditions that may be more suitable for electrification, and also may have more opportunities for leveraging public policy commitments and funding than commercial vehicles.

» Commercial vehicles (all distance ranges)—aligned with the Moderate scenario in 2030, increasing to the High scenario by 2040. The more conservative levels for this sector reflect the greater diversity of vehicle uses (including regional and long-haul) and the greater challenge of reaching a large number of relatively small fleet operators with varying degrees of financial and technical capacity.

FIGURE 2.9 STATEWIDE AVERAGE MHDV ZEV SALES AND STOCK SHARES UNDER COMPOSITE SCENARIO



Source: Analysis by ERG and Cambridge Systematics.

Appendix E documents the key assumptions and methods used to develop the scenarios.

3

BENEFITS OF MEDIUM- AND HEAVY-DUTY ZERO-EMISSION VEHICLES

3.1 Greenhouse Gas Emissions Reductions

According to the Maine DEP, transportation is responsible for 49 percent of Maine's GHG emissions.[22] Nearly one-quarter of transportation emissions are from medium- and heavy duty (Class 3–8) vehicles; this share is projected to increase as light-duty vehicle emissions decline more rapidly due to Federal emissions standards, increased availability, and decreased cost of light duty battery EVs. Overall, 10 percent of the state's total emissions are from trucks and buses.

Projections of truck activity by the U.S. DOT, as presented in the Maine DOT 2024 *Maine Integrated Freight Strategy*, indicate that the tonnage of freight moved in Maine is expected to increase by nearly 50 percent between 2019 and 2040. If Maine's MHDV stock grows at the same rate, the number of trucks and buses registered in Maine would increase from 62,000 in 2020 to 88,000 in 2040. With no additional policy actions, GHG emissions from trucks and buses would increase by 10 percent as improvements in fuel economy (driven by existing Federal regulations) are outweighed by VMT increases.[23]

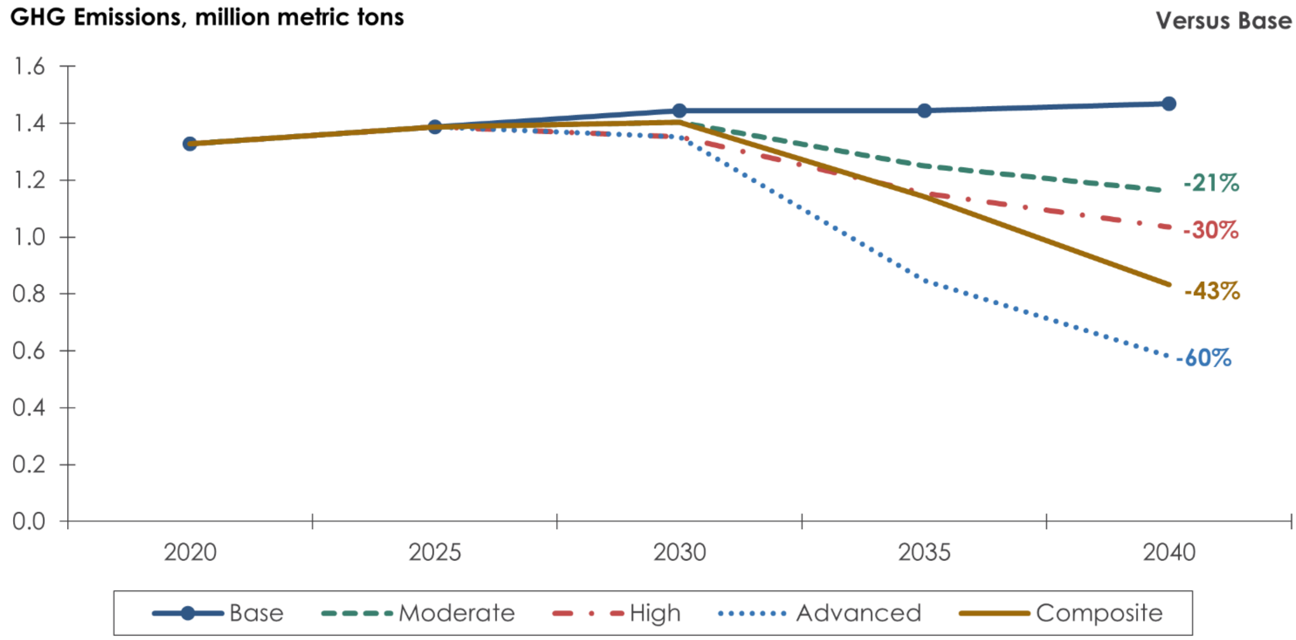
The scenarios outlined in Chapter 2 would reduce MHDV GHG emissions by 3 to 6 percent from baseline levels in 2030, and 21 to 60 percent from baseline levels in 2040 (Figure 3.1).

[22] Maine DEP (2024). 10th Report on Progress on Greenhouse Gas Reduction Goals.

[23] Assuming the same average miles per truck and share of vehicle types in the future as today.

After accounting for projected growth in VMT and vehicle stock, the GHG reduction in 2040 would range from 13 to 56 percent compared to 2020 levels.

FIGURE 3.1 MHDV GHG EMISSIONS BY SCENARIO



Source: Analysis by ERG. Note—2020 emissions were adjusted upward to account for a reasonable estimate of emissions without the reduction in travel resulting from the COVID pandemic.

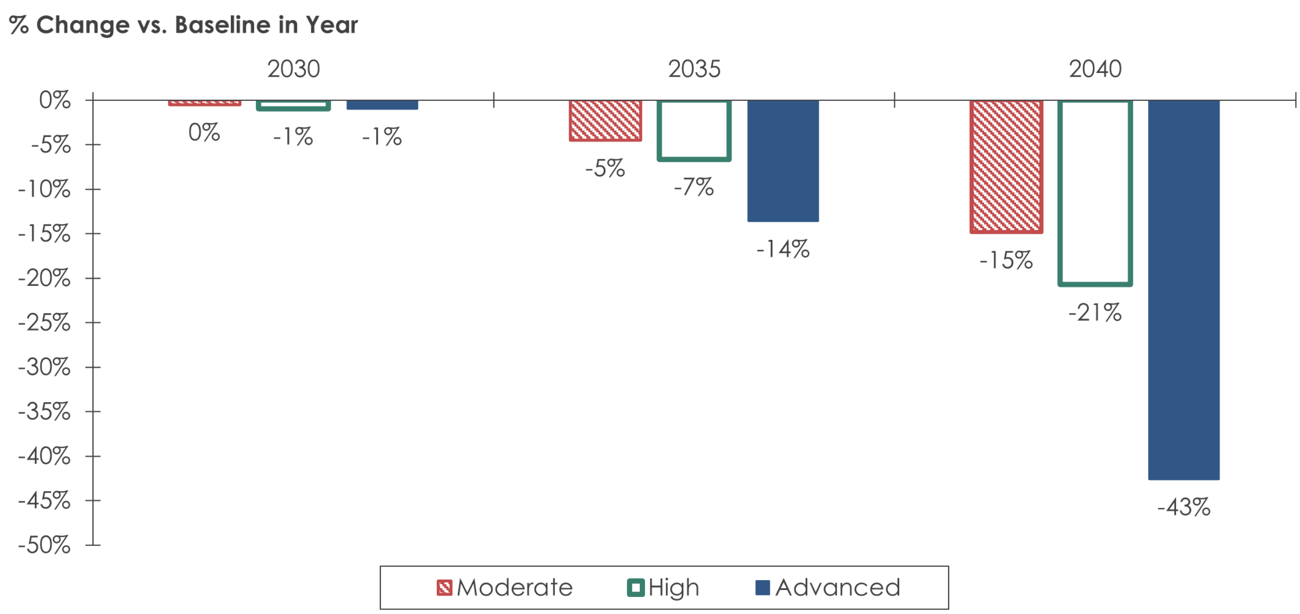
3.2 Energy Savings

In 2019, trucks and buses in Maine consumed approximately 280 million gallons of gasoline and diesel fuel. With no further action by the State of Maine, MHD energy consumption is projected to increase by 10 percent by 2040, as freight volumes increase but trucks and buses become more efficient as a result of Federal emissions standards. Because EVs are much more energy-efficient than gasoline and diesel vehicles, the three alternative scenarios modeled for this roadmap would reduce total MHDV energy use by 10 to 30 percent in 2040 compared to the baseline 2040 projection, helping to reduce Maine's reliance on imported energy.

3.3 Air Pollutant Reduction

Medium- and heavy-duty vehicles contribute disproportionately to other harmful air pollution, especially fine particulate matter ($PM_{2.5}$) and nitrogen oxides (NO_x). In 2020, MHDVs were estimated to be responsible for 20 percent of $PM_{2.5}$ and 40 percent of NO_x pollution from transportation sources in Maine based on analysis using the U.S. Environmental Protection Agency (U.S. EPA) MOVES emissions model. Over the past two decades, the U.S. EPA has implemented progressively more stringent emissions requirements for trucks and buses, with the latest rule setting standards starting in Model Year 2027.[24] Even with no further action on the state's part, $PM_{2.5}$ and NO_x emissions from MHDVs are projected to decline by over 90 percent and 75 percent, respectively, by 2040, as vehicles meeting these more stringent standards are increasingly phased into Maine's fleet. A transition to MHD ZEVs will further accelerate this decrease in harmful air pollutants. The alternative scenarios modeled for this roadmap suggest that MHD ZEVs could further reduce exhaust $PM_{2.5}$ from these vehicles by 15 to 43 percent (Figure 3.2) and NO_x pollution by 9 to 27 percent (Figure 3.3) from baseline 2040 levels, consistent with the share of vehicles on the road that would be zero-emission. These benefits are especially meaningful for buses as well as for trucks serving densely populated areas where exposure to harmful emissions may be higher. Vehicle operators and yard and maintenance workers will also benefit from reduced exposure to workplace air pollution.

FIGURE 3.2 PROJECTED CHANGE IN MHDV $PM_{2.5}$ EMISSIONS IN MAINE



Source: Analysis by ERG.

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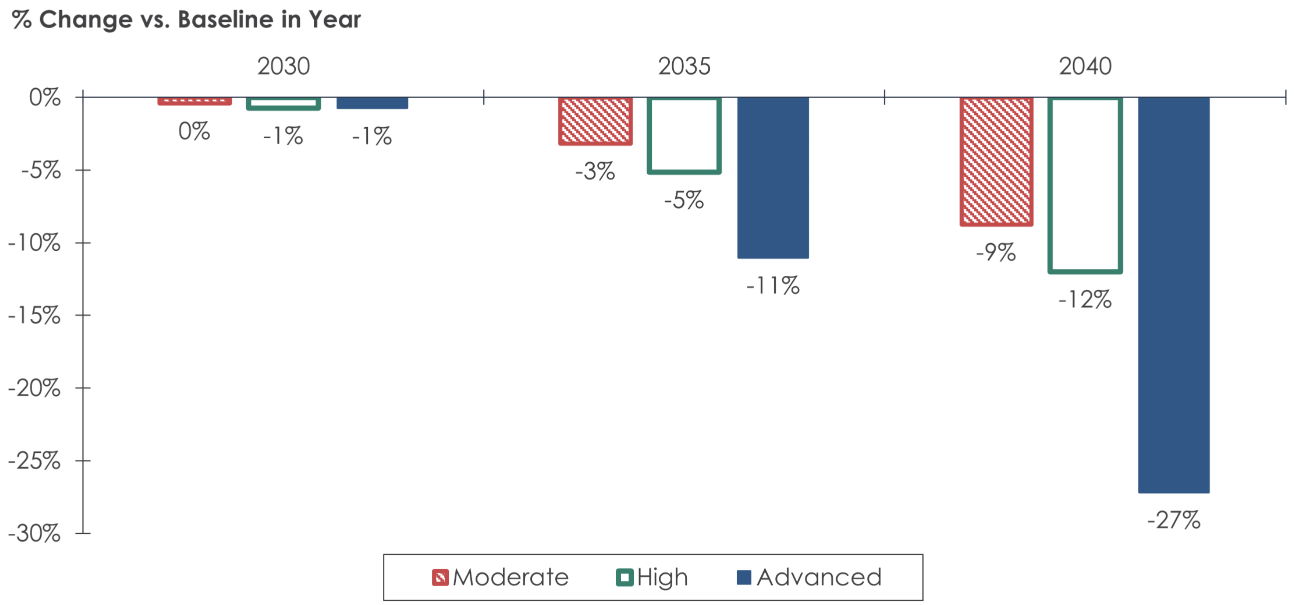
[24] Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards. 88 FR 4296.

FIGURE 3.3 PROJECTED CHANGE IN MHDV NO_X EMISSIONS IN MAINE



Source: Analysis by ERG.

Approximately 28 percent of these emission reductions are estimated to occur in Census Tracts identified as "disadvantaged" by Federal definitions.[25] Estimated reductions of criteria pollutants in these tracts would be 1 ton of $PM_{2.5}$ and 23 tons of NO_x in 2040 in the composite scenario, resulting in health benefits valued at \$1.0 to \$1.3 million in 2040.[26]

3.4 Other Benefits

MHD ZEVs will have other benefits for Maine's people and environment. ZEV trucks and buses operate more quietly than diesel vehicles. The noise benefit will be most notable at low speeds in cities and towns, as road noise dominates engine noise at higher speeds. ZEVs can also have maintenance and operations benefits for fleet owners and operators, as discussed in Section 4.1.2.

Investing in ZEVs and supporting infrastructure will also ensure that Maine keeps pace with leading states in this sector and captures job and business expansion opportunities associated with a new energy economy. Five states in the northeast have already adopted

[25] Disadvantaged tracts were identified using the White House Council on Environmental Quality Climate and Economic Justice Screening Tool. LOCUS Truck trip data was used to estimate the proportion of truck travel by tract.

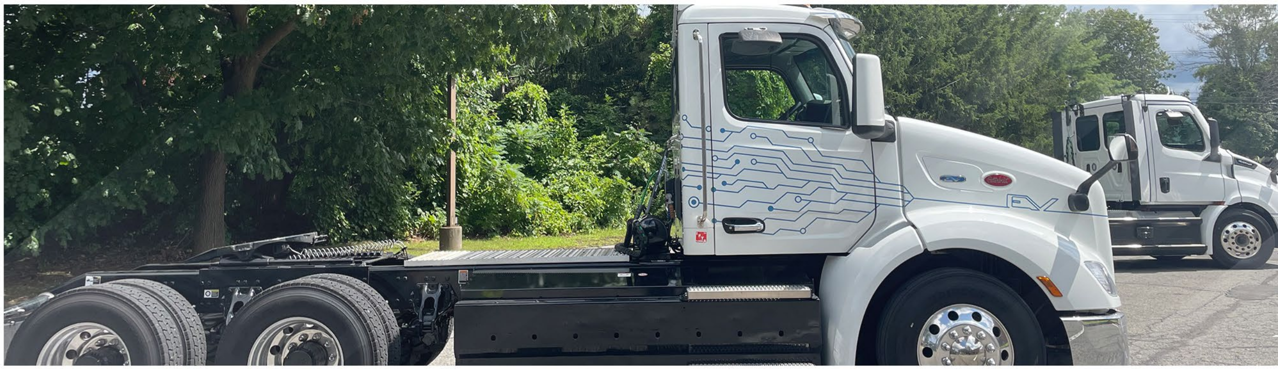
[26] Health benefits valued using the U.S. EPA COBRA Web Edition, accessed 10/29/24.

Advanced Clean Truck regulations; combined with corporate sustainability initiatives and increasingly favorable economics in some market segments, MHD ZEVs will be operating in the northeast regardless of whether Maine advances ZEV policies. With strategic investment, Maine can capture the economic and environmental benefits associated with hosting and servicing those vehicles.

Finally, managed charging helps ensure that ZEVs benefit the state's electricity grid. For example, many vehicles can charge overnight when overall electricity demand is lower—making use of existing electricity generating capacity and increasing utility revenues without requiring investments in new generating capacity. Vehicle-to-grid (V2G) integration could further benefit Maine's utility sector by paying ZET owners to feed electricity back into the grid at times of highest electricity demand with vehicle batteries serving as mobile and dispatchable generators. Managed charging and V2G integration are discussed further Section 4.2.2.

Appendix F documents the key assumptions and methods used to estimate the emissions and energy benefits of the MHD ZEV scenarios.

4



COSTS OF A ZERO-EMISSION VEHICLE TRANSITION

4.1 Costs and Cost Savings to Fleet Owners and Operators

Fleet and vehicle owners and operators will experience a variety of changes in costs associated with ZEVs as compared to conventional MHDVs. Some of these occur once, at the time of purchase of a vehicle, while others accrue over time, as summarized in Table 4.1. ZEVs typically cost more up-front for both the vehicle and any associated fueling infrastructure, but often provide a financial payback in the form of reduced fuel costs and reduced long-term maintenance costs when considered across the useful life of the vehicle.

TABLE 4.1 POTENTIAL ZEV COSTS AND COST SAVINGS

Timeframe of Costs/Savings	Potential Costs	Potential Savings
Up-Front (One-Time)	» Higher vehicle purchase cost. » Charging or fueling infrastructure costs (hardware, software, installation, infrastructure upgrades, maintenance, and support).	» Tax credits, rebates, and/or other Federal and state incentives to support vehicle and infrastructure acquisition and installation.
Annual/Ongoing	» Trucking-as-a-service contracts. » Operational changes necessitated by reduced range or payload (if any).	» Fuel cost savings. » Maintenance cost savings.

4.1.1 Up-Front Costs and Cost Savings

Depending on vehicle class, new MHD ZEVs typically cost between $50,000 and $400,000, roughly 30 to 200 percent more than a conventional or diesel truck or bus, with the price differential increasing based on the weight class, conventional vehicle payload, and range of the vehicle. Table 4.2 compares typical costs for some commercial vehicles with comparable ZEV offerings currently on the market. This current price differential is expected to decline as technology matures and manufacturers offer vehicles at scale. Prices of batteries—the primary cost premium for a ZEV compared to diesel trucks—are expected to fall by more than half, from over $200 per kilowatt-hour (kWh) in 2024 for heavy commercial vehicles to under $100 per kWh by 2030.[27] This cost decline is due to a combination of changes in battery chemistry and falling costs of critical minerals, manufacturing and engineering improvements, and increasing demand for batteries across MHDV and other electric supply chains. In some cases, smaller and shorter-range vehicles, such as Class 2b/3 trucks and vans, have already reached cost parity with gasoline or diesel counterparts; additional market segments will likely reach cost parity by 2030.[28] In the first half of 2024, ZEV truck sales exceeded 10 percent of the market in the cold-climate country of Norway, and 6 percent in Sweden.[29]

TABLE 4.2 CURRENT TYPICAL PURCHASE COSTS FOR CONVENTIONAL AND ZEV MHDVS

Vehicle Type	Conventional Vehicle Cost	ZEV Cost
Class 2b cargo van	$45,000	$51,000
Class 3 step van	$53,000	$89,000
Class 6 box truck	$97,000	$212,000
Day cab tractor	$180,000	$425,000
School bus	$130,000	$399,000

Source: CALSTART. Note that Class 2b vehicles are not considered in this study, but costs are shown for illustrative purposes as some vehicle platforms serve both Class 2b and Class 3 segments.

Vehicle and fleet owners will also need to purchase and install charging equipment. Level 2 chargers supplying 19.2 kilowatts (kW) and suitable for overnight charging of a medium truck

[27] Bloomberg New Energy Finance with the Smart Freight Centre. Zero-Emission Commercial Vehicles The Time Is Now: A Factbook for Investors (2024).

[28] Ibid.

[29] Ibid.

or school bus range in price from $500–$5,000 per port for hardware[30] depending upon factors such as the power level, whether the unit is networked (connected to the internet), capable of managed charging, two-directional (allowing vehicles to participate in V2G operations), or mounted on the wall versus a pedestal. Installation costs can also range from $500–$5,000; typical costs may double if transformer upgrades are needed, and increase further if 3-phase power is required to be brought in to the charging site. A typical Level 3 or DC fast charger, supplying 50 to 150 kW and suitable for overnight charging of full-size transit buses and heavier trucks, can range from $25,000 to $75,000 for hardware and $25,000 to $45,000 for installation and transformer upgrades. Additional costs related to utility power requirements and local grid capacity, also known as "make-ready" costs, could be incurred depending upon the site (see Section 4.2.1 for additional discussion of make-ready costs). Table 4.3 shows a typical range of infrastructure costs per charging port, broken out by hardware, installation, and utility-side make-ready work. These costs reflect commercial-grade, networked equipment suitable for MHDV depot charging site installation. In addition, annual maintenance costs are estimated to be approximately 10 percent of hardware costs, a figure that includes repair and/or replacement of equipment at the end of its lifetime. As noted, costs may vary considerably depending upon site and fleet requirements. See Appendix G for additional details and documentation of cost assumptions.

TABLE 4.3 TYPICAL RANGE OF PRIVATE INFRASTRUCTURE COSTS PER PORT

Component	Level 2 Depot (19.2 kW)	Level 3 Depot (50–100 kW)
Charging station hardware	$1,000–$5,000	$25,000–$65,000
Installation & local infrastructure	$1,000–$4,900	$10,000–$28,000
Utility-side make ready	$2,700–$4,900	$18,000–$28,000
Total per port	**$4,700–$14,800**	**$53,000–$121,000**

Source: Multiple sources as documented in Appendix G.

Federal and state incentives are available to offset up-front purchase costs. For example, the Federal Clean Commercial Vehicle Credit provides a tax credit of up to $7,500 for Class 3 vehicles and up to $40,000 for larger ZEVs.[31] Additionally, in September 2024, EMT announced $500,000 in total funding through the Medium- and Heavy-Duty Battery Electric Vehicle Demonstration Project, to help fleets purchase and place into operation at least one Class 3–

[30] Car and Driver. Tested: Best EV Chargers for 2024. Accessed October 2024.

[31] Internal Revenue Service. Commercial Clean Vehicle Credit. Accessed October 2024.

7 EV. Vehicle incentives range up to $40,000 to $120,000 depending on the weight class, and Level 2 chargers are eligible for an incentive of up to $3,000 per plug; technical support costs, including consultants, project management, electrician support, and other costs, are also eligible for incentives up to $15,000. For charging infrastructure, the Federal Alternative Fuel Vehicle Refueling Property Credit can provide 30 percent of the cost up to $100,000 for the installation of charging infrastructure (depending on location and labor practices). Finally, in June 2024 EMT announced funding for Level 2 EV chargers at large workplaces, community locations, and regional service centers – some of which could serve MHDV charging.

Leasing instead of purchasing a vehicle can help to minimize up-front purchase price impacts, as well as any risks associated with resale value uncertainty. It is not uncommon for fleet and vehicle owners to lease vehicles; and many OEMs, including Daimler[32] and Ford,[33] offer lease options for MHD ZEVs. Loans are another way of spreading purchase costs over a longer time period.

Up-front costs for vehicle purchase and charging or fueling infrastructure can also be converted to annual costs through contracts sometimes known as "trucking-as-a-service" (TaaS). In this model, the service provider offers a bundled price for ZEVs and charging that is equal to or lower than a diesel alternative. The company also provides the financing to capture long-term savings to offset upfront costs, and can provide active refueling services—guaranteeing a fully-charged vehicle at the time it is needed. In addition to delivering ZEVs with upfront cost parity to diesel vehicles, this solution provides the simplicity of a turnkey model, where fleet operators simply drive the trucks and the service provider takes care of everything else.

4.1.2 Costs and Cost Savings Over Time

Electric trucks and buses save on fuel/energy costs due to their much higher "well-to-wheel" energy efficiency. Battery EVs experience fewer drivetrain energy losses compared to diesel or gasoline vehicles, where much of the energy is lost in the form of heat and does not get transferred to useful work. Electricity costs may also be cheaper per unit of energy supplied compared to diesel or gasoline, if rate structures continue to be favorable or the site host

[32] Daimler Financial. "FMV Lease." Accessed October 2024.

[33] Ford. "Fleet Financing from the Fleet Experts". Accessed October 2024.

can generate and use renewable electricity on-site. A typical Class 3 electric van driven 12,300 miles annually in 2024 in Maine would save roughly $230 annually in fuel costs compared to a gasoline powered van,[34] while a typical electric Class 8 day cab driven 41,300 miles annually in Maine in 2024 would save roughly $16,000 annually in fuel costs compared to a diesel powered day cab.[35]

ZEVs also deliver operational savings through reduced maintenance costs. Both batteries and hydrogen fuel cells have fewer moving parts than internal combustion engines; this mechanical simplicity results in less required maintenance, and certain predictable cost savings, such as no oil changes, less brake wear due to regenerative braking, and no exhaust system. Currently, however, there are few local trained ZEV technicians in Maine, so accessing maintenance when needed can be challenging. As state governments and industry partners continue to invest in workforce development initiatives and manufacturers begin to sell ZEVs, the local maintenance force will grow to accommodate the increasing number of MHD ZEVs on the road. An October 2024 announcement by Volvo Trucks North America highlighted that O'Connor Motor Company was the first dealership in Maine to become a Volvo Trucks Certified EV Dealer, after completing the in-depth training program requirements offered by the OEM.[36]

Specific fleets may experience other potential costs or savings. For example:

- A fleet operator may incur additional logistics costs due to limited ZEV ranges and/or payload capacity for early-model ZEVs. These costs can be minimized or avoided by focusing ZEV roll-out on applications where ZEV range and payload is fully consistent with the operator's current requirements, and by planning delivery and travel routes to take advantage of "top up" charging at publicly accessible fast chargers to extend vehicle range.
- Charge management software helps fleets maximize cost savings by optimizing charging schedules, reducing demand charges, and ensuring efficient energy use. This software

[34] Based on an average battery capacity of 173 kWh and rated range of 160 miles equivalent to a fuel economy of 1.08 kWh/mile; and factoring in Maine's 2024 transportation electricity cost of $0.18/kWh for the electric option compared to 20 miles per gallon (mpg) fuel economy and $3.56/gallon fuel cost in Maine for the gasoline option. The estimated electricity cost includes demand charges.

[35] Based on an average battery capacity of 404 kWh and rated range of 185 miles, equivalent to a fuel economy of 2.183 kWh/mile; and with fuel costs as assumed in the previous example.

[36] TruckingInfo. "Volvo Trucks Celebrates Electric Truck Milestone." Accessed October 2024.

can schedule charging during off-peak electricity hours and avoid expensive demand charges by prioritizing vehicle charging based on availability and route requirements.[37] This in turn lowers utility costs significantly while providing more insight into energy consumption to help fleet managers plan better.

» Battery performance and state of health (the maximum amount of energy a battery can hold expressed as a percentage of its starting energy capacity) degrades over time, and batteries may need to be reconditioned or replaced during the useful life of the vehicle. Despite improving battery economics, a conservative rule of thumb is that today's batteries will lose about 5 percent of capacity per 1,000 equivalent charge cycles (based on CALSTART industry data). However, manufacturers are likely to warranty their batteries for some period of time which can reduce the risk to the owner, and such warranties are common practice for the first three to five years of a vehicle's life to protect against technical failures in the battery. Optimized charge management can also minimize battery degradation. As batteries degrade and the vehicle's range lessens over time, the vehicle may need to be reallocated to conducting shorter routes if sufficient charging infrastructure is unavailable; eventually the battery may degrade so much that the vehicle is no longer considered useful and needs to be retired or the battery pack replaced. Depending on intensity of use and the speed of battery degradation, this may occur as early as 7 to 10 years into the vehicle's operating life. However, this degradation rate is expected to lessen over time as battery technology improves, effectively extending the useful lifetime of the battery EV.

» Resale value of MHD ZEVs is not yet well-established. As ZEV performance and durability is fully proven in practice, it is expected that resale value will increase to be more consistent with conventional vehicles. In the meantime, resale values can be estimated based on valuation of individual components, including second-life batteries. Companies like Zenobé are using refurbished EV batteries to create temporary/portable power sources that serve as a clean alternative to diesel generators.[38] Based on this approach, the

[37] Commercial electricity rates are typically based on a combination of hourly rates (per kWh) and demand charges. Demand charges are applied monthly based on the maximum power draw (measured in kW) from the customer in that month.

[38] Zenobe. "Second-life Batteries." Accessed October 2024.

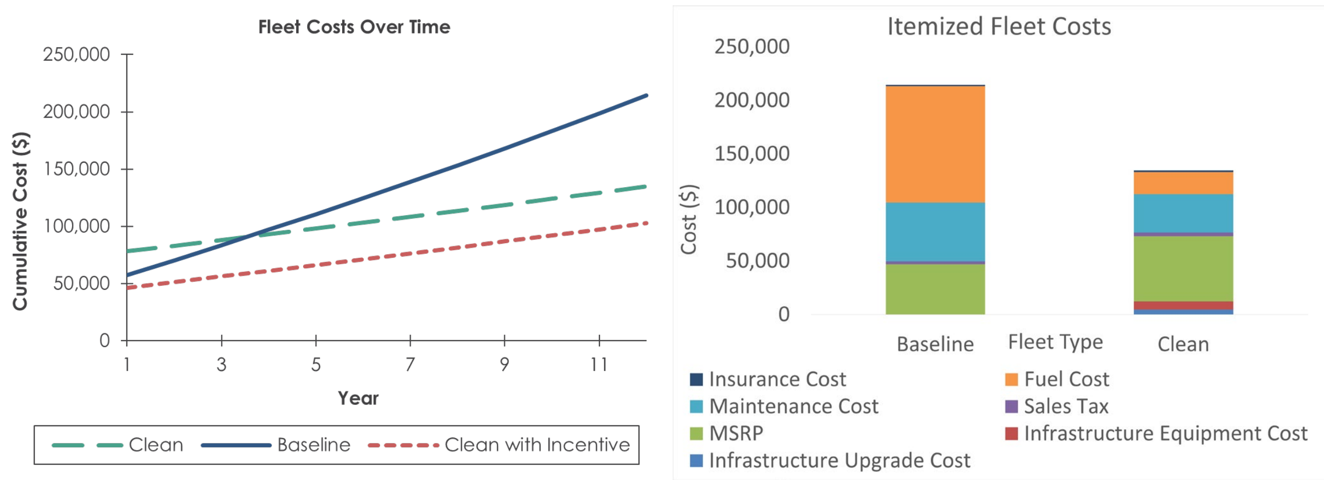
resale value of a typical Class 8 battery electric tractor can be competitive with that of a comparable diesel truck.[39]

4.1.3 Total Cost of Ownership Comparison

As part of the roadmap development, case studies were conducted with four vehicle fleets in Maine to examine different ZEV use cases. The case studies included "total cost of ownership" (TCO) analyses, calculating total costs and savings over the life of the vehicles (estimated at 12 years). This section illustrates how TCO compares for two representative but very different fleets. Additional examples are provided in Appendix B, and full case studies are available for review by interested parties.

Fleet 1 includes Class 3 gasoline transit vans that drive 96 miles a day or 25,000 miles a year. Due to the comparatively low retail price for an electric model ($61,000, versus $47,000 for a gasoline van), significant savings are projected over the vehicle's life. The EMT incentive for this electric or "clean" van would be 40 percent of $61,000, or $24,400. For this vehicle model, the ZEV ("clean") reaches cost parity with the gasoline "baseline" vehicle after year 3 without the EMT incentive, or in year 1 with the incentive (Figure 4.1).

FIGURE 4.1 TCO COMPARISON—MAINE FLEET 1

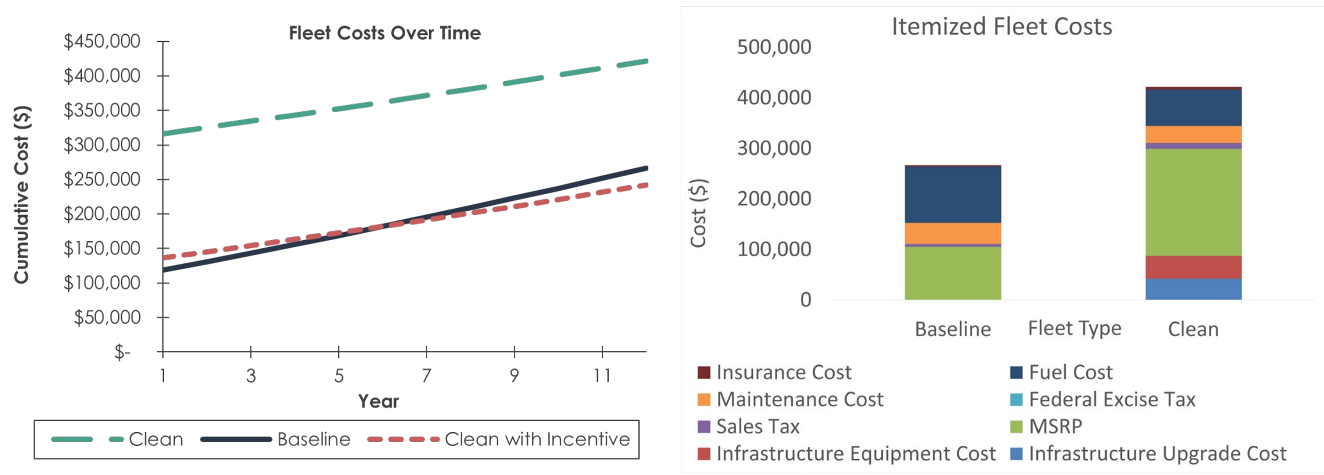


Source: CALSTART analysis based on data for a Maine-based fleet.

[39] CALSTART offers a tool available to industry partners interested in benchmarking residual values of a wide range of battery electric trucks, from delivery vans to regional haul Class 8 tractors. See: https://calstart.org/bet-component-residual-values/.

Fleet 2 includes Class 6 straight (single frame) trucks that drive 19,000 miles per year. Due to the high upfront capital costs and infrastructure upgrade costs, these trucks achieve cost parity in year 6 (Figure 4.2). This analysis compares a diesel truck with a purchase price of $105,000 with an electric truck at $212,000. The EMT incentive for this electric truck would be the maximum value for Class 6 of $100,000, and the $40,000 Federal tax credit is also included. This analysis assumes a $4.00/gallon price of diesel and an $0.18/kWh price of charging. The electric truck produces an estimated 22 percent savings ($760) in annual maintenance costs. The analysis includes estimated charging infrastructure costs of $87,050 upfront. Because the vehicle is Class 6, the proposed charging infrastructure is a 50-150 kW depot DC fast charger.

FIGURE 4.2 TCO COMPARISON—MAINE FLEET 2



Source: CALSTART analysis based on data for a Maine-based fleet.

Looking more broadly across the industry, a recent report[40] offers TCO comparisons for various truck classes, considering vehicle purchase and operating costs (but not infrastructure). The report projects greatly improved economics for ZEV options in 2030 as compared to 2025. For a Class 4 or 5 truck, the average cost per mile over the vehicle's life can already be comparable between an electric and diesel truck, depending on fuel and electricity costs. In 2030, a battery electric Class 4 or 5 truck is likely to have a lower cost per mile than a diesel truck. For a Class 8 truck, the average EV cost per mile is likely to be somewhat higher than a diesel truck in 2025, but may be comparable in 2030 depending on electricity and fuel prices.

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[40] Bloomberg New Energy Finance and Smart Freight Centre (*ibid*).

4.2 Costs to Upgrade the Electricity Grid

Adoption of MHD ZEVs will increase the load over time on Maine's electricity grid, and may require localized infrastructure upgrades to handle increased electrical loads at depots and public charging sites. In the long run, as electricity use expands due to electrification of transportation and building heating and cooling, Maine will require additional clean energy generating capacity. Managed charging, or vehicle charging that is planned to occur at times when the grid has excess energy available, provides a valuable opportunity to constrain the need for electricity infrastructure and the associated costs over time—as well as a potential revenue source for fleets, as V2G technology becomes integral to helping balance electricity supply and demand.

4.2.1 Infrastructure Upgrades

Electricity consumption by MHD ZEVs in Maine is expected to range between 79,000 and 138,000 mWh in 2030, and 556,000 to 1.3 million mWh in 2040, depending upon the ZEV adoption scenario modeled in this roadmap (Moderate to Advanced). For comparison, the 2040 range is comparable to the electricity currently used by 50,000—117,000 homes, or 5 to 11 percent of Maine's total 2022 electricity demand. About 80 to 85 percent of this electricity is expected to be used at depots or individual overnight charging sites, with the remainder used at publicly- accessible charging sites where vehicles stop on-route.[41]

Depot charging will be served by a mix of Level 2 chargers and fast chargers, with Level 2 chargers likely to require fewer electrical upgrades due to their lower power supply, ability to be served by single phase power at small sites, and lower complexity to install and manage. A typical MDT or school bus, traveling less than 100 miles a day on average, can meet its daily needs with about 4 hours of Level 2 charging supplying 19 kW of power, meaning that two or even three vehicles could share a charger over a 12-hour overnight period. An HDT, transit bus, or vehicle in long-distance service (more than 150 miles a day) may require a shared or dedicated higher-power charger (Level 3, or 50 to 150 kW) to meet its needs while at the depot due to both higher power requirements and shorter overnight dwell times. Since costs per kW can increase as power levels increase, optimizing charging to minimize the need for

[41] Estimated from assumptions about the mix of public vs. private charging specific to each market segment evaluated in this roadmap, as based on ICCT (2023). Near-Term Infrastructure Deployment to Support Zero-Emission Medium- and Heavy-Duty Vehicles in the United States. See Appendix G for details.

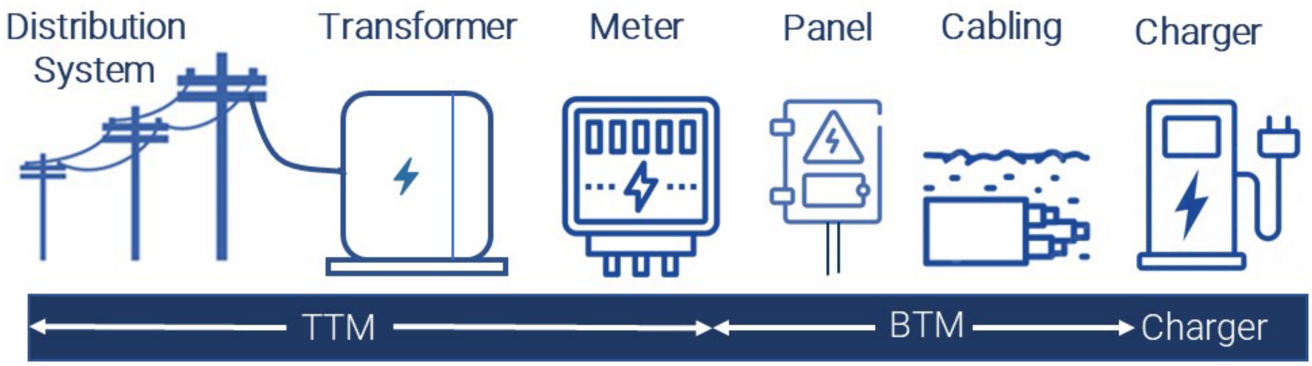
high-power investments is one key to making charging economical for the fleet operator, as well as minimizing power demands on the grid. While this requires operational planning by the fleet, smart chargers make such charging optimization easy and affordable.

Currently, the state helps subsidize the cost of many publicly available charging sites through a combination of generous Federal funding and state funding. Maine administers this funding in partnership with private entities who provide charging services; these entities gather revenue through charging vehicles to refuel. Public charging stations serving MHDVs will generally provide high-powered charging (50 kW or higher). Chargers in the 50–100 kW range could provide overnight charging at truck parking areas, and chargers with power levels of 350 kW to 1 MW would allow quick (20 to 30 minute) on-route charging.

In Maine, 150 kW public charging stations are being constructed along major travel corridors with the support of the Federal National Electric Vehicle Infrastructure (NEVI) Program and the Charging and Fueling Infrastructure (CFI) Discretionary Grant Program. EMT and the Maine DOT have incorporated pull-through considerations for vehicles towing trailers and medium-duty vehicles into their evaluation criteria for NEVI and CFI proposals. As of November 2024, Maine has awarded four NEVI charging sties —located in Augusta, Searsport, Waldoboro, and Bangor—that feature pull-through charging spots. However, each parking lot may have different capacities for handling larger vehicle types. The NEVI and CFI 150 kW pull-through charging stations in large parking lots will be able to support those medium-duty vehicles that are anticipated to electrify first. Maine also applied for Round 2 of the CFI program in August 2024, which includes plans for four medium-duty vehicle charging sites around the state, each featuring both fast (150 kW) and ultrafast (350 kW) charging stations.

Infrastructure upgrades can be separated into “customer-side” and “utility-side” upgrades, relative to the electricity meter at a property. As shown in Figure 4.3, customer-side upgrades may include electrical panels and cabling; utility-side upgrades commonly include new transformers and cabling, and may include other elements such as upgrading from single-phase to three-phase power. Infrastructure upgrades are commonly known as “make-ready” work. Currently in Maine, there is no provision for utilities to cover costs associated with make-ready work, so the customer must cover costs on both sides of the meter, with the assistance of any Federal and/or state incentives available.

FIGURE 4.3 UTILITY INFRASTRUCTURE TO SUPPORT MHDV CHARGING



Source: Cadmus. Note—in this example, utility-side is referred to as TTM (to-the-meter) and customer-side is referred to as BTM (behind-the-meter).

Recent pilot programs in Maine, conducted by both investor-owned utilities, have found make-ready costs (including both sides of the meter) to be in the range of $140 to $400 per kW of installed capacity for Level 2 and Level 3 fast charging sites up to 150 kW. These ranges are generally consistent with other sources suggesting costs of $100—$700 per kW, although one study in California found costs as high $1,200 to $1,900 per kW, possibly a result of higher-cost sites applying for state support (see Appendix G for documentation of sources). It is important to remember that costs vary *widely* from site to site; vehicle owners and operators should engage with their utility counterparts early in the planning process to understand site-specific challenges and opportunities for efficient siting and use of chargers.

Table 4.4 shows a typical range of public infrastructure costs per publicly-available charging port, broken out by hardware, installation, and utility-side make-ready work. These costs are estimated from various sources as documented in Appendix G, and reflect commercial-grade, networked equipment suitable for MHDV public charging site installation. In addition, annual maintenance costs are estimated to be approximately 10 percent of hardware costs, a figure that includes repair and/or replacement of equipment at the end of its lifetime. As noted, costs may vary considerably depending upon site requirements.

TABLE 4.4 TYPICAL RANGE OF PUBLIC INFRASTRUCTURE COSTS PER PORT

Component	150 kW Public	350 kW Public	1 MW Public
Charging station hardware	$55,000–$75,000	$130,000–$190,000	$300,000–$400,000
Installation & local infrastructure	$17,000–$43,000	$39,000–$57,000	$75,000–$100,000
Utility-side make ready	$28,000–$42,000	$105,000–$175,000	$400,000–$500,000
Total per port	**$99,000–$160,000**	**$274,000–$422,000**	**$775,000–$1,000,000**

Source: Multiple sources as documented in Appendix G.

Table 4.5 shows the estimated cost for publicly available charging infrastructure through 2040 under each ZEV scenario. The range considers variations from low to high costs, as shown above. An average of $4 to $6 million will be needed per year through 2040 to provide adequate charging infrastructure to serve the 15 to 20 percent of charging demand projected to be met at publicly available sites under the Moderate scenario, an average of $5 to $7 million per year will be needed to serve the High scenario. This is already within the range of Maine's current (2024) annual investments in publicly-accessible charging, funded by state and federal sources; additional capital will be needed to expand this infrastructure to better serve trucks and buses.

Owners of sites with publicly-accessible, fee-for-service chargers will generate revenue from charging. Table 4.5 also shows the gross revenues expected to accrue to charging site owners at current charging rates. While some of the revenue will cover the marginal costs of purchasing the power (i.e., the electric rate), some of this revenue will also accrue to help cover infrastructure as well as site operation and maintenance costs. Rates for fast charging at public sites in Maine are currently around $0.50 per kWh. Under the Moderate scenario, public fast charging would generate an average of nearly $7 million per year through 2040, a portion of which could offset the capital investments needed for these sites. Revenues would start out low but increase over time as utilization increases.

TABLE 4.5 ESTIMATED COSTS AND REVENUES FOR PUBLIC MHDV CHARGING INFRASTRUCTURE THROUGH 2040

Number or Cost of Chargers	Moderate	High	Advanced
Public chargers needed by 2030	45	85	90
Public chargers needed 2031–2040	250	250	750
Average annual infrastructure cost through 2040 ($M)[1]	$4.2–$6.1	$5.2–$7.4	$10.7–$15.7
Average annual charging revenue through 2040 ($M)[2]	$6.8	$8.8	$17.2

[1] Includes hardware, installation, customer-side and utility-side upgrades, and annual maintenance at 10 percent of hardware costs.

[2] Gross revenues at $0.50 per kWh, before variable expenses such as electricity, networking, and maintenance.

Hardware, installation, and infrastructure costs for depot sites are considered to be private costs that are factored into the total cost of ownership consideration at vehicle purchase, as discussed in Section 4.1. However, some states have introduced mechanisms which allow utilities to at least partially cover make-ready programs for private and/or public-sector customers. For comparison, the utility-side make-ready costs needed to support private depot charging are estimated to range from an average of just under $1 million per year under the lower-cost end of the Moderate scenario, up to $3.3 million per year under the Advanced scenario with high costs, between now and 2040.

Maine's utilities will also generate revenue from electricity consumed by public and private depot customers charging trucks and buses. Electricity rates in Maine are currently set to cover capital and operating costs for generating, supplying, and delivering the electricity; these do not include "make-ready" costs to upgrade distribution lines and equipment for MHDV charging (or other purposes). Charging that occurs outside of peak periods can be considered a "beneficial load" since it provides revenue without requiring additional generating or transmission capacity, thereby suppressing the rate that electric utilities need to charge to recover their fixed costs in the transmission and distribution system. Because of their potential for off-peak charging, *Maine Won't Wait* identifies EVs as contributing to beneficial electrification goals. In addition, a share of utility revenues from charging could meaningfully contribute to the utility-side make-ready work that is needed, were the utilities asked or allowed (by regulators) to account for this increased direct revenue in their infrastructure capital planning.[42]

4.2.2 New Generating Capacity

The extent to which new electricity generating capacity is needed will depend upon the degree to which MHDV charging can be managed to minimize use at times when electricity use by other users is highest, also known as peak period demands. In Maine, Versant has established optional time-of-use rates defining the peak period as 7 a.m. through 9 p.m., while Central Maine Power has defined peak periods as 7 a.m. to 12 p.m. and 4 p.m. to 8 p.m.[43] Additionally, in September 2024, the Maine Public Utilities Commission (PUC) opened an inquiry (Docket No. 2024-00231) to consider the implementation of time-of-use rates for standard offer and delivery service for customers of Maine's investor-owned utilities.[44] "Smart" or managed charging technologies, on-site energy storage, and rate structures that incentivize off-peak charging can help to limit peak demand increases and the need for additional generating capacity required to be available to meet the maximum possible demand. Some studies have found that EVs can actually benefit utilities by increasing off-peak loads and utility revenues without requiring additional, expensive peak capacity investments.[45]

The GEO, PUC, EMT, and the state's investor-owned utilities are currently collaborating on integrated grid planning studies. These studies are intended to assist in the cost-effective transition to a clean, affordable, and reliable electric grid.[46] Among other issues, the studies

[42] To provide a sense of scale, the average cost per kWh estimated in recent bus electrification transition studies for Maine transit operators would be about $0.15 to $0.22 (including per-hour and monthly demand charges) under current or proposed EV rate structures. At this rate, an annual average of about $7 to $10 million would be generated from depot charging through 2040 under the Moderate scenario. As noted, the cost per kWh will vary widely depending upon how demand charges are applied and any time-of-use rates; and those funds would not currently be eligible for use on make-ready work. See Appendix G for detailed assumptions and sources.

[43] Versant Power, Maine Public District: Subtransmission Power Service—Time Of Use Rate S-T; Central Maine Power, Optional Targeted Service Rate B-CPT.

[44] https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2024-00231

[45] Synapse Energy Economics (2024). Electric Vehicles Are Driving Rates Down for All Customers. Note that this study primarily reflects experience with light-duty EVs; the effects of medium- and heavy-duty EVs may vary depending upon their charging patterns and how charging is managed to support off-peak versus peak-period demand.

[46] https://www.maine.gov/energy/initiatives/gridplanning; https://www.maine.gov/tools/whatsnew/index.php?topic=puc-pressreleases&id=12895749&v=article088.

consider EV forecasting, advanced metering infrastructure to support managed and smart charging as well as other load management, and reliability and resilience improvements to better ensure that service is maintained in the event of weather-related or other disruptions. In addition, Maine continues to work to increase the amount of electricity generated by solar, wind, and other renewable source across the state; Maine's Renewable Portfolio Standard requires 80 percent of Maine's electric use to be from clean generation sources by 2040; the Governor has set a directive of 100 percent clean energy consumption in that same timeframe. As Maine's grid gets cleaner and more MHD ZEVs operate in Maine, the GHG impact from each vehicle will decrease.

V2G INTEGRATION

V2G integration describes a system in which EVs charge during off-peak times when electricity demand is low, and either deliver electricity back to the grid or reduce the rate of draw from the grid during times of peak electricity demand. V2G goes beyond simple managed charging, in which a fleet owner programs a vehicle to charge in off-peak periods when reduced rates are available.

V2G is enabled by bidirectional charging stations as well as smart meters that communicate with the grid, while also accounting for the vehicle's operational requirements (i.e., when it needs to be fully charged). V2G has been identified as a potentially important technology to help mitigate the increasing demand for electricity that EVs will create. It can help level peak loads and reduce the need for investment in generating capacity. Its value will increase in the future as intermittent renewable energy sources including solar and wind become a larger part of the energy base, as V2G can help store energy from those sources during times of high solar or wind production and feed energy back to the grid during times of low production.

While pilot V2G studies funded by the U.S. DOE have been undertaken using school buses in California, the technology still faces significant obstacles such as the costs of investing in a "smart grid" and bidirectional charging stations, and lack of regulatory consistency from state to state. The State of Maine should monitor the status of V2G research and development nationwide and coordinate with its utilities on research, policy, and incentive development to better understand the benefits, costs, barriers, and opportunities for this technology to support MHD EVs and grid reliability in Maine.

5

POLICIES AND PROGRAMS NEEDED TO TRANSITION TO ZERO-EMISSION VEHICLES

5.1 Opportunities and Challenges for Medium- and Heavy-Duty Zero-Emission Vehicles

As part of this roadmap, key stakeholders across the MHDV industry and supply chains were asked about the ZEV transition. The findings in this chapter reflect conversations across nearly 20 individual interviews and eight focus groups. The goal of the conversations was to learn from those involved in day-to-day truck and bus operations, identify common challenges, and better understand perspectives on, and questions about, clean trucks and buses along with charging and fueling infrastructure. Appendix C provides more detail on the individuals and organizations engaged.

Key *opportunities* associated with MHD ZEVs include:

» **Sustainability goals—**Several fleet operators acknowledged that the trucking industry overall is heading toward electrification, even though these vehicles are still new in Maine. Key drivers of this transition include corporate and municipal net-zero/low-emissions goals, as well as Advanced Clean Trucks and Advanced Clean Fleets regulations adopted in some other states.

» **Potential long-term cost savings—**Many fleet operators describe themselves as "fuel-agnostic" and are open to ZEV adoption if it makes business/financial sense. As more MHD ZEVs become available to purchase, are proven to meet performance requirements, and charging infrastructure becomes widely available, fleets will feel better about investing in these technologies.

- **Funding—**Several Federal and state funding sources already exist to support purchases of ZEVs and charging infrastructure, including programs administered by EMT and the Federal Government. Fleet operators who can procure grants or manage upfront vehicle costs are better able to feel the benefits of lower ZEV operating costs.
- **Low-hanging fruit—**Vehicles with relatively short and well-defined routes, which return "home" to a depot at regular intervals, and which have commercially available ZEV alternatives are the best candidates for early electrification. Examples include buses, short-range delivery and service trucks operating in more densely populated areas, and yard and drayage trucks. They also increasingly include longer-distance tractors. While these vehicle types and use cycles may be most suitable for early electrification, individual fleet operational characteristics, and the availability of models meeting performance requirements at a reasonable price point, will determine whether electrification is both operationally and financially viable.

The primary *barriers* that stakeholders perceive to ZEV adoption include:

- Concerns about **limited range** and impacts of cold weather. A battery range of 200 miles or less is not operationally suitable for many fleets, especially when adequate charging station infrastructure does not exist along most routes.[47]
- Lack of **maintenance providers** and long lead times for procurement and repair. When a truck or bus needs repair, fleet operators need to trust that someone can make the repairs locally and in a timely manner so that the vehicle can return to service as soon as possible. While EV-ready service shops are increasing in Maine, more are needed.
- High upfront **costs**, operating cost uncertainty, and uncertain resale potential. There are limited grant opportunities available for private-sector fleets; and many operators are not familiar with, or lack capacity to apply for, the Federal commercial clean vehicle tax credit. Many fleet operators purchase new trucks with the intention of reselling them

[47] As noted in Chapter 2, based on registration and national survey data the average daily range of a Maine-registered truck is less than 100 miles, but there is wide variation across vehicles and uses. In the case studies of four Maine-based fleets conducted for this roadmap, four use cases had daily ranges of less than 100 miles; five had ranges of 100 to 200 miles; and six had ranges of over 200 miles.

within a few years, and they know what price they can get for them; the resale market has not yet evolved for ZEV trucks, making it hard to plan for residual value.

- Lack of **charging infrastructure**, inconsistent electricity pricing, and concerns about grid reliability. Maine is a rural state, and—while disguised by the sector mileage averages above—some trucks may need to drive hundreds of miles each day. In some areas of Maine, the grid already struggles to meet power needs, resulting in frequent black-outs, and there are concerns that rapidly growing vehicle charging needs could challenge an already strained system.

5.2 Recommended Policy and Program Options

Accelerating the transition from diesel- and gasoline-powered trucks and buses to zero-emission alternatives requires a suite of supportive policies. While both carrots (incentives) and sticks (regulations/fees) have proven effective, a coordinated array of policy actions can facilitate a faster, more cost-effective transition to MHD ZEVs. This section addresses the categories of policy critical to decarbonizing trucks and buses, identifies Maine's progress to date, and offers actionable recommendations for next steps that will achieve near-term impacts.

Maine's current and potential future policies and programs to support MHD ZEVs can be considered in seven categories:

- Targets for ZEV adoption.
- Vehicle incentives.
- Infrastructure support.
- Fleet advisory support.
- Regulations.
- Economic development programs.
- Other innovative policies.

Table 5.1 identifies and describes seven types of policies or programs, identifies current or completed Maine policies or programs in that category, and provides recommended additional policies or programs for Maine to consider for adoption and implementation. Maine can build on successful implementation of these recommendations from other states, while tailoring them to the state's unique needs. Appendix A provides additional examples of programs implemented in other states.

TABLE 5.1 CURRENT AND RECOMMENDED MAINE POLICIES AND PROGRAMS TO SUPPORT MHD ZEVS

Policy Type	Justification	Current	Recommended
Target Setting	» Target setting establishes clear vision and sends signal to industry that Maine is open for ZEV business.	» Multi-state NESCAUM-led MHD ZEV memorandum of understanding. » Statutory clean school bus sales goal.	» Establish "lead by example" MHD ZEV targets for the state-owned fleet. » Complete a MHD state fleet transition plan.
Planning	» Provides a baseline of knowledge to support cost-effective policies and investments.	» Clean transportation roadmaps, NEVI Plan, PUC-led integrated grid planning.	» Continue stakeholder engagement after this roadmap is published. » Update and expand NEVI Plan guidance for MHD infrastructure. » Monitor and participate in planning for regional hydrogen infrastructure development.
Vehicle Incentives	» Helps to mitigate up-front cost differential for ZEV versus conventional vehicle.	» EMT work van incentives and MHD Pilot. » Federal tax credits.	» Develop a MHD ZEV voucher incentive program. » Assess opportunities for state tax credits.
Infrastructure Support	» Infrastructure costs pose an additional up-front cost barrier for fleets. » Coordinated planning between utilities, industry, and Government is critical.	» Central Maine Power "make-ready" pilot. » EV alternative charging rates.	» Convene MHD ZEV infrastructure stakeholder forum. » Develop MHD ZEV charging and fueling voucher incentive program. » Explore development of utility-run MHD infrastructure incentives. » Build on PUC proceedings requiring EV charging rates.
Fleet Advisory Support	» Fleet electrification can be challenging; support programs make transition more widely accessible.	» Central Maine Power electric school bus support.	» Launch no-cost MHD ZEV fleet advisory program.
Regulations	» Complement incentives to drive faster adoption of MHD ZEVs; may be necessary to meet emissions targets.	» None.	» Track MHD ZEV deployment in Maine and other states with clean truck regulations and their impact on MHDVs traveling to Maine.
Economic Development	» Train a new generation of workers and transition existing workers to service ZEVs and infrastructure.	» Workforce initiatives through community colleges, Maine Won't Wait, Clean Energy Partnership, Federal grants.	» Explore offering manufacturing tax credit for green investments. » Expand EV job training programs. » Expand Clean Energy Partnership clearinghouse to increase focus on the ZEV industry.
Innovative Policies	» Expand beyond what might be achieved through other actions.	» Regional Greenhouse Gas Initiative (RGGI). » Weight exemption for auxiliary power units (400 lb.).	» Evaluate potential allocation of RGGI funds to support strategic investment in MHD ZEV programs. » Plan for heavier MHD ZEVs on the road.

5.2.1 Target Setting

Setting clear goals and timelines for the transition to MHD ZEVs sends a critical signal to stakeholders, such as fleet operators, vehicle dealers, and other industry participants, about the state's objectives and desired outcomes for decarbonizing the transportation sector and improving air quality for Maine communities. By setting and committing to public goals, Maine can demonstrate leadership and signal intent to prioritize action and resources. The current best practice for state MHD ZEV target-setting is the Northeast States for Coordinated Air Use Management (NESCAUM) MHDV ZEV Memorandum of Understanding,[48] which Governor Mills signed on behalf of Maine in 2020. The MHD ZEV MOU establishes aspirational targets for MHD ZEV sales in participating states: 30 percent of new MHD vehicle sales to be ZEVs by 2030 and 100 percent of new MHD vehicle sales by 2050. (The 2030 target falls between the estimated 21 percent sales share under the Moderate scenario and 49 percent under the High scenario in this roadmap.) While these targets are not enforceable, they communicate a vision to industry and set a goalpost for policy-making. Maine also has goals to become a carbon neutral economy by 2045;[49] to establish "lead by example" clean energy and transportation targets for state agencies;[50] and to reduce GHG emissions from the public school bus fleet by 2035.[51]

Recommended Next Steps

» **Establish "lead by example" targets for the state's MHD vehicle fleet—**Maine can build on existing "lead by example" targets for the state's light-duty fleet by establishing similar zero-emission procurement targets for medium- and heavy-duty vehicles. Other states including Massachusetts, Michigan, and New York have set similar directives. Maine should consider adopting the following ambitious yet achievable targets for the state's MHD fleet:

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[48] https://www-f.nescaum.org/documents/multi-state-medium-and-heavy-duty-zero-emission-vehicle-action-plan/.

[49] Maine Office of the Governor (2019). "An Order to Strengthen Maine's Economy and Achieve Carbon Neutrality by 2045." Executive order 10 fiscal year (FY)19/20.

[50] Maine Office of the Governor (2019). "An Order for State Agencies to Lead by Example Through Energy Efficiency, Renewable Energy and Sustainability Measures." Executive order 13 FY19/20.

[51] Maine Revised Statutes Title 20-A S5401, https://www.mainelegislature.org/legis/statutes/20-a/title20-asec5401.html.

- By 2030, 50 percent of newly purchased or leased MHD state fleet vehicles, with appropriate use cases, will be ZEVs.
- By 2040, 100 percent of all newly purchased or leased MHD state fleet vehicles, with appropriate use cases, will be ZEVs.

» To support achievement of the lead by example targets, Maine should **complete a comprehensive MHD fleet transition plan**, detailing vehicles ready for electrification over the next five years and identifying use cases that should be exempted from the target.

5.2.2 Planning

Planners and policy-makers must be coordinated and armed with robust data to achieve MHD ZEV transition targets and meet regulatory compliance standards. As considered in this roadmap, the state must continue to understand changing MHDV populations, user types, travel patterns, and the energy needs of these vehicles to develop achievable decarbonization pathways.

Maine has undertaken a number of planning activities to date including the 2021 Clean Transportation Roadmap for light-duty vehicles; the Maine Integrated Freight Strategy[52] examines statewide, national, and global trends as Maine DOT prioritizes investments and future projects; Maine Won't Wait, the state's four-year climate action plan; the Maine DOT Carbon Reduction Strategy,[53] NEVI Plan,[54] and Long-Range Transportation Plan[55] that guide transportation policy and funding, including planning for EV infrastructure; and the Integrated Grid Planning proceeding to inform priorities for upcoming utility grid plans,[56] supporting a "cost-effective transition to a clean, affordable and reliable grid." Maine is also covered in the Northeast Freight Corridors Charging Plan,[57] a study led by National Grid and

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[52] Maine DOT (2024). Maine Integrated Freight Strategy.

[53] Maine DOT (2023). Carbon Reduction Strategy.

[54] Maine DOT (2023). Maine's Updated Plan for Electric Vehicle (EV) Infrastructure Deployment (Maine's NEVI Plan).

[55] Maine DOT (2023). Working to Move Maine: MaineDOT's Long-Range Transportation Plan.

[56] Maine Public Utilities Commission (2024). Final Report Regarding the Development of an Integrated Grid Plan Pursuant to Public Law, 2021, chapter 702.

[57] National Grid. "Readying the Northeastern U.S. for Electric Trucks: National Grid to Build DOE Funded Roadmap." October 16, 2023, accessed October 2024.

funded by the U.S. DOE to develop 20-year electric truck charging demand forecasts for the northeast and New England states and to help guide investment and policy decisions.

Recommended Next Steps

» **Continue stakeholder engagement—**This roadmap is informed by robust feedback from MHD vehicle stakeholders. Maine GOPIF, DOT, GEO, and other agencies should continue this engagement as the state works to implement the roadmap's action items.

» **Maine DOT should continue to expand NEVI planning and funding to expressly support MHD ZEV charging infrastructure—**The Maine NEVI Plan identifies the need to deliver public charging for MHD ZEVs in the program's later years; revisions to the plan should build on recent work and expand guidance on MHD ZEV investment ahead of the next funding round.

5.2.3 Vehicle Incentives

Despite declining battery costs and new manufacturing investments, higher upfront costs of MHD ZEVs remain a major barrier to broader adoption. Input from Maine fleet operators, provided through focus groups, mirrors national feedback—reducing upfront capital costs of ZEV purchases is the most critical objective to support ZEV adoption at scale. The most direct means of addressing the purchase price is by providing vehicle incentives to partially or fully cover the incremental costs of ZEVs. Vehicle incentives can be delivered in a variety of manners, all of which accelerate deployment of ZEVs and support the growth of early-stage market segments. Incentives can be designed to focus on particular vehicle types or use cases or targeted geographies, and can be adapted based on available funding.

The EMT is currently administering EV rebates for businesses and organizational fleets, which includes rebates for battery electric pickup trucks and cargo vans.[58] As required by the Maine legislature,[59] EMT also recently (2024) launched the Medium- and Heavy-Duty Battery Electric Vehicle Demonstration Project which offers funding for Class 3-7 EVs and Level 2

[58] https://www.efficiencymaine.com/ev-rebates-for-businesses-and-organizations/.

[59] LD 122, An Act to Update the Electric Vehicle Rebate Program and to Establish a Pilot Program to Support the Uptake of Medium Duty and Heavy Duty Zero-emission Vehicles.

chargers for businesses to demonstrate the use and implementation of MHD ZEVs.[60] Other states, including New Jersey, New York, and California also offer MHD voucher incentives.

Recommended Next Steps

- **Develop a statewide MHD ZEV voucher incentive program—**Expand on EMT's limited MHD ZEV incentive offerings by providing statewide access to point-of-sale vouchers for zero-emission Class 3–8 vehicles. Approximately $5 million in initial funding would likely be sufficient to launch a pilot voucher incentive program (VIP) and sustain it for three years, while $10 million would allow for a more robust program with greater funding certainty beyond three years. The initial $5 million could help support approximately 60 to 120 new ZEVs depending upon the average award amount. As a point of reference, there have been 75 approved Massachusetts Offers Rebates (MOR)-EV truck vouchers for Class 3–8 vehicles since the program's launch in late 2021, and 779 Class 2 vouchers.[61] These initial budgets would need to be expanded to support the level of MHD ZEV deployment discussed in this roadmap over the medium and longer term. As discussed in Chapter 6, multiple Federal funding programs created through the Bipartisan Infrastructure Law and Inflation Reduction Act (IRA) offer funds that may be able to be utilized to capitalize a MHD ZEV VIP. Funding opportunities will change as additional programs are reauthorized or discontinued. At the state level, Maine can evaluate dedicating a portion of its Regional Greenhouse Gas Initiative (RGGI) proceeds to fund a MHD ZEV VIP and other vehicle electrification efforts as other states have done.
- **Assess state tax credit options—**Conduct research and begin conversations with stakeholders to determine the feasibility of tax credit options. This would lessen the cost of the vehicle or lease basis by the tax credit amount.

5.2.4 Infrastructure Support

In order to prepare for more ZET and buses on the road, Maine will need to ensure charging infrastructure is effectively and cost-efficiently planned for and built out. This will require ongoing partnership with utilities as well as the private sector, including companies providing charging as a service. This will require continued and expanded engagement by utilities and

[60] Efficiency Maine. "PON EM-006-2025: Medium- and Heavy-Duty Battery Electric Vehicle Demonstration Project," accessed October 2024.

[61] CALSTART, MOR-EV Trucks Dashboard, accessed October 2024.

the Maine PUC in the state's EV planning and preparatory efforts; the PUC could consider a new proceeding to plan for more transportation electrification and to allow utilities to consider new rates and programs for commercial EVs.

Currently, Versant Power offers a "Business Eco Rate" for commercial Level 2 charging stations and battery storage.[62] Maine Public District's General Service and Bangor Hydro District General Service, owned by Versant Power, also offer this rate. The Bangor Hydro District also has a "DC Fast Charging and Storage Eco Rate" for Level 3 charging and battery storage. In 2020 Central Maine Power administered an EV charger make-ready pilot program that provided up to $4,000 in incentives for infrastructure costs for Level 2 chargers and was fully subscribed by 2021. Versant and Central Maine Power also offer time-of-use rates that can lower EV charging costs by reducing rates for off-peak charging. In 2024, Maine was awarded funding from the U.S. DOE's Grid Resilience and Innovation Partnership Program for technology to implement flexible interconnection.

Recommended Next Steps

- **Continue to convene a MHD ZEV infrastructure stakeholder forum—**EV infrastructure planning necessitates close coordination between electric utilities, regulators, state agencies, industry, and nongovernmental organizations. Creating a forum for these stakeholders to engage, identify challenges, and coordinate on solutions is critical to deploying MHD charging infrastructure in a timely and cost-effective manner. Maine can build on nearby examples from Massachusetts[63] and New York[64], as well as on the series of stakeholder workshops convened by the Maine PUC through the Integrated Grid Planning proceeding, and on the work completed as part of this roadmap.
- **Develop a state-administered MHD charging and fueling voucher incentive program—**This incentive could be expanded within EMT's Medium- and Heavy-Duty Battery Electric Vehicle Demonstration Project, or designed as a complementary standalone program focused on MHD ZEV charging equipment at private depot sites with the option to include hydrogen fueling infrastructure. This program can build on existing MHD ZEV

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[62] Versant Power, "Electric Vehicles," accessed October 2024.

[63] Massachusetts Electric Vehicle Infrastructure Coordinating Council.

[64] New York Electric Vehicle Infrastructure and Interconnection Working Group.

infrastructure programs, like the Fleet-ZERO Program in Colorado[65] and EnergIIZE Commercial Vehicles in California,[66] both of which incentivize private depot charging and public charging deployments to serve MHD ZEVs. Initial funding of $3 million would likely be sufficient to launch a pilot infrastructure incentive program and sustain it for three years, while $6 million would allow for a more robust program with greater funding certainty beyond three years. Given the wide range in costs for depot charging projects, incentive caps would need to be established to ensure access (as an example, the Fleet-ZERO program has a cap of $500,000 per applicant). Various Federal funds, discussed below, could be purposed towards a MHD charger program, and Maine could also evaluate dedicating a portion of its RGGI proceeds for this purpose.

» **Explore development of utility-run MHD infrastructure incentives—**The Maine PUC can build on examples of MHD make-ready pilots in other states, and could consider initially approving limited utility funding for projects serving public sector customers, including transit operators and schools, as a way to evaluate program impacts.

» **Build on regulatory proceedings requiring EV charging rates—**The Maine PUC should build on existing EV-rate design orders by asking Maine's electric utilities to design and offer rates specifically for commercial EV charging, enabling consumers to benefit from time-of-use rates and demand charge alternatives. Rate design should include guidance on how to ensure developers installing EV chargers who avoid upgrade costs pay for their fair share of the software and technology. The PUC could also consider adoption of flexible capacity/interconnection utility tariffs, encouraging customers to accept some responsibility for capacity management in exchange for reduced rates, either through utility dispatch or customer management; and providing guidance to ensure that new EV charging loads are one of the use cases for flexible interconnection.

5.2.5 Fleet Advisory Support

Navigating the transition from internal combustion engine trucks and buses to electric and hydrogen alternatives can be complex. While MHD ZEVs offer many benefits over conventional vehicles, their incorporation into a fleet presents a wide range of questions that fleet operators need to be able to answer with confidence. Some early adopter fleets already have the internal experience and capacity to navigate this process comfortably, but

[65] Colorado Energy Office. "Fleet-ZERO EV Charging Grant." Accessed October 2024.

[66] EnergIIZE Commercial Vehicles. Accessed October 2024.

most fleets will benefit from additional support. While external guidance from vehicle manufacturers, dealers, charging equipment installers, and other companies is invaluable, impartial support through state or third-party experts can help fleets evaluate electrification costs, benefits, and vehicle and charging options without pressure to push towards a sale. Given the complexities involved in navigating a fleet transition, particularly for small fleet operators, a trusted advisor with no financial stake in the fleet's decision is a valuable resource. To date, Central Maine Power has offered an electric fleet assessment pilot program for school bus fleets.

FLEET TESTIMONIAL, MASS FLEET ADVISOR

"The Mass Fleet Advisor team has been assisting us with our effort to electrify our fleet of 50+ vehicles since early 2022. The information they have provided to us, such as vehicle options, charging options, and potential rebate programs has been invaluable. As we move closer to transforming our fleet, we are confident we will be doing so with the most up to date information we could possibly have, thanks to this group."

—Steve Senior, Director of Distribution and Services, Woods Hole Oceanographic Institute

Recommended Next Steps

- **Launch a state-administered fleet advisor pilot program—**Fleet advisor programs can start as relatively small pilot programs, allowing a state to understand demand for these services, to target specific fleet types, and to begin with modest funding. An estimated $500,000 would be needed to launch a program in Maine; several Federal funding sources could potentially be used for this purpose. Similar fleet advisor programs are operating in California, Massachusetts, and New Jersey; in Massachusetts alone, over 50 fleets have enrolled in the program over its first two years, receiving no-cost electrification reports, site assessments, and, for those choosing to proceed with vehicle purchases, support navigating procurement and incentives.

5.2.6 Regulations

Setting enforceable requirements for achieving MHD ZEV targets is not a prerequisite for action, but rather serves as an industry accelerator. There are a range of options available to states for implementing clean truck and bus regulations, including the Advanced Clean Trucks rule, Advanced Clean Fleets rule, and Heavy-Duty Omnibus regulation.

Recommended Next Steps

- **Track MHD ZEV deployment in Maine and in states with clean truck regulations—**While state clean truck regulations are likely not feasible to adopt in the two-year timeframe of these roadmap recommendations, Maine should continue to evaluate implementation and track progress in first-mover states. This includes quantifying the benefits to Maine, and to trucks traveling to and through Maine, from regulatory approaches in neighboring jurisdictions. Challenges and successes experienced elsewhere can inform Maine's future action. Advanced Clean Trucks and Heavy-Duty Omnibus emissions rules are already in effect in 11 states, including Massachusetts, New Jersey, New York, Rhode Island, and Vermont in the northeast. The Advanced Clean Trucks rule requires manufacturers to sell an increasing percentage of MHD ZEVs over time, but does not require any individual fleet or vehicle owner to buy a MHD ZEV—requiring OEMs to target their ZEV offerings to the most cost-effective use cases. The Heavy-Duty Omnibus rules require manufacturers to sell lower-emissions engines, which could include ZEVs. California has also implemented the Advanced Clean Fleets regulation, requiring certain MHD fleets to convert to ZEVs by 2035.[67]

5.2.7 Economic Development

Zero-emission technologies, vehicles and infrastructure offer significant opportunities for economic growth and job creation in Maine. States with strong market and regulatory support for these technologies will be attractive sites for ZEV service and support, while large-scale manufacturing, including sites receiving IRA funding,[68] is likely to be located near historical manufacturing centers. In particular, infrastructure installation and maintenance jobs are "hyper-local"—they must be done in-region—and are a powerful area for job training, incentives and favorable policies. By encouraging companies developing, producing, and maintaining ZEV components, systems and vehicles to establish facilities in Maine, the state can effectively align climate objectives with economic policy.

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[67] The Advanced Clean Fleets Regulation applies to drayage fleets at seaports and intermodal rail yards; Federal, state, and local fleets; and to entities that have more than $50 million in gross revenue or control more than 50 vehicles.

[68] U.S. DOE. "Biden-Harris Administration Announces $15.5 Billion to Support a Strong and Just Transition to Electric Vehicles, Retooling Existing Plants, and Rehiring Existing Workers." August 31, 2023, accessed October 2024.

To date, Eastern Maine Community College has an Electric & Hybrid Automotive Technical Training Program[69] and Southern Maine Community College has an Electric Vehicle Repair Training Program[70] to prepare workers with the skills to repair EVs. The state has secured more than $4 million in Clean Energy Partnership grants to develop programs and tools to support Maine's clean energy workforce[71] and awarded $6.6 million through the Maine Grid Resilience Grant Program to projects that will improve electric grid reliability with an emphasis on creating new workforce opportunities.[72] Developed by the Maine GEO, the Maine Clean Energy Jobs Network supports growth in clean energy by being an online platform for jobseekers, employers, and training.[73]

Recommended Next Steps

» **Support green investments by evaluating manufacturing tax credits—**Providing tax credits could encourage companies to establish facilities in the state supporting the green economy and aligning climate policy goals; Maine should evaluate the impact of this option. Massachusetts and New York currently offer investment tax credits for qualifying clean businesses.

» **Expand on Maine's existing Community College green job training/workforce development programs—**Continue to offer EV training programs at community colleges and expand by partnering with state colleges and/or trade unions to develop and host programs. Create a guide on implementing replicable workforce training programs.

» **Build on Maine's Clean Energy Partnership Clearinghouse—**Expanding this clearinghouse to better serve the ZEV industry will assist businesses looking to locate in-state to find workers, understand state goals and regulations, and offer vehicles for sale.

5.2.8 Innovative Policies

Spurring widespread MHDV electrification requires creating a broad and innovative ecosystem of policies and investments that encourage and reward ZEV and infrastructure

[69] Eastern Maine Community College. Electric & Hybrid Automotive Technician Training. Accessed October 2024.

[70] Southern Maine Community College. Electric Vehicle Repair Training Program. Accessed October 2024.

[71] State of Maine. "Clean Energy Partnership - Workforce Initiative." Accessed October 2024.

[72] Maine GEO. "Maine Grid Resilience Grant Program." Accessed October 2024.

[73] Maine GEO. "Maine Clean Energy Jobs Network." Accessed October 2024.

adoption. This all-of-Government approach should focus on creating benefits for low- and zero-carbon technologies and fuels, and discouraging heavily polluting technologies and fuels. Maine has been a member of the RGGI since that program's launch, securing funding for strategic investment in clean energy initiatives while decarbonizing the grid. However, unlike in other states, Maine statute does not allow the use of its RGGI proceeds for ZEVs or ZEV-related infrastructure.

Separately, Maine Statute Title 29-A, Chapter 21 states that "For a heavy-duty vehicle equipped with an auxiliary power unit, the gross vehicle weight or axle weight used to determine the fine for a violation under this section is the actual gross vehicle weight or axle weight reduced by 400 pounds."[74] This is an example of a limited weight exemption for a vehicle that is heavier than designated weight. For ZETs, a 2,000-pound weight exemption is in effect at the Federal level on the Interstate highway system[75] and in some states, though MHD ZEVs can weigh as much as 4,000–10,000 pounds more than diesel alternatives.[76] The transition to ZEVs will require Maine to assess roadways that are safe and adequate to continue to move goods through and to the state in ZEVs. Simultaneously, Maine must identify infrastructure bottlenecks and infrastructure such as roads, bridges, and culverts, that may need to be upgraded to handle a fleet that will grow heavier over time.

Recommended Next Steps

» **Evaluate investment of RGGI proceeds to support vehicle electrification, including MHD ZEVs—**Using RGGI proceeds to support investments that cost-effectively reduce pollution and create clean energy jobs, including through investments in MHD ZEVs and infrastructure, will require legislative consideration and action.

» **Develop a plan to providing adequate safe and weight-rated routes for ZEVs—**Maine should evaluate and plan to provide adequate safe and rated routes for ZEV trucks, and communicate those plans to the trucking community.

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[74] https://legislature.maine.gov/statutes/29-A/title29-Asec2360.html

[75] Section 422 amended 23 U.S.C. 127(s)–Vehicle weight limitations—Interstate System.

[76] New Jersey Department of Environmental Protection (2024). A Roadmap to Zero-Emission Medium- and Heavy-Duty Vehicles in New Jersey.

6

ROADMAP FOR ACTION

6.1 Action Plan

Multiple agencies and authorities will be involved in implementing the recommendations of this roadmap. These include the executive and legislative branches of Government, where new or expanded authority is often required to implement new programs or direct the use of any new or existing funding sources; the GEO, GOPIF, Maine DOT, and the EMT for research, policy development, and technical support; and the Maine PUC for issues related to utility regulation.

Table 6.1 summarizes an action plan for the recommendations in this roadmap, including lead and supporting responsibilities and a proposed timeframe. Some of the actions are contingent upon identifying funding; ability to attract funding may affect the implementation timeframe.

TABLE 6.1 ACTION PLAN

Policy Recommendation	Responsibility	Timeframe
1. Lead by example MHD ZEV targets for public fleet	Lead By Example Initiative	July 1, 2025
2. MHD state fleet transition plan	GOPIF, Department of Administrative and Financial Services, and Maine DOT	December 31, 2026
3. Continue MHDV stakeholder engagement	GOPIF and Maine DOT	Ongoing
4. Update and expand NEVI Plan guidance for MHD infrastructure	Maine DOT	2025 NEVI planning cycle and ongoing

Policy Recommendation	Responsibility	Timeframe
5. Develop MHD ZEV voucher incentive program	EMT	July 1, 2025; launch as soon as funding is available
6. Assess state tax credit options	GOPIF and Bureau of Tax and Finance	December 31, 2025
7. Develop MHD ZEV charging and fueling voucher incentive program	EMT, Maine DOT	July 1, 2025; launch as soon as funding is available
8. Explore development of utility-run MHD infrastructure incentives	PUC, GEO	2025
9. Build on regulatory proceedings requiring EV charging rates	PUC, GEO	Ongoing, in rate cases
10. Launch no-cost fleet advisory program	Various	By 2026
11. Track MHD ZEV deployment in Maine and states with clean truck regulations	GOPIF, Maine DEP	Ongoing
12. Explore offering manufacturing tax credit	GOPIF, Department of Economic and Community Development	2025
13. Expand EV job training programs	GEO, through the Maine Clean Energy Partnership	Ongoing to meet demand
14. Expand Clean Energy Partnership clearinghouse to increase focus on the ZEV industry	GEO	July 1, 2026
15. Evaluate use of RGGI funds to support ZEVs	GOPIF, Maine DEP, GEO, EMT	December 31, 2025
16. Plan for heavier MHD ZEVs on the road	Maine DOT	December 31, 2026

The state will implement this roadmap under the Maine Climate Council's leadership, as a pathway to achieving meaningful statewide emissions reductions. State agencies will meet regularly to track and assess progress, and the project team will continue to engage with both public and private sector stakeholders to understand challenges and opportunities for action.

6.2 Funding Requirements and Sources

Implementation of many of the above recommendations will require varying degrees of funding.

Table 6.2 outlines the funding requirements for recommended programs and policies, and identifies potential funding sources for each recommendation. Existing Federal programs could support some of these recommended initiatives; Table 6.3 identifies which of the various Federal programs have eligibility to support different investment strategies. Maine program budgets may be able to support activities that require modest costs, such as planning and regulatory proceedings, and lead by example and policy assessments. The federal funding programs identified below are subject to change, as are the eligibility requirements for each program.

TABLE 6.2 POTENTIAL FUNDING REQUIREMENTS

Policy Recommendation	Funding Requirements	Potential Sources
1. Lead by example MHD ZEV targets for public fleet	None to set targets, but additional funds will be required to support vehicles and charging infrastructure	U.S. DOT, EPA, and DOE programs supporting clean vehicles Bonds repaid through long-term operating cost savings
2. MHD state fleet transition plan	Agency staff time + procured services	U.S. DOT and EPA programs supporting clean vehicles; existing program budgets
3. Continue MHDV stakeholder engagement	Agency staff time	Existing program budgets
4. Update and expand NEVI Plan guidance for MHD infrastructure	Agency staff time	U.S. DOT State Planning and Research program
5. Develop MHD ZEV voucher incentive program	Scales with the number and size of vouchers. Estimated $5M to launch and sustain for 3 years, $10M to extend through 5 years; higher levels may be needed to support more rapid ZEV deployment	U.S. DOT and EPA sources for eligible fleets Potential use of RGGI funds
6. Assess state tax credit options	Limited agency staff time Potential need to address foregone tax revenue, depending upon level of utilization	N/A
7. Develop MHD ZEV charging and fueling voucher incentive program	Scales with the number and size of vouchers. Estimated $3M to launch and sustain for 3 years, $6M to extend through 5 years; higher levels may be needed to support more rapid ZEV deployment	U.S. DOT and EPA sources for eligible fleets Potential use of RGGI funds
8. Explore development of utility-run MHD infrastructure incentives	Agency staff time	Existing program budgets
9. Build on regulatory proceedings requiring EV charging rates	Agency staff time	Existing program budgets
10. Launch no-cost fleet advisory program	$500,000 to launch program	U.S. DOT, EPA, and DOE programs supporting clean vehicles
11. Track MHD ZEV deployment in Maine and states with clean truck regulations	Agency staff time	Existing program budgets
12. Explore offering manufacturing tax credit	Agency staff time Potential need to address foregone tax revenue depending upon level of utilization, which may be offset by manufacturing job growth	N/A

Policy Recommendation	Funding Requirements	Potential Sources
13. Expand EV job training programs	Various	Program tuition and fees U.S. DOE funding for clean energy workforce development
14. Expand Clean Energy Partnership clearinghouse to increase focus on the ZEV industry	Agency staff time	Existing program budgets
15. Evaluate use of RGGI funds to support ZEVs	Limited agency staff time for evaluation No net cost, but would require some funds to be repurposed from other uses	N/A
16. Plan for heavier MHD ZEVs on the road	Agency staff time + procured services	Existing program budgets and other resources

TABLE 6.3 FEDERAL FUNDING SOURCES TO SUPPORT POLICY RECOMMENDATIONS

Federal Funding Program	State, Municipal, and Utility Fleets and Infrastructure	Planning and Needs Assessments	Point-of-Sale Vouchers	Depot Charging Incentives	Publicly Accessible Charging and Refueling	Workforce Development	Fleet Assessment Services
Advanced Transportation and Technology Innovation[1]	✓	✓			✓		
Advanced Technology Vehicles Manufacturing Loan Program[4]						✓	
Bus and Bus Facilities Formula Program[2]	✓						
Carbon Reduction Program[1]	✓	✓		✓	✓	✓	✓
Charging and Fueling Infrastructure Grant Program[1]	✓				✓	✓	
Clean Heavy-Duty Vehicles Grant Program[3]	✓	✓					
Clean Ports Program[3]	✓	✓[5]	✓	✓			

Federal Funding Program	State, Municipal, and Utility Fleets and Infrastructure	Planning and Needs Assessments	Point-of-Sale Vouchers	Depot Charging Incentives	Publicly Accessible Charging and Refueling	Workforce Development	Fleet Assessment Services
Clean School Bus Rebate Program[3]	✓					✓	
Congestion Mitigation & Air Quality Improvement Program[1]	✓	✓	✓	✓	✓		✓
Formula Grants for Rural Areas Program[2]	✓						
Industrial Training and Assessment Centers[4]						✓	
Infrastructure for Rebuilding America Grant Program[1]					✓		
Low or No Emission Grant Program[2]	✓	✓					
National Electric Vehicle Infrastructure Program[1]					✓	✓	
National Highway Performance Program[1]	✓				✓	✓	
National Highway Freight Program[1]		✓	✓	✓	✓		✓
Reduction of Truck Emissions at Port Facilities[1]	✓	✓	✓				
Rural Surface Transportation Grant Program[1]				✓	✓	✓	
State Infrastructure Banks	✓				✓		
State of Good Repair Grants Program[2]	✓						

Federal Funding Program	State, Municipal, and Utility Fleets and Infrastructure	Planning and Needs Assessments	Point-of-Sale Vouchers	Depot Charging Incentives	Publicly Accessible Charging and Refueling	Workforce Development	Fleet Assessment Services
Surface Transportation Block Grant Program[1]				✓	✓	✓	
Tribal Transportation Program[1]		✓	✓	✓	✓	✓	✓
Urbanized Area Formula Grant Program[2]	✓	✓		✓	✓	✓	

[1] U.S. DOT—Federal Highway Administration.

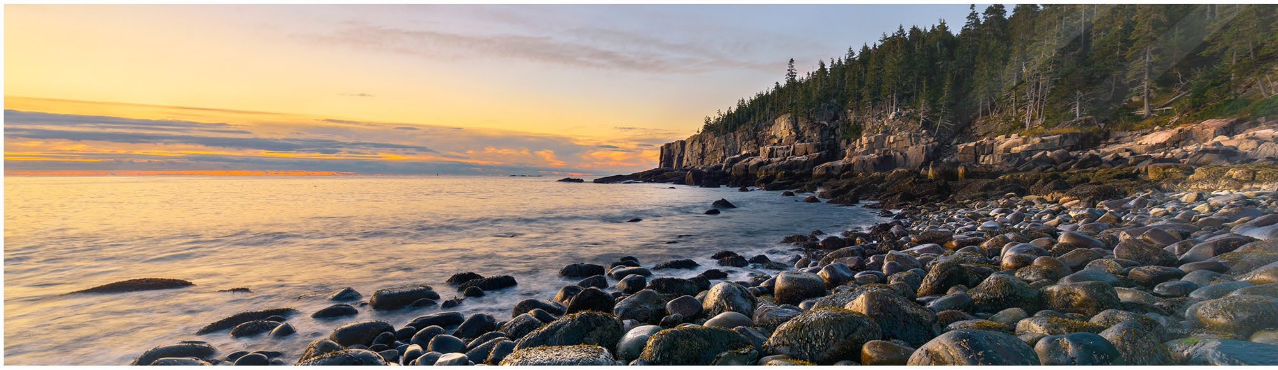
[2] U.S. DOT—Federal Transit Administration.

[3] U.S. EPA.

[4] U.S. DOE.

[5] Maine DOT was awarded $1 million through the U.S. EPA Clean Ports Program; Climate and Air Quality Planning Competition. This funding, focused on the Port of Portland, will support an emissions inventory, electrification feasibility analysis, and community collaboration.

A



EXAMPLES OF OTHER STATE PROGRAMS

This appendix to the Maine Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles provides examples of policies and programs in other States that help accelerate adoption of zero-emission medium and heavy-duty vehicles (MHDV).

A.1 Target Setting

1. Massachusetts: Executive Order No. 594
   a. This order establishes actions and targets for state Government operations to decarbonize and improve resiliency. These targets include converting 75 percent of the state government's fleet to zero-emission vehicles (ZEV) by 2040 and 100 percent by 2050, including for medium- and heavy-duty state vehicles.
2. Michigan: Executive Directive No. 2023-5
   a. This directive calls for the transition of the state's fleet to ZEVs at appropriate state agencies. For MHDVs, this order sets a target for a full transition to ZEVs by 2040.
3. New York: Executive Order No. 22
   a. This order lays out actions and targets for state agencies on a number of sustainability measures. This includes converting 100 percent of MHDVs to ZEVs by 2040.

A.2 Vehicle Incentives

1. California: Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)

    a. Since launching in 2009, HVIP has provided vouchers for 3,881 Class 2b–8 ZEVs, totaling $475 million in redeemed vouchers for these vehicles. In additions to ZEVs, HVIP has provided vouchers for hybrid electric vehicles, natural gas vehicles, and electric power takeoff equipment.

2. New Jersey: New Jersey Zero-Emission Incentive Program (NJ ZIP): Voucher Pilot for Medium Duty and Heavy Vehicles

    a. NJ ZIP was launched in 2021 by the New Jersey Economic Development Authority using Regional Greenhouse Gas Initiative (RGGI) funds. The program has a $90 million total voucher pool which is broken into two phases. In phase one, $16 million in vouchers were approved (with $13 million redeemed to date). In phase two, $46 million in vouchers were approved (with $2.3 million redeemed to date).

3. Massachusetts: Massachusetts Offers Rebates for Electric Vehicles (MOR-EV)

    a. MOR-EV launched in 2014 and expanded to include MHD vehicles through MOR-EV Trucks in 2021. Since 2021, MOR-EV Trucks has distributed $8.21 million total rebate funds for a total of 811 rebates approved between pickup and Class 2b vehicles and Class 3–8 vehicles.

A.3 Infrastructure Support

1. Stakeholder Forum

    a. New York: Electric Vehicle Infrastructure and Interconnection Working Group (EVIIWG)

        i. The New York State Department of Public Service facilitates the EVIIWG to bring together stakeholders from industry, electric utilities, and state agencies to confer and develop solutions to the challenges and barriers with the EV interconnection process.

    b. Massachusetts: Electric Vehicle Infrastructure Coordinating Council (EVICC)

i. EVICC was established as prescribed by An Act Driving Clean Energy and Offshore Wind with the mandate to "develop strategies resulting in an equitable, interconnected, accessible and reliable electric vehicle charging network in Massachusetts." EVICC membership includes representatives from relevant state agencies/offices and state legislators. Meetings are open to the public.

2. MHD Charger Voucher Incentive Programs

a. California: Energy Infrastructure Incentives for Zero-Emission (EnergIIZE)

ii. EnergIIZE offers MHD commercial fleets (Class 2b–8) grants for ZEV infrastructure costs. Four funding lanes are available for fleets to choose from: EV Fast Track Lane (for projects ready for infrastructure deployment), EV Jump Start Funding Lane (for targeted fleet types), EV Public Charging Station Funding Lane, and Hydrogen Funding Lane. Since launching in 2022, EnergIIZE has awarded $146 million to 253 projects, supporting 3,555 chargers or hydrogen fueling nozzles.

b. Colorado: Fleet Zero Emission Resource Opportunity (Fleet-ZERO)

i. Fleet-ZERO, administered by the Colorado Energy Office, provides grant funding to for EV charging to fleet owners and operators at private depots, as well as third-party providers and electric vehicle charging-as-a-service to fleets. Competitive grants are awarded for private depot charging, public and semi-public fleet charging, and fleet charging-as-a-service. Fleet-ZERO prioritizes investment in disproportionately impacted communities and offers enhanced incentives for eligible qualifying entities.

c. Massachusetts: Electric Vehicle Incentive Program (EVIP)

i. The Massachusetts Department of Environmental Protection administers MassEVIP, which includes several programs to support EV charging stations. This includes a Workplace and Fleet Charging Incentives program for employers and fleet operators, and a Fleet Incentives program for eligible public entities.

3. Utility-Run MHD Infrastructure Incentives

a. New York: Medium-and Heavy-Duty EV Make-Ready Pilot Program

i. As authorized by the New York State Public Service Commission, the state's investor-owned utilities launched this pilot program which covers up to 90 percent of utility-side infrastructure costs and up to 50 percent of customer-side costs for MHDV operators. To be eligible, the charging must be publicly accessible or the customer must participate in a qualified voucher incentive program.

b. Massachusetts: National Grid Fleet EV Charging Program

i. National Grid covers up to 100 percent of the electrical infrastructure costs for fleet customers installing EV charging. Incentives apply to both utility-side and customer-side infrastructure upgrades, and additional charger rebates are available for public fleets.

4. Regulatory Proceedings

a. New York:

i. Department of Public Service Case 22-E-0236, *Proceeding to Establish Alternatives to Traditional Demand-Based Rate Structures for Commercial Electric Vehicle Charging*, requires New York's investor-owned utilities to propose reasonable alternatives to existing demand chargers, better enabling cost effective DC fast charging.

ii. Department of Public Service Case 24-E-0364, *Proactive Planning for Upgraded Electric Grid Infrastructure*. Requires New York's investor-owned utilities to propose frameworks for anticipatory investment in infrastructure upgrades to enable deployment of EV charging.

A.4 Fleet Advisory Support

1. California: Cal Fleet Advisor

a. Cal Fleet Advisor supports truck and school bus fleets by evaluating ZEV options and assisting with procurement. Enrolled fleets receive a customized resource packets including total cost of ownership projections, ZEV model availability, incentives, and charging information. The program also works with fleets to navigate the HVIP process, support discussions with vehicle dealers, and identify appropriate insurance, financing, and leasing options.

2. Massachusetts: Mass Fleet Advisor

a. Administered by the Massachusetts Clean Energy Center, the Mass Fleet Advisor program offers no-cost technical support for fleet electrification to private and nonprofit fleets. Enrolled fleets receive detailed fleet electrification reports identifying suitable ZEV alternatives, total cost of ownership projections, and site assessments performed by an electrical contractor.

3. New Jersey: New Jersey Fleet Advisor

   a. Administered by New Jersey Department of Environmental Protection, New Jersey Fleet Advisor offers free technical assistance to private, nonprofit, and public fleets that have MHDVs and 20 or fewer vehicles in their fleet.

A.5 Regulations

These regulations are in effect in the following jurisdictions:

1. Advanced Clean Trucks (manufacturer-based requirements for ZEVs place in service): California, Colorado, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, Washington
2. Heavy-Duty Omnibus (MHDV emissions regulations): California, Colorado, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, Washington
3. Advanced Clean Fleets (fleet-based requirements for ZEVs in use): California

A.6 Economic Development

4. Workforce Training

   a. Massachusetts: Grants for clean energy workforce development, including EV charging and EV technician programs.

      i. $16 million in grant awards was announced in September 2024 "to invest in planning, capacity, training, and equipment for climate-critical jobs in the clean energy and climatetech sector."

   b. New York: Freight Electrification as-a-Service for Transformation (FEaST)

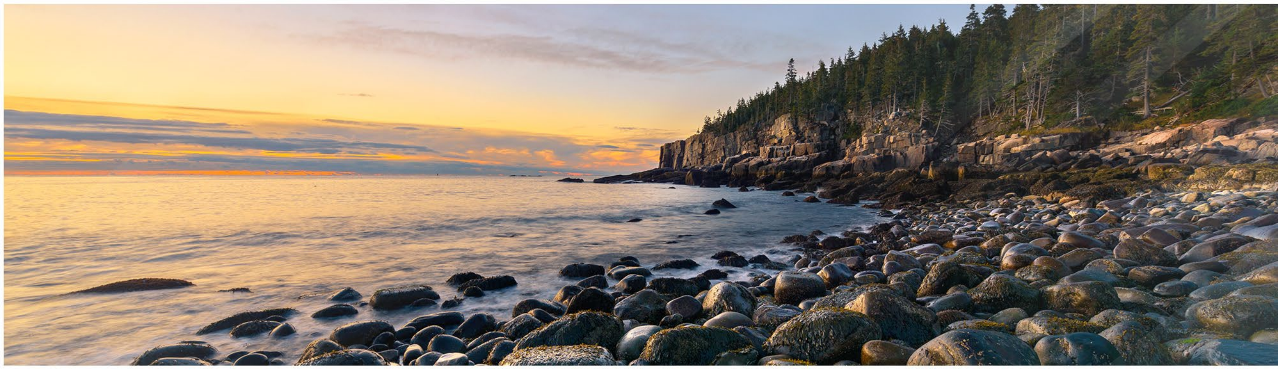
      i. Through the New York State Energy Research and Economic Development Authority's Clean Transportation Prizes, the FEaST project includes workforce training in the New York City area focused on electric trucks and charging infrastructure.

5. State Clearinghouse
    a. California: Governor's Office of Business and Economic Development (GO-Biz)
        i. Through GO-Biz, business owners can receive a variety of free consultation services. GO-Biz Teams include Energy and Climate, and Zero-Emission Vehicle Market Development.

A.7 Innovative Policies

6. Investment in MHD ZEV Transition funded by the Regional Greenhouse Gas Initiative (RGGI)
    a. Massachusetts RGGI
        i. Massachusetts has used RGGI proceeds capitalize its EV incentive programs, MOR-EV and MOR-EV Trucks, in addition to providing ongoing support for the Green Communities program and utility energy efficiency programs.
    b. New Jersey: RGGI
        i. New Jersey's 2023-2025 RGGI Strategic Funding Plan details how RGGI funds will be invested to "Catalyze Clean, Equitable Transportation." RGGI funds support a variety of MHD ZEV programs that benefit environmental justice communities, including the New Jersey Zero-Emissions Incentive Program (NJ ZIP), Diesel Fleet Modernization Program, and multiple EV charging programs.
    c. New York: RGGI
        i. New York has used its RGGI funding to support over 50 programs across multiple areas, including the Drive Clean Rebate program for EVs and the Green Jobs Green New York program to support the growing clean energy workforce.

B



CASE STUDIES

B.1 Introduction

This appendix to the Maine Clean Transportation Roadmap for Medium- and Heavy- Duty Vehicles (MHDV) summarizes findings from a series of case studies conducted with Maine businesses to identify real world opportunities and challenges for fleet electrification. The case studies are intended to 1) serve the participating fleets by providing customized fleet electrification assessments; and 2) augment the roadmap by evaluating electrification use cases, total cost of ownership, and barriers in the context of actual Maine business operations.

The appendix also includes a broader list of sites that were identified across the state as potentially being high-demand charging sites, should trucks or buses at those sites be electrified in the future. This list was used to help identify case study locations and could also be used for future assessments of electricity grid investment needs to support MHD zero-emission vehicles (ZEV).

Total Cost of Ownership Analysis

Each case study included total cost of ownership (TCO) estimates for the various MHDVs and use applications for each participating fleet. Calculating the total cost of ownership (TCO) for a vehicle offers fleet owners information to evaluate direct and indirect costs of EV purchases, as well as potential savings over the life-cycle of purchased vehicles. The transition to EVs involves a shift in perspective regarding TCO components. Traditional internal combustion engine (ICE) vehicle costs are usually presented as capital cost for vehicles and dollar per gallon costs for fuel, as well as lifetime maintenance expenses. An analysis of TCO for EVs must consider power output, dollars per kilowatt, grants and incentive programs, and planning and installing charging infrastructure. While EVs are typically more expensive upfront, they are often less expensive to operate and maintain than comparable ICE vehicles; in many cases, these operational savings can offset higher upfront costs across the lifespan of the vehicle, resulting in a positive TCO.

TCO is calculated by combining the vehicle capital and operating costs over a set period of operations. For this analysis, the vehicle price points came from industry averages. Calculations assume a purchase in 2025 and a 12-year vehicle life, which is average across Maine trucks. Infrastructure costs per charging port were developed for this roadmap, based on data from pilot programs run by Maine's utilities as well as literature on other applications throughout the U.S., and are documented in Appendix G. TCO calculations accounted for the Efficiency Maine vehicle incentives and the federal Commercial Clean Vehicle tax credit.

Financing ZEVs and Charging Infrastructure

Commercial Clean Vehicle Tax Credit

The Federal Government's adoption of the Infrastructure Reduction Act (IRA) enacted new federal tax credits (IRC Section 45W) for commercial clean (electric or hydrogen fuel cell) vehicles in 2022. Eligible entities include businesses and tax-exempt organizations that purchase commercial clean vehicles between January 1, 2023 and before January 1, 2033. Heavy-duty vehicles with a gross vehicle weight rating (GWVR) of 14,000 lbs. or greater are eligible for a tax credit up to $40,000, or 30 percent of the incremental cost of the vehicle as compared to a gasoline or diesel vehicle, whichever is lower. Applicable electric vehicles must have a battery with at least 15 kilowatt-hours (kWh) of capacity and be made by a qualified manufacturer (see the IRS's list for examples). For tax exempt entities, such as schools, governments, or non-profit organizations, the tax credit is available through a mechanism commonly known as direct, or elective, pay.

Alternative Fuel Infrastructure Tax Credit

Beginning on January 1, 2023, installation of electricity fueling equipment, or EV chargers, is eligible for a federal tax credit of 30 percent of the installation costs (or 6 percent in the case of property subject to depreciation), not to exceed $100,000. As above, tax-exempt entities are eligible to claim these credits through direct or elective pay.

These tax credits are only available to business locations and tax-exempt entities with the following census tract requirements:

- A population census tract where the poverty rate is at least 20 percent.
- Metropolitan and non-metropolitan area census tract where the median family income is less than 80 percent of the state median family income level.

Fleets should work with their charging infrastructure installers to determine eligibility by identifying their census tract using this tool and determining if it is included in the IRS's list. If eligible, tax form 8911 should be completed.

Efficiency Maine Medium- and Heavy-Duty Vehicle Incentive Pilot

In October 2024, the quasi-state agency Efficiency Maine Trust launched a pilot program to demonstrate potential use cases and performance of zero-emission MHD vehicles in the Maine. Awards will be issued in three rounds, with applications open through the end of February 2025, with the possibility of further rounds of funding in the future. In order to be eligible, applicants must be based in Maine and already own a Class 3 to 7 vehicle in their fleet. The maximum award for different vehicle classes is as follows:

TABLE B.1 EFFICIENCY MAINE INCENTIVE LEVELS

Vehicle Class	Maximum Award
Class 3	40% of purchase price up to $40,000
Class 4	40% of purchase price up to $60,000
Class 5	50% of purchase price up to $80,000
Class 6	50% of purchase price up to $100,000
Class 7	50% of purchase price up to $120,000

Along with awards for vehicle purchases, the program also offers incentives for Level 2 charging and professional services such as consulting. For further information, and to apply, fleets should visit the program website.

Charging and Infrastructure

Fleet Electrification Overview

Fleet electrification involves coordination between the fleet and their electric utility, contractors, developers, vehicle original equipment manufacturers, and Electric Vehicle Service Providers to determine the power, quantity, and arrangement of electric vehicle supply equipment (EVSE), or vehicle charging, for a particular site. Once vehicle quantity and duty cycles are defined, the quantity and power of EVSE needed can be determined. In most fleet charging configurations, it is typical to install one dedicated charging plug per EV. This is to support overnight charging, when electricity rates are low and vehicles are ordinarily not in operation; overnight charging typically lends itself to less costly EVSE due to the lower power usage required to charge a vehicle over a long dwell time. For use cases with higher energy needs and/or less available dwell time for charging, higher-power chargers may be required to meet the energy needs of EVs.

Regardless of the quantity or power of charging equipment, it is important to keep in mind the additional space necessary for charging dispensers, transformers, and other considerations which may change a site's traffic pattern or "flow."

It is recommended that any chargers installed are networked, which means they include the capability to communicate over cellular networks. Most businesses choose to install networked chargers due to access control, ensuring that only the fleet's service vehicles can charge at these chargers. Alternatively, fleets can install "behind the fence" non-networked charging in a secure location only accessible to fleet vehicles, assuring the same charging restrictions and availability. However, networked chargers can provide a bevy of technical information, including duration of charge and charge rate, useful for operational planning and decision-making.

Inductive (wireless) charging equipment, which uses an electromagnetic field to transfer electricity to an EV without a cord, is now commercially available as an aftermarket add-on, and has the potential to support rapid MHDV charging at depots and in warehouse environments where trucks park for extended periods of time, such as loading bays

Spreading a charging schedule across as many hours as possible will often lead to the lowest capital and operational cost; thus, it is important to weigh various charging solutions against business needs. The next section describes in greater detail some solutions for how this can be addressed.

Charging Equipment

EV charging equipment is classified by battery charging rates. Time to charge will vary depending on battery state of charge, total energy storage, the type of battery, and the type of charging equipment. Charging time can range from less than 20 minutes to 20 hours or more, depending on these factors.

There are three types of charging: Level 1, Level 2, and Level 3 (direct current or DC Fast). Level 1 charging is the slowest method and uses a standard alternating current (AC) wall outlet. It adds two–five miles of range per hour of charging. Because of its slow rate, Level 1 charging is typically only used at home for personal vehicles or workplaces. Level 2 is another AC method that is significantly faster than Level 1. Level 2 is the most common method of charging as it allows most light and medium-duty vehicles to charge overnight while also being significantly cheaper and easier to install than Level 3 chargers. Level 2 chargers are most commonly found for commercial vehicles and in public places like parking garages, shopping centers, and tourist attractions. Level 3 (DC Fast) charging is the fastest method of charging, but also the most expensive for both the charger and infrastructure required. These chargers are typically only recommended for heavy-duty trucks and vehicles that only dwell for a few hours.

Across the United States, there are four major plug types: J1772 (“J-plug”), Tesla (aka NACS, or SAE J3400), CHAdeMO, and CCS.

- The J1772 standard is used for Level 1 and 2 AC charging.
- Tesla is used for Level 2 and 3.
- CHAdeMO and CCS are used primarily for Level 3 (DC fast) Charging.

While other proprietary plugs exist for MHD vehicles, these four represent the majority of those in use. The National Electric Vehicle Infrastructure (NEVI) program has standardized federally funded plugs across Level 2 and Level 3 charging, helping build out a national network of publicly-available charging equipment with predictable plug configurations. In 2022, Tesla opened their previously proprietary charging standard to other EV manufacturers. In the coming years, their North American Charging Standard (NACS) will become the most prevalent charger connection. This connector is also referenced as SAE J3400. All connector types are shown below in Figure B.1, but fleets should anticipate a growing share of vehicle options to utilize the NACS standard.

Industry leaders have introduced the concept of the Megawatt Charging Solution, designed to provide higher levels of power needed by MHD vehicles over a shorter period of charging time. Megawatt chargers require significant infrastructure investment (1–3 million of volt-amperes/ MVA) and may allow for faster adoption of electric vehicles for long-haul trucking. However, most local or regional delivery businesses can be supported by Level 2 or DC fast chargers.

FIGURE B.1 TYPES OF CHARGERS

Type	Level 1 Charging	Level 2 Charging		Level 3 DC Fast Charging			Megawatt
Connector	 J1772	 J1772	 Tesla/ NACS/ SAE J3400	 CHAdeMo	 CCS	 Tesla/ NACS/ SAE J3400	 MCS
Voltage	120 V AC	208–240 V AC		400 V–1000 V DC			1–3 kV A
Power Output	1 kW	7 kW–19 kW		50–350 kW			900 kW+

Managed Charging

Energy management can greatly decrease operational costs associated with fleet electrification. Managed charging, sometimes called "smart charging," entails the purchase and use of EVSE that can actively track and modulate charging, and a subscription for energy management software provided by the EVSE manufacturer or network provider to keep consumption levels within a predetermined range. While there are additional up-front and monthly costs associated with these technologies, their long-term benefits should be considered from a total cost of ownership perspective.

Depending on the design of local electricity rates, electricity pricing can be based upon the time of day during which electricity is used, where marginal pricing is greater during times of high demand and lower when strain to the grid is at its lowest. Fleets may also be exposed to demand charges, which are increased electricity charges incurred from large, simultaneous power draws—such as when multiple heavy-duty trucks simultaneously plug into fast charging at the same location. However, charging when electricity costs are lowest is not always feasible or operationally convenient for fleets. Utilizing managed charging software automates charging to coincide with dwell times while enabling fleets to benefit from lower electric rates and/or mitigating demand charges.

On-Route versus Depot Charging

Most commercial EV deployments currently in operation rely solely on depot charging, or a "return-to-base" schedule where a fleet keeps vehicles parked at one location owned/leased by the organization operating those vehicles. While policy efforts and unprecedented federal funding are advancing the development of strategically sited on-route fast charging and public charging hubs, it is recommended that current EV deployments include ample planning for on-site charging, where feasible.

Wherever possible, fleets should plan to charge overnight at depots; however, there are public options available for charging mid-route if needed. The Alternative Fuels Database, provided by the Department of Energy (DOE), includes a tool to find publicly available charging stations, as does the similar PlugShare tool. Users can also map a route, similar to Google Maps, and see all charging stations along the route. These tools compile data from many networks of charging stations, such as ChargePoint, Electrify America, EVgo, and Tesla. By clicking on a particular charging station, one can view the number of available charging ports, as well as the type of charging connector.

Not all charging stations listed on this site will be appropriate for charging MHDVs. Most Class 2b and Class 3 vehicles will be able to use charging stations designed for light-duty vehicles. However, Class 4–8 vehicles are often too large for typical light-duty charging parking spots, and may require higher power levels to keep charging time reasonable. It is anticipated that most public charging stations for medium- and heavy-duty trucks will require power levels of 350 kW or more per port, paired with increased height clearance and pull-through parking. These may not be available at stations which appear in the DOE or PlugShare tools.

B.2 Summary of Fleet Findings

Fleet 1: Pine State Trading

Pine State Trading is a regional beverage distributor whose fleet conducts last-mile delivery operations of beer, wine, liquor, and non-alcoholic beverages throughout the State of Maine. Pine State Trading's fleet domiciles at sites in Bangor and Gardiner. Their fleet consists of three cargo vans, nine Class 6 trucks, two Class 7 trucks, and 57 Class 8 trucks.

Pine State Trading's fleet travels between 55–130 miles per day and returns to either the Bangor or Gardiner site to domicile for 11 hours overnight. This duty cycle is well-suited to electrification, since the range fits what electric models offer and there is ample time to fully charge overnight. Pine State Trading's Class 7 and Class 8 vehicles would require fast charging (Level), while the others can be charged using Level 2 charging.

Total cost of ownership analyses were performed for each vehicle class in Pine State Trading's fleet, across an assumed lifespan of 12 years and taking into account available incentives in addition to purchase, infrastructure, and operational costs. Pine State Trading's cargo vans and Class 6 trucks produced favorable TCO projections, making them excellent near-term candidates for electrification. Their Class 7 and 8 trucks did not produce favorable TCO projections, though incentives got them much closer to reaching cost parity to traditional models. These vehicles are still great longer-term candidates for electrification due to their well-suited duty cycle and use case.

Fleet 2: Lynch Logistics

Lynch Logistics is a full-service logistics and transportation provider doing business throughout Maine, the U.S., and Canada. This report assesses their vehicles which domicile on Rice Street (RMC/SOS), as well as the shredding facility on Odlin Road (Lynch Logistics), and the maintenance facility on Lexington Drive (MEMoving/MEDelivery), all located in Bangor.

The medium-duty trucks at the Rice Street facility travel approximately 135 miles a day and are primarily used for commercial moving. Their travel patterns and overnight dwell times are well-suited to electric or hydrogen vehicles, and transitioning to these zero-emission alternatives would result in immediate fuel and maintenance cost savings. Despite that, a zero-emission replacement is not projected to produce lifetime savings due to high upfront capital costs for electric and hydrogen trucks.

The Odlin facility houses both gasoline Ford Transit vans which pick up classified materials, and Class 6/7 trucks which serve as on-site mobile shredding units. Even without incentives, electrification of the vans results in cost savings within the first four years of ownership; with incentives, savings are immediate. With incentives, the electrification of the Class 6 trucks is also immediately lower cost than the internal combustion alternative. Although the zero-emissions transition would result in immediate maintenance and fuel cost savings for the Class 7 trucks, there are not projected to be lifetime savings due to the high upfront capital costs.

The Class 8 trucks operating out of the Lexington Drive facility travel between 250–280 miles per day and are primarily used for moving freight. These vehicles can be away from the domicile location for up to two weeks at a time, and would need to rely on on-route charging for electric alternatives. These trucks could be replaced with hydrogen fuel cell vehicles, where longer ranges are available, though more significant fueling station infrastructure challenges exist. Though fuel and maintenance cost savings are immediate, there are no lifetime savings due to the high upfront costs of Class 8 vehicles.

Fleet 3

Fleet 3 is a delivery freight fleet serving the State of Maine. They have two warehouses: Warehouse 1 in Penobscot County with seven tractor trailers and Warehouse 2 in Aroostook County with two tractor trailers. Both electric and hydrogen fuel cell replacement options are detailed for Fleet 3's tractor trailers.

The trailers based in Warehouse 1 travel approximately 220 miles per day and return to a depot overnight. These travel patterns and overnight dwell times are well-suited to electric or hydrogen vehicles and transitioning to these zero-emission alternatives would result in immediate fuel and maintenance cost savings. Despite that, a zero-emission replacement is not projected to produce lifetime savings due to high upfront capital costs for electric and hydrogen trucks.

The trailers based in Warehouse 2 travel approximately 560 miles per day. A zero-emission replacement would be projected to produce lifetime savings for this duty cycle starting in the 9th year; however, these vehicles would need to be charged along their route, which may not be feasible or cost-effective at this time. Alternatively, Fleet 3 could consider hydrogen fuel cell vehicles where longer ranges are available; more significant fueling station infrastructure challenges exist at this time.

Fleet 4

Fleet 4 is a retail goods delivery business that has central warehousing and makes retail deliveries statewide. The vehicles domicile at a southern Maine warehouse, including 97 Class 8 heavy-duty cabs, tractors, and sleepers.

The Class 8 cabs and sleepers performing retail delivery travel approximately 244 miles per day and do not have a precise domicile schedule, though it was estimated to be from 5 p.m. to 6 a.m. The warehouse also uses five yard tractors to switch trailers, operating approximately 55 miles per day. These travel patterns and overnight dwell times are well-suited to electric vehicles. These vehicles could be charged fully within a dwell time of three hours using Level 3 DC fast chargers, and transitioning to these zero-emission alternatives would result in immediate fuel and maintenance cost savings. Despite that, a zero-emission replacement is not projected to produce lifetime savings due to high upfront capital costs for electric trucks.

B.3 Potential High-Demand Charging Sites

To identify potential high-demand charging locations across the state, general areas of potential high demand for charging from future MHD ZEVs were identified using three sources:

» The EPRI eRoadMAP, which displays the estimated daily energy requirements across the United States necessary to power a fully electrified road vehicle scenario, including MHDV requirements, for small areas (hexagons at different scales).

» LOCUS Truck data showing truck trip origins by census tract based on telematics data collected from vehicle fleets in 2023, provided by Geotab and further processed by Cambridge Systematics (see Appendix D).

» Registration data on the number of Maine-registered trucks by ZIP code of registration (provided by Maine Department of Environmental Protection and processed by ERG, as described in Appendix D).

These three sources generally showed similar patterns of high versus low demand indicators, with higher demand areas generally in the state's population and industrial centers. Higher-demand areas were then searched on Google Maps satellite imagery to identify locations in which larger areas of truck parking were observed. The address and ownership of these sites was then checked on Google Maps.

The identified sites can be divided categorically as follows:

- Ports, airports, and intermodal terminals: five sites.
- Warehouses and distribution centers: six sites.
- Private yards or depots: seven sites.
- Truck stops or rest areas: three sites.
- Bus yards: one site.
- Large industrial areas of interest without a single address: two sites.

The geographic distribution of the sites is as follows:

- Kittery area: two sites.
- Portland area: eight sites.
- Lewiston/Auburn area: six sites.
- Bangor area: six sites.
- Rural/close to Canadian border (Presque Isle/Calais): two sites.

Table B.2 lists the potential high-demand locations. The table also notes the utility territory in which the site is located, as well as the hosting capacity according to the load hosting maps of the utility, either Central Maine Power (CMP) or Versant (CMP Hosting Capacity; Versant Hosting Capacity). A higher hosting capacity means there is less likely to be a need for infrastructure upgrades to serve the same unit of charging demand.

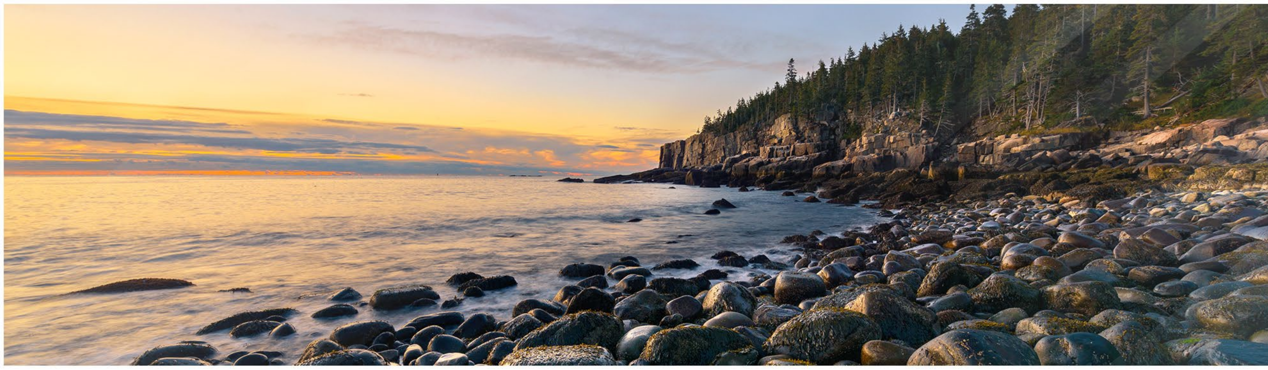
TABLE B.2 POTENTIAL HIGH-DEMAND LOCATIONS

Site Type	Name	Address	Utility	Hosting Capacity
Ports, airports, intermodal	Presque Isle International Airport	650 Airport Dr, Presque Isle, ME 04769	Versant	5000–9999 kW
Ports, airports, intermodal	International Marine Terminal	460 Commercial St, Portland, ME 04101	CMP	3 Phase, 2.0 MVA to 5.0 MVA (Overhead)
Ports, airports, intermodal	CSX Transportation Rigby Yard	Site office: 20 Rigby Rd, South Portland, ME 04106	CMP	3 Phase, 1.0 MVA to 2.0 MVA (overhead)
Ports, airports, intermodal	Portland International Jetport	1001 Westbrook St, Portland, ME 04102	CMP	3 Phase, 2.0 MVA to 5.0 MVA (Underground)
Ports, airports, intermodal	Bangor International Airport	287 Godfrey Blvd, Bangor, ME 04401	Versant	200–499 kW (or 1000–4999 kW)
Warehouses, distribution centers	Pepsi Beverages CO	191 Merrow Rd, Auburn, ME 04210	CMP	3 Phase, > 5.0 MVA (underground)
Warehouses, distribution centers	FedEx Center	27 Mack Ln, Hermon, ME 04401	CMP	3 Phase, < 0.5 MVA (Overhead)
Warehouses, distribution centers	Procter & Gamble Tambrands	2879 Hotel Rd, Auburn, ME 04210	CMP	3 Phase, < 0.5 MVA (underground)
Warehouses, distribution centers	Hannaford Distribution Center	54 Hemco Rd, South Portland, ME 04106	CMP	3 Phase, 1.0 MVA to 2.0 MVA (underground)
Warehouses, distribution centers	International Paper	175 Allied Rd, Auburn, ME 04210	CMP	3 Phase, > 5.0 MVA (overhead)
Warehouses, distribution centers	Brockway Smith Co	7 Rand Rd, Portland, ME 04102	CMP	3 Phase, 2.0 MVA to 5.0 MVA (underground)
Private yards, depots	Auburn Asphalt, LLC	Auburn Asphalt, LLC 3189 Hotel Rd, Auburn, ME 04210	CMP	3 Phase, < 0.5 MVA (underground)
Private yards, depots	Bison Transport USA	281 1st Flight Dr, Auburn, ME 04210	CMP	3 Phase, > 5.0 MVA (underground)
Private yards, depots	Messer	9 Ranger Dr, Kittery, ME 03904	CMP	3 Phase, <0.5 MVA (overhead)
Private yards, depots	R.H. Foster Energy—Hampden	81 Mecaw Rd, Hampden, ME 04444	Versant	1000–4999 kW
Private yards, depots	Sibley Transportation Inc	242 Miller St, Bangor, ME 04401	Versant	Under 199 kW
Private yards, depots	Casella Waste Systems	87 Pleasant Hill Rd, Scarborough, ME 04074	CMP	3 Phase, 2.0 MVA to 5.0 MVA (overhead)

Site Type	Name	Address	Utility	Hosting Capacity
Private yards, depots	FirstFleet Inc.	61 Twin Rd, Auburn, ME 04210	CMP	3 Phase, 2.0 MVA to 5.0 MVA (overhead)
Truck stops, rest areas	Baileyville Big Stop	32 Houlton Rd, Baileyville, ME 04694	Eastern Maine Electric Cooperative	Unknown
Truck stops, rest areas	Hampden North	I-95 175, Bangor, ME 04401	Versant	Under 199 kW
Bus yards	Portland Transportation Center	100 Thompson's Point Road, Portland, ME 04102	CMP	3 Phase, > 5.0 MVA (Overhead)
Industrial areas	Portsmouth Naval Shipyard	37J6+42 Kittery, Maine	CMP	Unknown
Industrial areas	Bayside area, Portland	USPS facility: 125 Forest Ave, Portland, ME 04101	CMP	3 Phase, 2.0 MVA to 5.0 MVA (Overhead)

A separate study, the Northeast Freight Corridors Charging Plan led by National Grid, identified major truck parking locations along the I-95 corridor as likely sites for public electrification infrastructure. These sites, which mainly include service plazas, rest areas, and truck stops, are not included in the above table.

C



SUMMARY OF STAKEHOLDER ENGAGEMENT ACTIVITIES AND FINDINGS

C.1 Engagement Overview

This appendix to the Maine Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles summarizes the stakeholder engagement that was conducted to inform this roadmap. Nearly 20 individual interviews and 8 focus groups were conducted with key stakeholders across the medium- and heavy-duty vehicle (MHDV) industry and supply chains about the zero-emission vehicle (ZEV) transition. The study was also guided by an Advisory Group that met five times to review and comment on study methods and findings.

The goal of the engagement was to learn from those involved in day-to-day truck and bus operations, as well as in ZEV policy, vehicle, and infrastructure development, to identify common challenges and better understand perspectives on and questions about clean trucks and buses and charging and fueling infrastructure. Table C.1 provides a list of the stakeholder groups and categories engaged through interviews and focus groups. Table C.2 shows Advisory Group membership. Table C.3 outlines the topic areas discussed and how they relate to the tasks and objectives in the roadmap.

TABLE C.1 STAKEHOLDERS ENGAGED THROUGH INTERVIEWS AND FOCUS GROUPS

Stakeholder Group	Definition	Organizations Engaged
Charging and fueling infrastructure (CFI) providers	Entities that install and/or provide CFI as a commercial or public service (includes ports and airports)	5
Cross-sector industry groups	Organizations that represent multiple interests and stakeholders across the ZEV industry/supply chain	2

Stakeholder Group	Definition	Organizations Engaged
Environmental and community groups	Groups or individuals representing environmental advocacy and/or potentially affected communities	3
Fleet operators (private and public)	Companies, organizations, and transit authorities that operate medium- or heavy-duty fleets in Maine	12 public fleets; 16 private fleets
Labor groups	Labor interests that may be affected by ZEV transition	1
Original equipment manufacturers (OEMs)	Companies that make ZEV MHDVs and sell them to dealers or direct to consumers	3
Public agencies	State, Federal, regional, and/or local governance agencies; also includes public education institutions	3
Truck and bus dealers	Entities that sell MHDVs, which may include ZEV MHDVs, through retail or wholesale operations	4

TABLE C.2 ADVISORY GROUP MEMBERSHIP

Stakeholder Group	Organization
CFI Provider	ReVision Energy
Cross-Sector Industry Groups	Maine Motor Transport Association
Cross-Sector Industry Groups	Cornerstone Government Affairs (representing Associated General Contractors)
Environmental and Community	Natural Resources Council of Maine
Environmental and Community	VEIC
Fleet Operator (Private)	Bison USA
Fleet Operator (Private)	Hannaford Bros, Co.
Fleet Operator (Private)	Pine State Trading Co.
Fleet Operator (Private)	The Lynch Group
Fleet Operator (Private)	Thomas School Buses (WC Cressey and Sons, dealer)
Fleet Operator (Public)	Biddeford Saco Old Orchard Beach Transit (BSOOB)
Labor Group	American Progress
Public Agency	Efficiency Maine Trust
Public Agency	Governor's Energy Office
Public Agency	Governor's Office of Policy Innovation and the Future
Public Agency	Maine Department of Environmental Protection
Public Agency	Maine Department of Transportation
Public Agency	Maine Public Utilities Commission
Truck and Bus Dealer	Freightliner of Maine
Utility	Central Maine Power
Utility	Versant Power

TABLE C.3 STAKEHOLDER INPUT NEEDED ON ROADMAP OBJECTIVES

Key Objectives	Input Topics
Describe the characteristics of the MHDV sector in Maine.	» Understand MHD ZEV availability in Maine at present and in the near future (OEMs, dealers). » Understand how the new and used MHDV sales markets in Maine operate (OEMs, dealers, fleet operators).
Estimate potential MHDV market adoption for different vehicle technologies and segments through 2035, including most likely early adopters.	» Understand interest/willingness/likelihood to purchase and use MHDV ZEVs within a given timeframe and by vocation/use case (fleet operators).
Estimate the potential need for charging infrastructure and energy capacity serving MHDV ZEVs and the evolution of this need, both spatially and over time, including needs and opportunities for high-demand charging locations; identify needs to support development of charging infrastructure.	» Potential charging/use patterns including high-demand charging locations (fleet operators, dealers). » Potential grid upgrades to support charging demand and associated costs (utilities). » Permitting and regulatory requirements, barriers, and solutions (utilities, CFI providers, municipalities, fleet operators). » Policies, incentives, and/or other programs that could support/accelerate infrastructure development (fleet operators, utilities, CFI providers).
Identify the implications of existing policies for MHDV ZEV adoption; potential additional policies, programs, and incentives to encourage MHDV ZEV uptake; and potential costs and benefits.	» Policies and incentives that would be most effective at accelerating MHDV ZEV adoption (fleet operators, labor groups, CFI providers). » Policies and incentives to enhance benefits and mitigate any negative impacts of ZEV transition (fleet operators, labor groups, environmental and community interests). » Immediate opportunities for grant applications and demonstration projects (fleet operators).
Develop roadmap for how Maine will convert its MHDV fleet to zero-emissions.	» Is the technical analysis sound? Are conclusions properly supported? Do policy recommendations cover the right priorities and address key needs? Are proposed implementation timelines reasonable (all groups and especially Advisory Group)?

C.2 Key Findings

The following section documents findings from interviews and focus group conversations.

Characteristics of the MHDV Sector in Maine

Understanding the types of medium- and heavy-duty vehicles that currently operate in Maine and what (if any) ZEV alternatives are available is an important first step in the ZEV transition. Through conversations with fleet operators, transit operators cross-sector industry groups, OEMs, and truck and bus dealers, we learned that:

- **Medium-duty ZEV cargo vans are available for purchase and are operational in Maine.** Several fleets in Maine operate ZEV cargo vans. These vans usually drive less than 250 miles a day, so charging needs are predictable and consistent. Additionally, truck dealers in Maine sell these vehicles and provide maintenance.
- **Some ZEV Class 6/7 transit buses, some school buses, and one Class 7 refuse truck currently operate in Maine.** Two transit operators in Southern Maine—Biddeford Saco Old Orchard Beach Transit (BSOOB) and Greater Portland METRO—have electric buses in their fleet. The City of Portland deployed one electric refuse truck in June 2024. More than 10 school districts have purchased electric school buses through U.S. Environmental Protection Agency (EPA) funding to date, though the buses from one particular manufacturer have had mixed results in practice.

LESSONS LEARNED FROM ATTEMPTING TO PURCHASE A ZEV CLASS 8 TRUCK

In 2019, one Maine fleet operator received a grant to procure an electric Class 8 truck that would be used for on-site ash hauling needs. Low mileage and predictable workload made this vehicle a good candidate for electrification. The fleet manager contracted with an electric truck manufacturer to build the vehicle but ultimately had to cancel the order because the manufacturer was not able to build a viable product. Specifically:

1. The manufacturer was not able to ensure enough torque to withstand heavy loads.
2. There were concerns that loose ash could fall into the truck and cause additional maintenance issues.
3. There was no known test data about how the vehicle would perform in colder climates.

- **No ZEV Class 8 trucks currently operate in Maine and none are currently available on the lot through Maine truck dealers.** Class 8 trucks are often highly customized and built to order. Many Class 8 trucks serve long-haul routes across state lines.
- **Fleet turnover varies by operator.** Understanding fleet turnover rates can help anticipate future purchasing patterns. Generally, larger companies turn fleets over more quickly, roughly every five years, reselling used vehicles or moving them into less-intensive operations. In Maine, vehicle lifespan may be reduced due to exposure to road salts that corrode the vehicle undercarriage.
- **Some fleet operators view non-ZEV alternative fuel vehicles as a more realistic next step than electrification.** Many fleet operators and truck dealers expressed limited interest in purchasing or leasing heavy-duty ZEV trucks at this time. Currently, some fleets in Maine use alternative non-ZEV fuels (such as renewable diesel and propane). Fleet operators prefer these fuels due to lack of additional upfront capital costs. For example, using renewable diesel requires no retrofitting for internal combustion engine vehicles that use conventional diesel and is compatible with existing warranties. There are limited suppliers of alternative fossil fuels in Maine.
- **Some training for EV automotive technicians exists in Maine, but awareness of the program is limited.** Southern Maine Community College (SMCC) offers a free course in EV maintenance. SMCC began offering the course at the request of VIP Tires and Service, and Maine Quality Centers subsidizes the program. While the class focuses on light-duty EVs, much of the information applies to medium- and heavy-duty vehicles as well. Some auto dealers and maintenance shops have sent groups of staff through the program, but overall interest has been limited.
- **There are examples of MHDV off-road vehicles beginning to transition to zero-emission vehicles in Maine**. For example, the Portland Jetport received its first electric pushback tug for aircraft in 2023, replacing a diesel tug. This tug meets the operational needs of its predecessor because it is able to charge in between aircraft pushbacks. The airport also recently added two Ford F-150 Lightnings and two electric service vans to their fleet.

Potential for MHDV Market Adoption

Interest in and willingness/likelihood to purchase or lease MHDV ZEVs varies greatly based on vocation, use case, and timeframe. This section outlines some of the key opportunities and motivators for ZEV adoption, summarizes the barriers and challenges that fleets perceive, and identifies the best use cases for early adoption.

Perceived Opportunities for and Drivers of ZEV Adoption

- **The ZEV transition is coming/feels inevitable.** Several fleet operators acknowledged that the trucking industry overall is heading toward electrification, but Maine is not there yet. They cited regulatory approaches such as Advanced Clean Trucks and Advanced Clean Fleets as key drivers in other states. In Maine, some companies have adopted their own net-zero or low-emissions goals and transitioning to ZEVs will help them achieve emission reductions. One fleet operator noted that fleets that serve national corporations with Scope 3 emissions reduction goals may be required to use ZEVs in the next few years.
- **ZEVs must make sense from operational and financial perspectives.** Many fleet operators describe themselves as "fuel-agnostic" and are open to ZEV adoption if it makes business and financial sense. However, not every use case is a candidate for early adoption, and there are few known examples of successful HD ZEV trucks in Maine or states with similar climates across those stakeholders engaged. Most fleet operators agreed they will "take the path of least resistance" so long as it makes financial and operational sense. As more HD ZEVs become available to purchase and are proven to have

DOWNEAST TRANSPORTATION RECEIVED GRANT TO ELECTRIFY BUSES

In July 2024, Downeast Transportation received $23.5 million in Federal grant funding to replace 21 of its propane fueled buses with at least 23 electric buses. The buses are expected to be used for the Island Explorer in the areas surrounding Acadia National Park from June through October, and will also be used on nearby rural transit and workforce transportation routes year around. Delivery for the buses is anticipated between 2027 and 2028. This lines up with the timing of the existing propane-fueled buses reaching the end of their useful life, leading to an efficient replacement of the fleet. The grant was provided by the U.S. DOT's Rebuilding American Infrastructure with Sustainability and Equity (RAISE) program, funded by the 2021 Bipartisan Infrastructure Law.

successful implementation and use cases—and as charging station infrastructure becomes widely available—fleets will feel better about investing in these technologies.

- **Grants, tax credits, and other incentives exist to offset purchase costs.** There are currently several Federal funding opportunities available for medium- and heavy-duty ZEVs and charging station infrastructure. The Efficiency Maine Trust, which together with Maine Department of Transportation administers the state's Federal and state EV charging allocations, offers periodic funding opportunities for installing charging stations. Fleet operators who can procure grants or manage upfront vehicle costs are able to feel the reduction in overall ZEV operating costs (as compared to conventional vehicles) more immediately.
- **Different stakeholders see different benefits of ZEVs.** While some fleets are motivated by the climate and air quality benefits of ZEVs, others feel more compelled by the lower total cost of ownership and reduced maintenance needs. For some, electric vehicles feel controversial and are perceived to signal certain political associations. One transit provider who operates ZEV buses noted that riders appreciate the noise reduction that ZEVs offer. Thus, there is no "one size fits all" approach to encouraging ZEV adoption, and messaging around the benefits of ZEVs should be tailored by audience.
- **A good relationship with a local dealer or vehicle manufacturer can build confidence.** Nearly every private fleet and transit operator expressed the importance of having a good working relationship with a local dealer or manufacturer who understands their vehicle(s), has properly trained staff, and can provide timely maintenance. Some dealerships even assist customers with grant application processes, charger installation, and project planning. Conversely, a representative from a waste management company who operates a few ZEV refuse trucks in Vermont noted that the biggest challenge they have faced is repair times. The closest dealer who can service their trucks is in Massachusetts, which leads to long wait times for repair and difficult logistics to bring the vehicles in for service.

Perceived Barriers to ZEV Adoption

Stakeholders cited several perceived barriers to ZEV adoption.[77] These include:

- **Limited range and impacts of cold weather.** By nature, many heavy-duty trucks serve long-haul routes. A battery range of 200 miles or less is not operationally suitable for many fleets, especially when adequate publicly-accessible charging station infrastructure does not exist along many routes. Many fleet operators expressed concern that cold weather battery range impacts would make it difficult to transition to an all-electric fleet.
- **Lack of maintenance providers and a sufficient maintenance labor force.** When a truck or bus needs repair, fleet operators need to trust that someone can make the repairs in a timely manner so that the vehicle can return to service as soon as possible. Losing a vehicle to a long maintenance process can lead to operational, and ultimately financial, losses.
- **High upfront costs and uncertain resale potential.** ZEV trucks and buses are expensive. While some grants exist to offset this cost, private sector fleets may be ineligible for those grants. While a few fleet operators had heard about the Federal commercial clean vehicle tax credit, they lacked adequate capacity to understand and complete the application process. Moreover, there is uncertainty around vehicle resale potential, and the battery and hardware lifespan for ZEVs. Many fleet operators purchase new trucks with the intention of reselling them within a few years, and they know what price they can get for conventional vehicles. Th resale market has not yet evolved for ZEV trucks.
- **Uncertainty that electrification is here to stay.** One CFI provider felt that the industry might move toward hydrogen and therefore did not want to invest too heavily in electrification for heavier trucks. Some fleet operators also felt that hydrogen is more suitable for long-haul, heavy-duty trucks, and expressed a preference to wait until hydrogen becomes more widely available before investing in a clean truck.
- **Operating cost uncertainty.** Some fleet operators did not feel confident that operating costs of ZEVs would be less than an ICE vehicle. This perception is due to anticipated high maintenance requirements and costs for early production ZEVs, before production quality

[77] These barriers in some cases may not be supported by real-world data. However, as perceptions they point out areas where additional information and education about ZEV capabilities may be needed, as well as improvements to technology, economics, and ZEV support systems.

has stabilized and when a locally trained maintenance force does not yet exist. They also worry about payload reductions and increased tire wear due to battery weight.

- **Long lead times for procurement and repair.** OEMs, including infrastructure manufacturers, can go out of business. A lot of time and effort goes into procuring a new truck, and many fleet operators question what will happen if an order is canceled, no local shop can repair the vehicle or equipment, or an asset's value crashes. Moreover, fleet operators are only familiar with a few commonly available models of MHDV ZEVs, and the industry continues to face supply chain barriers to delivering vehicles on time—which is also currently true, though to a lesser extent, for ICE vehicles. Many fleet operators in Maine are small businesses that own fewer than 10 trucks, and lack capacity to spend extensive time on procurement.
- **Lack of charging infrastructure and inconsistent electricity pricing.** Maine is a rural state, and trucks may need to drive hundreds of miles each day. In some areas of Maine, the grid already struggles to meet power needs, and there are concerns that rapidly growing vehicle charging needs could break a strained system. Additionally, utility providers could do more to support the transition to MHDV ZEVs through make-ready and other support programs, which have yet to be authorized by the Maine Public Utilities Commission.
- **The potential for dangerous and costly fires caused by malfunctioning batteries**. Fleet operators, ports and intermodal hubs noted concern with charging vehicles inside and the potential for battery fires that are dangerous and expensive. Those who expressed this concern noted there is no assurance that fire departments and first responders would be able to easily extinguish battery fires. They also mentioned that insurance companies may not always cover all fires and may require vehicles to be parked outside in order to be covered. In 2024, the State of Maine partnered to provide two firefighter EV training sessions and continues to work to combat misinformation about fire safety; available data demonstrates that EVs are much less likely to catch fire than ICE vehicles.

Best Use Cases for Early Adoption

Many stakeholders expressed that vehicles with relatively short and well-defined routes, which return "home" to a depot at regular intervals, and which have commercially available ZEV alternatives are the best candidates to electrify. These vehicles may include:

- Buses, including school buses.
- Short-range, door-to-door delivery or last-mile trucks and vans.
- Class 6 and 7 trucks with consistent daily operating patterns, especially those that have low hauling requirements, such as yard and drayage trucks.
- Class 2b–4 pickup trucks and vans.

C.3 Charging Infrastructure and Energy Capacity

Most MHD ZEVs in the near- and medium- term will be powered by electricity. The switch from internal combustion engines to battery electric vehicles will require the construction of electric vehicle charging locations in public areas such as truck stops and private depots. This shift will include new permitting and regulatory requirements for charging infrastructure locations as well as grid upgrades for some locations. Policies and incentives need to support the development of charging infrastructure to ensure a seamless transition. Fleet operations will adapt to new infrastructure and charging demand patterns will need to be well understood. Consequently, charging infrastructure opportunities and barriers were discussed by interviewees and focus group participants.

Charging Infrastructure Opportunities

- **Charging connectors have become more standardized.** Over the past few years, charging ports among electric vehicles have become more unified and standardized. For MHDVs, a new SAE standard (SAE J3271) is under development for megawatt charging and is expected to become the industry standard. All MHDVs that are battery electric vehicles should be able to use this standard, or an existing standard for lower voltage charging that is increasingly becoming more unified (Tesla's North American Charging Standard, being standardized as SAE J3400).
- **Trucks stops are appropriate locations for charging.** Existing truck stop rest areas should be used as sites for publicly available MHDV charging. A current National Grid study is

investigating the potential for MHDV charging along interstate corridors in the Northeast, including at least four locations in Maine, with locations along major highways being considered.[78] Unique layout needs for charging trucks should be considered, such as pull through charging lanes.

» **Fleets may not need one charger per vehicle, reducing capital costs required for the installation of more chargers.** Depending on operational schedules, fleets may not require one charger for each vehicle. Operators may find that two vehicles can "share" a charger (i.e., as one is charging, the other is operating). Fleet operators may also consider loading bays with inductive charging as this technology improves and becomes less costly. Inductive charging could decrease the number of chargers needed due to the fast rate of charging.

» **Lower power (<500 kW, Level 3 or lower) charging is possible for vehicle fleets with long dwell times between operations**. Some fleet operators expressed concerns about the high voltage of power that will be needed for certain MHDVs, due to increased costs to bring that power to a particular charging site. However, not all fleets will require megawatt charging. This will especially be true for fleets that have long dwell times (i.e., overnight parking) with no operation between deployments; these fleets can often make use of lower powered, Level 2 or Level 3 charging.

Perceived Concerns about Charging Infrastructure

Stakeholders cited several perceived concerns related to truck charging.[79] These include:

» **Currently, there are few public chargers in the state that meet the charging need of MHDVs.** Several fleet operators acknowledged that they would mostly need to rely on depot charging for their fleet. Many MHDVs require high voltages (as high as 1 MW) to charge in a reasonable timeframe, due to the large capacity of their batteries or the operational cycle of the truck in question. Publicly available chargers may not always receive their maximum power rate from the grid (such as if two plugs are sharing power supplied through a single charger), which could make charge times variable and inconsistent.

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78 National Grid, Northeast Freight Corridors Charging Plan.

79 In some cases, these "perceived concerns" may not be supported by real-world data. However, as perceptions they point out areas where additional information and education about charging capabilities may be needed.

- **Major investments are needed to ensure plentiful public and private MHDV charging.** Installing high voltage DC and AC chargers for MHDVs takes time and can require significant capital investment. Utilities are prepared to support fleets in the transition, but the process of installing chargers at depots and public locations can take months to years. Fleet operators therefore need to be forward thinking and inform utilities in advance of their interest in installing chargers. This type of work is different from the planning that conventional truck operators have traditionally done, requiring additional coordination and capacity.
- **Operators fear that there is not enough grid capacity for the transition.** Fleet operators expressed skepticism that the overall grid capacity in the region would be able to meet the rising electricity demand as an increasing share of vehicles on the road are electric. The State and regional grid operators are both engaged in planning efforts to ensure that infrastructure is planned and deployed to meet this need.

C.4 Policies and Incentives for Accelerating MHDV ZEV Adoption

Stakeholders discussed many kinds of policies and incentives. These policies were aimed at accelerating MHDV ZEV adoption and enhancing the benefits of the transition while minimizing any negative impacts. One area that was frequently discussed was the cost barrier of the ZEV transition; fleet operators noted that they will not pursue ZEVs if the cost of the vehicles and associated infrastructure remain prohibitively high. Therefore, incentives and policies to mitigate these costs are considered and noted.

General Policies

- **Streamline communication about MHDV ZEVs, noting their benefits and assuaging fears of the transition.** OEMs and environmental groups suggested that clear communication that describes the benefits of ZEVs and dismantles negative myths could help encourage fleet transition to ZEVs. As more positive experiences grow with MHDV ZEVs in the state, these experiences should be documented and shared publicly. One example could be leveraging the case studies included as part of this roadmap (see Appendix B).
- **Raise awareness about MHDV ZEVs through educational opportunities like "ride and drives."** Putting on public "ride and drive" events where operators can see and

experience ZEVs in person can increase confidence in the vehicles. Other states such as Massachusetts and Vermont have held regular "ride and drive" events of ZEVs for the general public. The State of Maine could partner with an OEM to showcase ZEVs and allow reporters and fleet operators to test drive vehicles. For example, Mack Trucks showed off their medium-duty ZEV at the Sonoma Raceway in California in 2023 at an event, allowing reporters to take part in the ride and drive.[80] The State of Maine is partnering with Maine Clean Cities and CALSTART to host an electric truck showcase in 2025.

- **The state should lead by example by being early adopters of ZEVs.** Many fleet owners suggest that the State of Maine and local governments should take the lead on adopting MHD ZEV fleets. This would jumpstart the installation of charging infrastructure and increase the market presence of MHD ZEV companies in the state.
- **Define environmental justice ("EJ") communities so that the geographic impacts of the MHDV ZEV transition can be more properly studied.** Environmental organizations noted that other states have defined EJ communities at the block group or census tract level with census data related to income, housing cost burden, percent people of color, percent speaking a language other than English at home, and those that also bear disproportionate impacts of air, land, and water pollution. Defining these communities and quantifying potential disproportionate impacts from conventional vehicles within these communities can help accelerate adoption of cleaner vehicles in those locations.
- **Avoid premature regulatory requirements.** Fleet operators and OEMs cautioned that premature MHDV ZEV requirements could result in operators keeping their old ICE vehicles longer to get around new purchase requirements. If regulatory requirements do not come with proper incentives to encourage investment in ZEVs, there could be limited near-term transition to ZEVs.
- **Engage in workforce development to support the new maintenance skills required for ZEVs.** Training for ZEV maintenance technicians will be needed to support the transition to ZEVs. As the number of ZEVs grows, there will be increased demand for more mechanics that have the skills and knowledge to repair and maintain ZEVs. The State can support this need by attracting more prospective mechanics to trainings such as the courses taught

80 https://www.ttnews.com/articles/mack-trucks-md-electric.

at SMCC automotive technology department. The State can also fund programs in other locations across the state.

Financial Incentives and Transition Tools

- **Develop state-supported pilot programs.** Maine should develop programs to incentivize the purchase and operation of MHDV ZEVs. A pilot program, such as the MHD ZEV pilot launched in October 2024 by Efficiency Maine Trust, could include both financial assistance and educational assistance. Fleet operators need to determine use case, charging strategy, and infrastructure/charging capacity before procurement begins; the pilot program should provide this support as well.
- **Develop a fleet grant program for MHDV ZEVs.** The State should consider establishing a competitive grant program, and supporting applications to Federal grant programs, for fleets to support the transition of MHDV fleets to ZEVs. This program could provide a match for the costs of purchasing ZEVs and constructing associated charging and fueling infrastructure. Colorado developed a ZEV grant program for fleets; Maine could model their program on this one.[81] This sort of program could also complement a requirement for fleet operators to disclose the emissions of their fleets, which could help support further ZEV adoption. California's law that requires companies to disclose fleet emissions is anticipated to speed ZEV adoption, especially among companies with a large public profile.[82]

LD 122 MAINE EMT PILOT PROGRAM

In the 131st session, the Maine legislature has passed a bill (LD 122) authorizing an MHD ZEV pilot program administered by Efficiency Maine Trust. This program aims to use Federal or other funding sources to support the uptake of MHD ZEVs through a rebate program to support the purchase of the vehicles and their associated charging or fueling infrastructure. This bill also establishes a report to study vehicle-to-grid (V2G) technologies, to evaluate the benefits of using battery electric MHDVs as energy storage resources that can deliver electricity to the grid when vehicles are not being used. The MHD ZEV pilot program was launched in late 2024. The funding for the program is $500,000.

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81 https://energyoffice.colorado.gov/fleet-zero#:~:text=Colorado's%20Fleet%2DZERO%20grant%20program,heavy%2Dduty%20fleets%20to%20EVs.

82 https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets.

- **Establish utility programs to support charging infrastructure.** Utilities can build tools to help fleet operators identify whether they have charging capacity at their proposed charging sites. For example, Central Maine Power offers an interactive Load Hosting Capacity Map. They should also have services to easily identifying the cost of grid upgrades that may be needed like CMP's school bus advisory service that is already in place. Utilities should also have or expand clearly defined rate designs for EV charging that avoids high demand charges and provides a consistent, easy to predict cost. Both major utilities in the state, CMP and Versant, have already begun this process by developing electric vehicle rates[83,84] in their service areas. The Maine Public Utilities Commission opened an inquiry (Docket No. 2024-00231) to consider the implementation of time-of-use rates for standard offer and delivery service for customers of Maine's investor-owned utilities.[85]
- **State support for applications for Federal funding.** Maine can unify and streamline applications for many Federal funding programs including:
  - U.S. Environmental Protection Agency (EPA) Clean Heavy Duty Vehicles Program.
  - Federal Transit Administration Low or No Emission Grant Program (LoNo).
  - U.S. EPA Clean Ports Program.
  - U.S. Department of Transportation Charging and Fueling Infrastructure Discretionary Grant Program.

83 https://www.cmpco.com/account/understandyourbill/newelectrictechnologyrate.

84 https://www.versantpower.com/energy-solutions/electric-vehicles/.

85 https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2024-00231.

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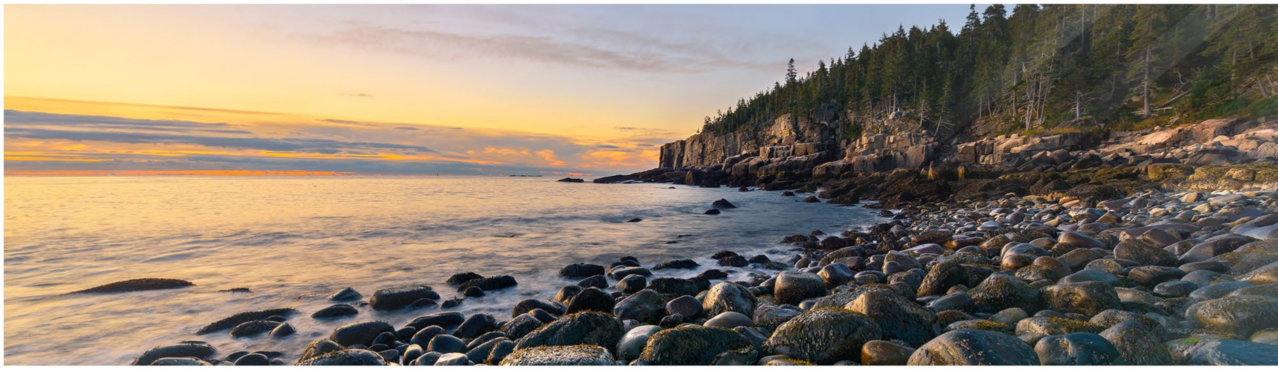


MAINE'S MEDIUM- AND HEAVY-DUTY VEHICLE LANDSCAPE

D.1 Objectives

Maine's Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles ("roadmap") charts a path for Maine to decarbonize the trucks and buses moving people and goods within and through the state. This appendix to the roadmap provides a description of the current medium and heavy-duty vehicle (MHDV) sector in Maine. It examines available data sources to characterize Maine's MHDV fleets in terms of vehicle types, vocations, age distributions, and annual miles per vehicle by market segment and geography. The objectives of characterizing the existing market are to:

- Assist in identifying market segments with the greatest potential for near-term and longer-term introduction of zero-emission vehicles (ZEV).
- Provide a basis for developing scenarios of future MHDV populations and usage in Maine, including conversion to ZEV technology.
- Provide data to inform estimates of current and forecast emissions from MHDVs and the potential emission reduction benefits of introducing MHDV ZEVs.
- Provide data to inform estimates of charging demand for battery electric MHDV ZEVs and how that may evolve over time and space.

D.2 Data Sources

No single data source provides a comprehensive picture of Maine's MHDV fleet, and different data sources have different inherent advantages and limitations. In some cases, the data sources provide complementary information; in other cases, the information may be redundant (but not necessarily the same, due to different definitions, sample sizes, and methods). The following data sources were used to characterize Maine's MHDV sector:

- The **MERI vehicle registration database**, provided by Maine Department of Environmental Protection (DEP), includes individual car and truck registrations statewide from Maine's Bureau of Motor Vehicles (BMV) as of July 1, 2023. 2020 registration data were also analyzed to provide mileage accumulation rates prior to COVID. The database additionally denotes vehicle vocation (based on the U.S. Environmental Protection Agency or EPA MOVES model source type) and weight class (based on the U.S. EPA MOBILE6 model vehicle class). Additional vehicle attributes in the database include an aggregate truck weight class (light, medium, or heavy), model year, odometer, ZIP code, registration class code (RCC), and (for some records) organization name. RCC provides specialty plate data for each vehicle, which serves a proxy of vocation for many trucks. Organization name, where available, can provide additional detail on vocational categories beyond MOVES source types or RCC.

  Registration data has the advantage of being comprehensive in its coverage of all vehicles registered in Maine. However, it does not capture populations and activities of vehicles registered in other States, but operating part-time in Maine. Also, while some trucks can be identified with vocational information based on the type of registration, for a large fraction of vehicles no information on activity patterns can be inferred other than annual miles driven. Finally, the location where the vehicle is registered may not always correspond to the area in which it is primarily driven and domiciled; business' headquarters often differ from fleet depot locations.

- The U.S. Department of Transportation (U.S. DOT) **Vehicle Inventory and Use Survey (VIUS).** This nationwide 2021 survey provides information from a sample of trucks, including model year, weight class, vehicle type, lease status, replacement plans, annual miles, primary range of operation, fuel type, refueling location, kind of business, primary use, and home base type.

The VIUS dataset represents a good-sized sample and provides information on usage patterns beyond what can be estimated from registration data. Its primary limitation for this study is that it is only available at a statewide level—no substate geography is available. Also, because the survey relied upon the willingness of vehicle owners to respond, it is not necessarily a random sample.

» **LOCUS Truck**, provided by Cambridge Systematics based on Geotab telematics data, for year 2023. LOCUS Truck provides truck activity information for three weight classes (light, medium, and heavy) and five vocational categories, at the Census Tract geographic level. Information is available on number of trip origins and destinations, vehicle-miles traveled (VMT), dwell time, trip lengths (miles), and time of day (four periods).

LOCUS Truck has the advantages of providing information on actual activity patterns (trip-ends, VMT, and dwell times) by substate geography, as well as distinguishing vocational classes that may be more or less suited to electrification. It also captures travel by truck trips with an origin or destination in another State. Its primary disadvantages are that it does not provide an inventory of individual trucks (only truck trips) and the location where the trucks are registered or domiciled is not known. It is also based on only a partial sample of about 15 percent of truck trips taken in Maine. The sample is expanded to match population total truck travel by market segment using statistical methods.

The five LOCUS Truck vocational categories, as described by Geotab and based on the vehicle's activity patterns, are shown in Table D.1.

TABLE D.1 LOCUS TRUCK VOCATIONAL CATEGORIES

Vocation	Description	Examples
Long Distance	The vehicle has a very large range of activity and typically does not rest in the same location. The vehicle is also neither hub-and-spoke nor door-to-door.	» Freight Trucking » Rental or Company Vehicles
Regional	The vehicle has a wide range of activity, over the 150-mile threshold for short-haul exemption, but tends to rest in the same location often. The vehicle is also neither hub-and-spoke nor door-to-door.	» Building Supplies » Fuel Carrier
Local	The vehicle's range of activity is below 150-air-miles thus qualifies for the short-haul exemption under Hours of Service Regulations. In addition, the vehicle does not exhibit behavior in line with other vocations such as hub-and-spoke and door-to-door.	» HVAC » Beverage Distribution

Vocation	Description	Examples
Hub-and-Spoke	The vehicle spends many of its work days making multiple round trips from a singular location (a centralized hub). Typically the vehicle would average over one round trip per working day, with round trips accounting for the majority of its total mileage.	» On-Demand Services or Delivery » Suppliers
Door-to-Door	The vehicle makes significantly more stops than most per work day but also tends to spend very little time per stop.	» Last-Mile Deliver » Waste Collection

Other data sources relating to MHDVs operating in Maine were considered but not used:

- The **International Registration Program** (IRP) provides information on vehicles in fleets registered for interstate commerce, including the share of travel apportioned to Maine and was considered as a source to estimate travel by vehicles registered outside of Maine but operating partly within the state in long-haul use. The raw data were obtained but there was insufficient documentation to make use of it. The project team considered the LOCUS Truck data set (which includes information on trips and VMT for truck trips starting or ending outside of the state) sufficient to characterize travel by out-of-vehicles.
- The Federal Motor Carrier Safety Administration (FMCSA) **Motor Carrier Management Information System** (MCMIS), which includes information from vehicle inspections at weigh stations, was considered as an additional source of vehicle age distributions. However, the geographic sampling is limited (primarily on Interstate highways) and the source did not appear to provide meaningful additional value beyond what is available from registration data and VIUS on age distributions.

Findings from the three data sources that were used are first described separately. This is followed by a discussion of additional market segmentation and characterization that was obtained by combining information from MERI and LOCUS.

D.3 Vehicle Registration Data (MERI)

The MERI database was segmented to the degree possible based on weight class, RCC, and organization name. For each segment, the following information was tabulated by ZIP code of registration:

- Number of registered vehicles (population).
- Average model year and age of vehicles.
- Average miles per year.

Overall, as of 2023, there were 68,128 vehicles registered in Maine in weight Class 3 or higher. The largest vehicle class is Class 3, which comprises 42 percent of total registrations. The second highest share is Class 8, which consists of 25 percent of the total number of medium- and heavy-duty vehicles. The remaining weight classes each represent approximately 5 to 8 percent of total vehicles registered (Table D.2).

When taking into consideration the mileage of the different vehicles class (assuming pre-COVID accumulation rates from 2020 registration data), the breakdown of VMT by vehicle class presents a different picture. Class 8 vehicles produce 768 million miles of vehicle travel each year on average, which is 48 percent of total vehicle miles traveled for MHDVs in Maine. Class 3 vehicles have the next largest share at 444 million VMT, comprising 28 percent of the total. The remaining 24 percent is split between the other vehicle classes, with each producing between 3 to 6 percent of the total share on average each year.

TABLE D.2 CHARACTERISTICS OF MAINE MEDIUM- AND HEAVY-DUTY VEHICLES BY CLASS

Vehicle Class	Number of Registered Vehicles (2023)	Mean Miles per Year Per Vehicle (2020)	Total VMT Per Year by Vehicle Class (millions)
Class 3	28,369	15,650	444
Class 4	3,726	12,323	46
Class 5	5,214	17,081	89
Class 6	4,072	23,569	96
Class 7	5,410	18,285	99
Class 8	17,254	44,491	768
Bus	4,083	11,275	46

The steps to perform the analysis were as follows:

7. Segmented into truck weight category based on weight classes from MERI:
   a. Medium-duty truck (MDT) = 8,501–14,000 lbs. gross vehicle weight rating (GVWR), Class 2b–3.
   b. Heavy-duty truck (HDT) = 14,001–80,000 GVWR, Class 4–8.
8. Segmented into industry categories based on available information from MERI, including vehicle class, source type, registration class. The name of the organization to which the vehicle was registered was use to infer industry for additional vehicles when possible (e.g.,

construction, landscaping, home services, refuse, emergency, rental or leasing, banking, utility, education). A "commercial" category includes commercial-plate vehicles that could not be categorized more specifically based on the organization name; and any non-commercial leftover vehicles are categorized as "other." A check of individual records in the "other" category shows that the large majority are medium-duty pickups and sport utility vehicles registered as personal vehicles.bSegmented into ZIP code based on mailing addresses in MERI database.

9. Segmented into ZIP code based on mailing addresses in MERI database.

Table D.3 (trucks) and Table D.4 (buses) provide summary statistics for registration data at a statewide level. Because many of the "other" vehicles are not in this study's target market, the share of total truck registrations is shown with and without the "other" category. Some observations follow:

» MDTs are driven an average of about 16,800 miles per year compared to nearly 29,000 miles per year for HDTs. However, the HDT mileage is skewed by long-haul trucks which will likely be some of the hardest to electrify; removing long-haul trucks, HDTs average 17,700 miles per vehicle, only slightly more than MDTs. Thise average annual distance driven equates to 53 miles per day for MDTs and 96 miles per day for HDTs—distances that easily fall within the range of most current and future MHD ZEVs. That said, daily averages may obscure day-to-day differences such that the required range on some fraction of days is longer than the range of available electric vehicles.

» MDTs have an average age of 10 years compared to 15 years for HDTs, suggesting that the MDT fleet is likely to turnover more quickly and therefore achieve benefits faster, but also highlighting the importance of beginning a transition of the HDT fleet as soon as practical.

» The following industry categories might be considered as relatively more suitable for electrification based on typical use patterns (operating in a constrained service area): city/town, banking, education, home services, landscaping, refuse, state, utilities. These categories collectively make up about 15 percent of non-"other" vehicles.

» The following industry categories might be considered as relatively less suitable for electrification based on typical use patterns: agriculture (old vehicles, typically rural operations), construction (may require high power loads and be in continuous operation away from power sources), emergency (high power demand with unpredictable dwell schedules), long-haul, lumber (typically rural operations), motorhome (low miles/year, old vehicles, long-distance use). These categories collectively make up about 22 percent of non-"other" vehicles.

» About 37 percent of trucks (or 55 percent excluding "other") could only be classified as "commercial" with no further industry breakdown. The next section describes how the LOCUS data were used to make some inferences about vocations and suitability for electrification within this market segment.

» Leasing, rental, and utility vehicles (4 percent of "non-other") are among the youngest vehicles with relatively high miles per vehicle. Some of the leasing and rental vehicles are likely to be engaged in long-distance service and therefore less suitable to electrification; however, utility trucks are more likely to operate locally within constrained ranges and therefore be suitable for electrification.

» While the "city/town" and "state" vehicle categories (seven percent of "non-other") might appear to be low-hanging fruit from an institutional perspective for electrification, these vehicles show low miles per year which suggest that limited benefits (such as cost savings from lower operational expenses) would be obtained, other than using the vehicles as "lead by example" new technology demonstrations. However, an investigation of odometer data shows considerable missing or suspiciously low values, so the mileage estimates for these sectors may not be reliable.

» School buses make up over three-quarters of the bus population but drive just over one-third of the annual miles per year of a transit or "other" (intercity or charter) bus. School buses average about 33 miles per school day, while transit and other buses average 57 miles per day.

Figure D.1 shows the geographic distribution of registrations by ZIP code while Figure D.2 shows the total truck and bus VMT generated by vehicles registered in that ZIP code. Both of these metrics are normalized to a per square mile of land area to correct for the variation of ZIP code sizes. As expected, most registrations and vehicle trips are concentrated in Maine's population centers—the Portland region, Kittery, Lewiston-Auburn, Brunswick, Augusta, Waterville, and the Bangor area. Within the highest density category there is significant variation, with 15 ZIP codes showing over 100 registrations per square mile.

Figure D.3 shows the density of older MHDVs (2009 model year or older). The number of older MHDVs appears to generally reflect the vehicle population distribution of the state. It is important to note that, across the state, 40 percent of vehicles are model year 2009 or older, which is the final model year to not be subjected to the full phase-in of 2010 heavy-duty rule ("Phase I"), which made emission standards more stringent for heavy vehicles. 51 percent of vehicles are older than model year 2014, which is the first year regulated under "Phase II" of the heavy-duty rule issued jointly by EPA and NHTSA, which again significantly strengthened emissions standards.

Average annual VMT was also evaluated by county to see if there were significant differences across regions of the state. Average annual VMT per vehicle is greatest in Cumberland, Androscoggin, and Aroostook counties, where vehicles average greater than 23,000 miles per year, and lowest in other coastal counties, including Sagadahoc, Knox, and Washington counties where vehicles average less than 16,000 miles per year. Any of these average ranges are suitable for electrification (less than 100 miles per day), but again, averages can obscure significant differences between vehicles and use cases.

TABLE D.3 SUMMARY STATISTICS—MHDV TRUCKS REGISTERED IN MAINE

Vocation	MD Pop.	HD Pop.	Total MHD Pop.	Share of Pop.	Share of Pop. Excl Other	Mi/Year (MD)	Mi/Year (HD)	Mi/Day (MD)	Mi/Day (HD)	Avg. Age (MD)	Avg. Age (HD)
Agriculture	2,218	2,001	4,219	3.5%	5.1%	13,149	12,665	44	42	13.3	24.8
Banking	197	81	278	0.2%	0.3%	13,531	35,816	45	119	3.4	8.1
City/Town	1,328	2,915	4,243	3.5%	5.2%	1,033	1,590	3	5	10.1	13.8
Commercial	31,815	12,932	44,747	37.1%	54.5%	17,467	20,717	58	69	9.9	15.8
Construction	3,895	3,474	7,369	6.1%	9.0%	21,509	23,567	72	79	8.4	16.4
Education	256	33	289	0.2%	0.4%	6,967	9,252	23	31	9.2	15.1
Emergency	144	247	391	0.3%	0.5%	17,159	7,679	57	26	10.6	14.3
Home Services	2,365	428	2,793	2.3%	3.4%	22,476	14,593	75	49	7.1	13.8
Landscaping	1,325	871	2,196	1.8%	2.7%	17,724	15,935	59	53	7.8	14.3
Leasing	250	196	446	0.4%	0.5%	23,839	54,495	79	182	5.0	7.0
Long Haul	210	5,045	5,255	4.4%	6.4%	24,015	85,510	80	285	7.0	10.3
Lumber	440	734	1,174	1.0%	1.4%	21,047	26,570	70	89	8.5	15.5
Motorhome	1,657	2,337	3,994	3.3%	4.9%	4,154	4,012	14	13	19.2	16.0
Other	36,544	1,914	38,458	31.9%	NA	14,626	33,849	49	113	10.3	15.0
Refuse	103	470	573	0.5%	0.7%	19,139	37,314	64	124	9.2	12.5
Rental	167	192	359	0.3%	0.4%	27,147	45,936	90	153	6.4	5.0
State	737	787	1,524	1.3%	1.9%	267	2,126	1	7	7.5	11.1
Utilities	1,191	1,019	2,210	1.8%	2.7%	20,413	22,330	68	74	6.3	8.7
Grand Total	**84,842**	**35,676**	**110,815**	**100.0%**	**100.0%**	**15,894**	**28,856**	**53**	**96**	**10.0**	**14.7**

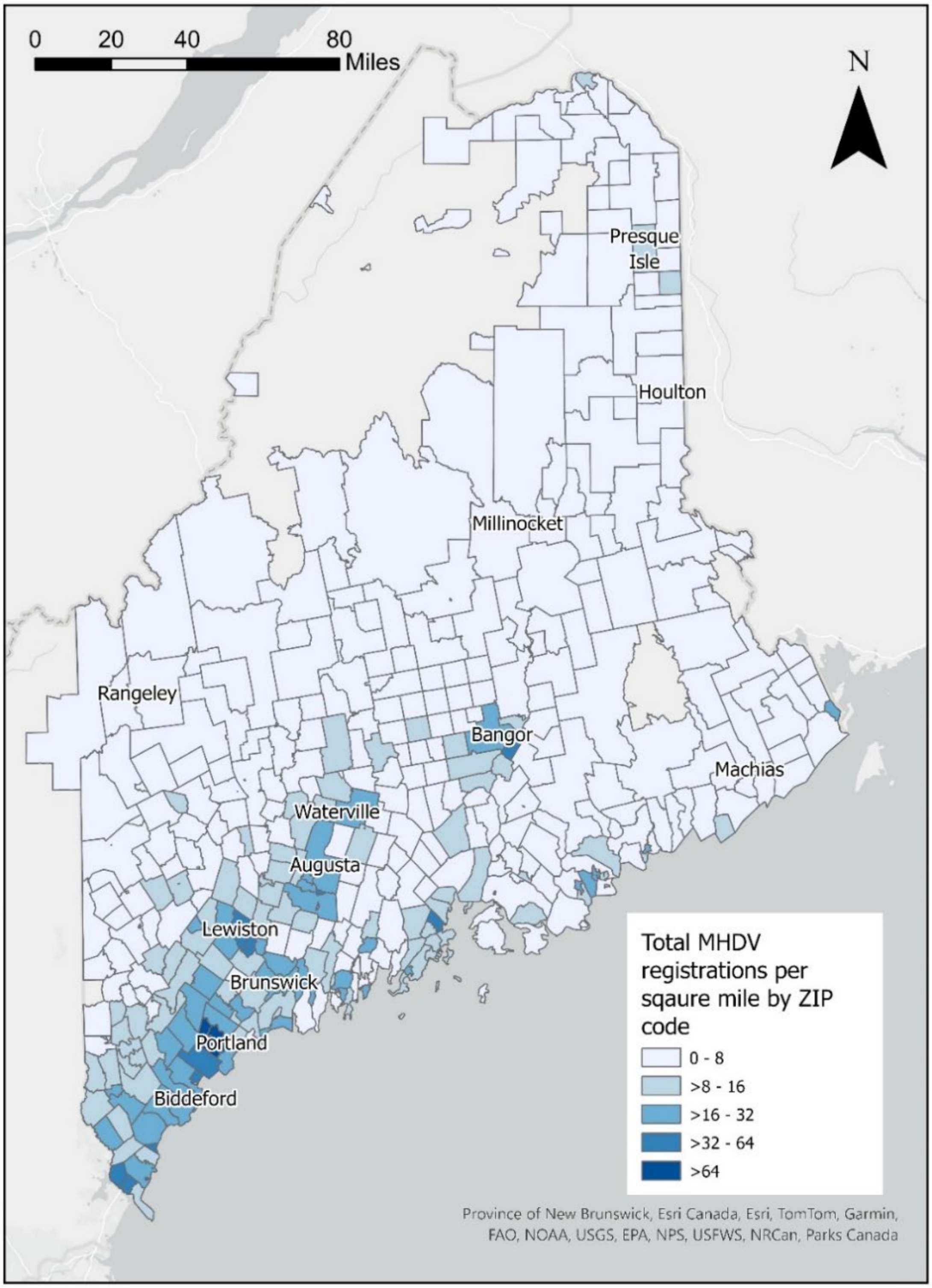
Source: Analysis of 2020 and 2023 Maine vehicle registration data by ERG as provided by Maine DEP. Daily mileage uses an annualization factor of 300.

TABLE D.4 SUMMARY STATISTICS—BUSES REGISTERED IN MAINE

Vocation	Bus Pop.	Mi/Vehicle/Year	Mi/Vehicle/Day	Average Age
Other bus	564	16,892	56	11.7
School bus	3,172	6,001	33	8.2
Transit bus	347	17,091	57	9.3
Total	**4,083**	**8,337**	**28**	**8.7**

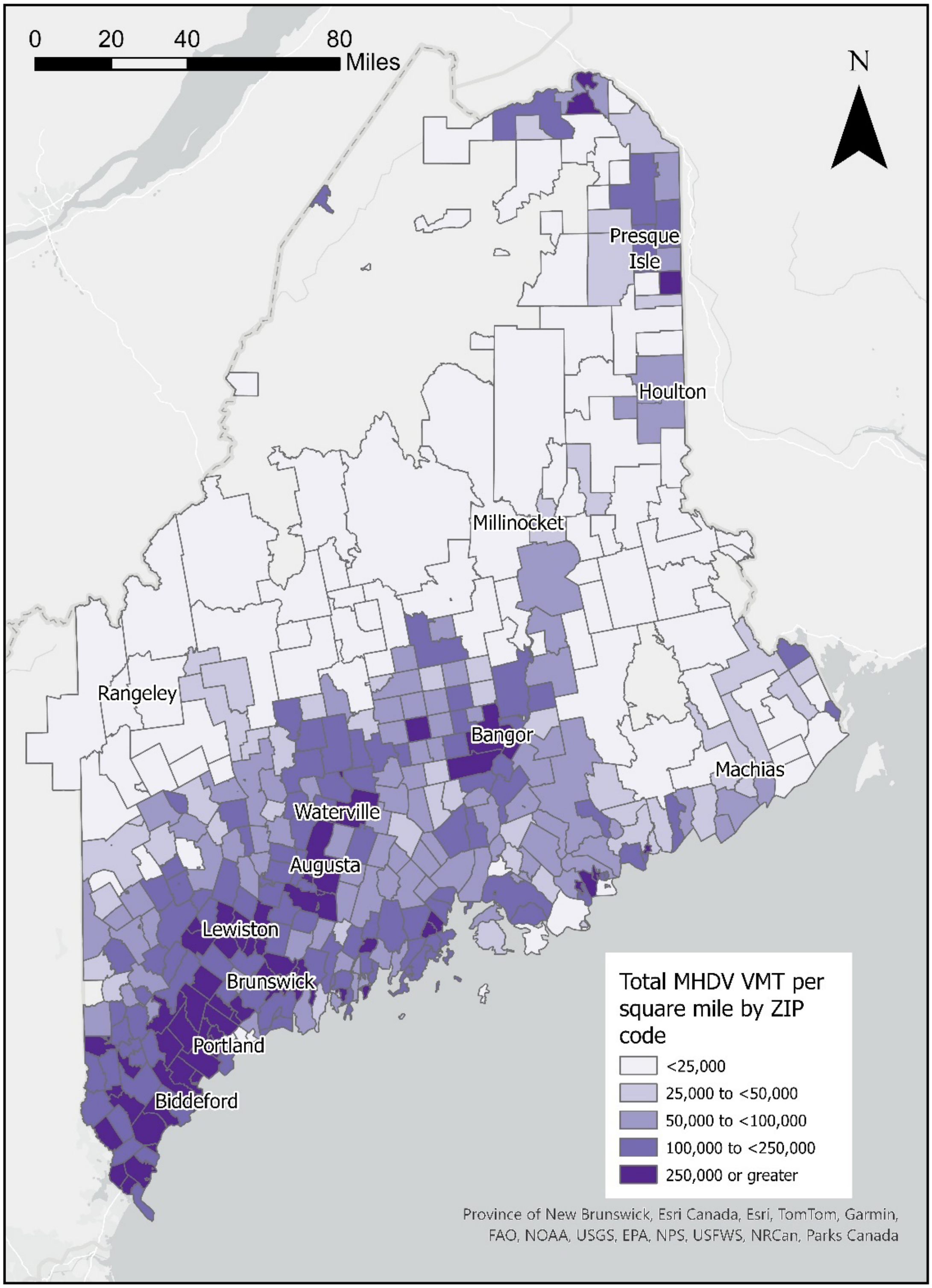
Source: Analysis of 2020 and 2023 Maine vehicle registration data by ERG as provided by Maine DEP. Daily mileage uses an annualization factor of 300 for transit and "other" buses and 180 for school buses.

FIGURE D.1 TOTAL TRUCK AND BUS REGISTRATIONS PER SQUARE MILE BY ZIP CODE



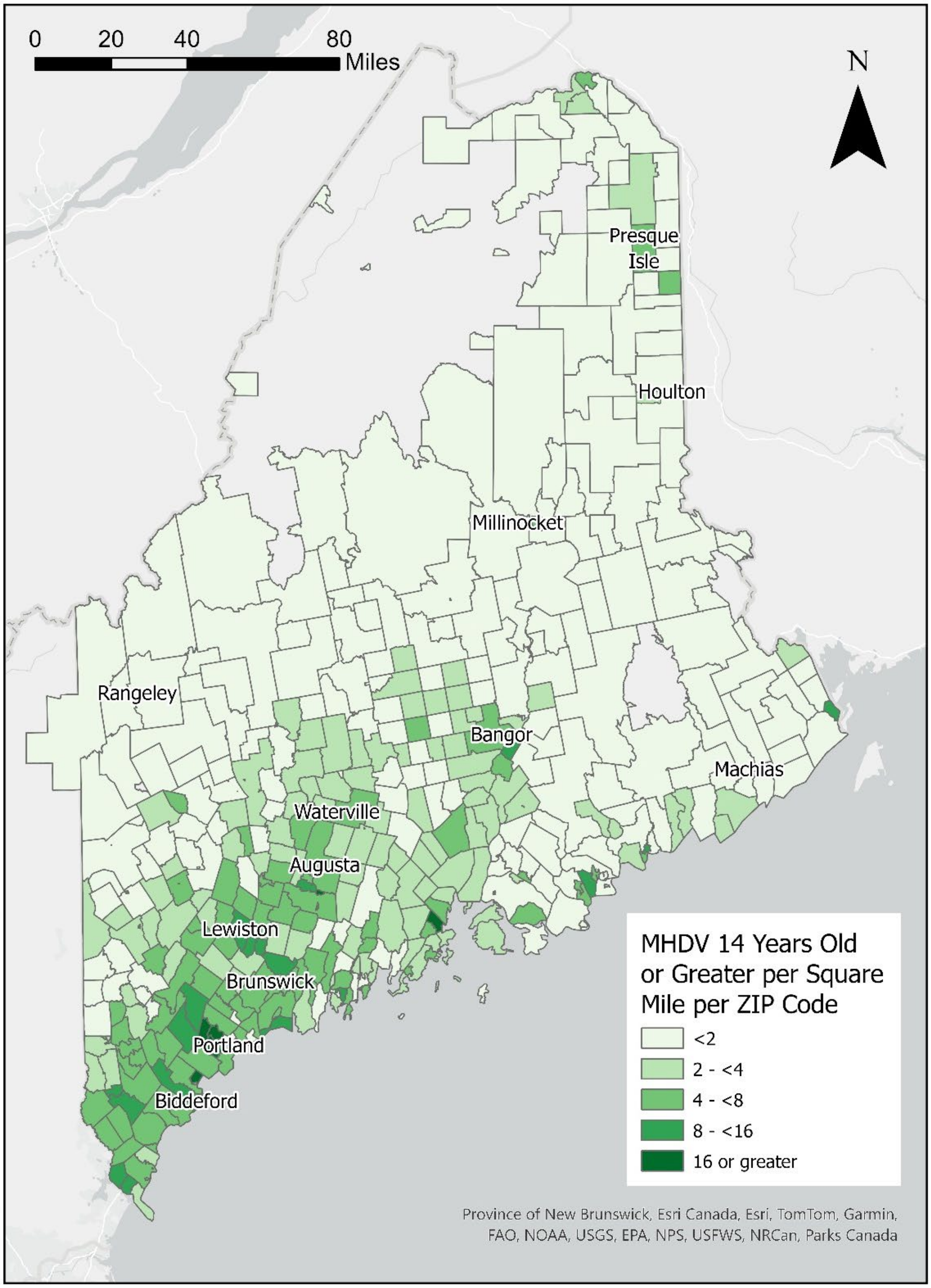
Source: Analysis of 2020 Maine vehicle registration data by ERG and CS as provided by Maine DEP.

FIGURE D.2 TOTAL TRUCK AND BUS VMT GENERATED BY ZIP CODE



Source: Analysis of 2020 Maine vehicle registration data by ERG and CS as provided by Maine DEP.

FIGURE D.3 NUMBER OF TRUCKS MODEL YEAR 2010 OR OLDER



Source: Analysis of 2020 Maine vehicle registration data by ERG and CS as provided by Maine DEP.

D.4 LOCUS Truck Data

LOCUS Truck data are extracted from a nationwide sample of truck trips for calendar year 2023 as processed and provided by Geotab, based on telematics data. The data are based on a nationwide population of nearly 2.5 million vehicles. Cambridge Systematics expanded the sample data to represent all trips and extracted trips starting and/or ending in Maine.[86] The expanded data reflects the total truck trips based on a combination of truck survey data and employment by industry data. For truck trip generators such as warehouses, ports, and intermodal facilities that generate trips out of proportion to their employment, additional factors related to the volume of traffic were used to expand the data.

To further validate the expanded data, VIUS data were compared to LOCUS Truck. Since VIUS does not provide VMT by State (based on actual trips), but rather by state of registration (assigning all VMT to the state in which a vehicle is registered), these data were used and compared with the LOCUS Truck data for Maine. Specifically, LOCUS internal VMT trips within Maine and LOCUS external VMT for trips that extended beyond the state but are less than 200 miles were used for the comparison with VIUS Maine data. This 200-mile threshold is applied to external trips to prevent skewing total VMT with very long external trips. The VIUS and LOCUS Truck VMT estimates are relatively consistent with some differences, with LOCUS showing about 21 percent higher VMT than the VIUS-based estimate. Because VIUS VMT is based on the state of registration and not the actual location where the VMT occurred as it is for LOCUS Truck, differences might be expected.

Table D.5 shows the number and share of daily truck trips by vehicle weight class and Geotab vocation (included as part of the LOCUS tool). Table D.6 shows the corresponding share of VMT by weight class and vocation. The expanded LOCUS annual VMT (including all external trips, not just those under 200 miles) show approximately 1.33 billion annual miles (using an annualization factor of 365 days), or about 16 percent less than MERI, which provides an estimate of 1.59 billion miles. Note that MERI is based on *registered* vehicles and considers the average VMT per vehicle over each vehicle's lifetime; whereas LOCUS is based

[86] The LOCUS Truck dataset includes weight Class 2b through 8 trucks. However, expansions have not yet been developed for weight Class 2b (Light) given the difficulty of obtaining appropriate expansion factors. Therefore, only Class 3–6 (Medium) and Class 7–8 (Heavy) truck data are reported here, which is also consistent with the classes of trucks considered in this roadmap.

on *vehicles active in Maine* in the observation year (2023), so the numbers may differ. LOCUS also does not include buses.

TABLE D.5 DAILY STATEWIDE 2023 TRUCK TRIPS BY WEIGHT CLASS AND VOCATION

Vocation	Medium-Duty Trucks (Class 3–6)	Heavy-Duty Trucks (Class 7–8)	Total
Door to Door	247	122	369
Hub and Spoke	5,710	3,324	9,034
Local	14,736	10,598	25,335
Regional	1,106	3,150	4,256
Long Haul	7,752	7,648	15,400
Unknown	4,393	3,449	7,842
Total	**33,944**	**29,291**	**62,235**
Door to Door	0%	0%	1%
Hub and Spoke	10%	6%	17%
Local	27%	19%	47%
Long Haul	2%	6%	8%
Regional	14%	14%	28%
Total	54%	**46%**	**100%**

Source: LOCUS Truck. Shares represent the share of known vocations.

TABLE D.6 DAILY VMT FOR STATEWIDE 2023 TRUCK TRIPS BY WEIGHT CLASS AND VOCATION

Vocation	Medium-Duty Trucks (Class 3–6)	Heavy-Duty Trucks (Class 7–8)	Total
Door to Door	5,054	3,599	8,653
Hub and Spoke	193,361	241,380	434,741
Local	411,140	371,780	782,920
Regional	55,223	583,422	638,645
Long Haul	372,996	835,995	1,208,990
Unknown	166,597	389,276	555,873
Total	**1,204,371**	**2,425,452**	**3,629,823**
Door to Door	0.2%	0.1%	0.3%
Hub and Spoke	6.3%	7.9%	14.1%
Local	13.4%	12.1%	25.5%
Long Haul	1.8%	19.0%	20.8%
Regional	12.1%	27.2%	39.3%
Total	**33.8%**	**66.2%**	**100.0%**

Source: LOCUS Truck. Shares represent the share of known vocations.

Some observations follow:

» Just over half of medium- and heavy-duty truck trips are taken by medium-duty trucks and these trips generate one-third of all truck VMT. In contrast, heavy-duty trucks represent a little less than half of all trips but well over half (66 percent) of VMT.

» Trucks in long-haul vocations especially generate VMT disproportionate to trips, accounting for 19 percent of all VMT but only 8 percent of trips. Conversely, "local" and "regional" vocations generate three-quarters of all trips, but only 65 percent of all VMT.

» Door-to-door vocations make up only a very small fraction of trips and VMT.

» The vocation and weight class categories may be qualitatively considered based on suitability for electrification (high, medium, low) based on weight class and vocation. Based on these groupings, as shown in Table D.7, about two-thirds of trips and half of VMT are generated by "higher" potential categories, while 22 percent of trips and just over one-third of VMT are generated by "lower" potential categories.

TABLE D.7 SHARE OF TRIPS AND VMT BY ELECTRIFICATION POTENTIAL

Electrification Potential	Categories	Share of Trips	Share of VMT
Higher	Door to Door, Hub and Spoke, and Local vocations (all weight classes 3 through 8)	64%	40%
Moderate	Regional (medium)	14%	12%
Lower	Regional (heavy); Long Haul (all weight classes)	22%	48%

Table D.8 shows the distribution of weight classes by vocational class (based on trip-ends). While Door to Door is dominated by light vehicles and Long Haul is dominated by heavy vehicles, other vocational classes show a mix of vehicle weights.

TABLE D.8 WEIGHT CLASSES BY VOCATIONAL CLASS

Vocation	Medium	Heavy
Door to Door	20%	11%
Hub and Spoke	37%	24%
Local	32%	23%
Long Haul	16%	61%
Regional	22%	29%
Unknown	25%	23%

The LOCUS data provide information on the spatial patterns of trips by Census Tract. Most tracts have a low density of trips (less than 150 daily per square mile). However, some tracts have higher densities, ranging as high as 700 to 800 per square mile. The higher concentrations of trips are found mainly in the state's population centers, including the Portland region, Lewiston-Auburn, Augusta, Fairfield-Waterville, and Bangor.

LOCUS also provides information on trip lengths and stop durations. The statewide distribution of trip lengths by vehicle weight class is shown in Table D.9. It can be seen that most (just under 80 percent) of medium-duty vehicle trips are less than 50 miles in length. Just over 35 percent of heavy vehicle trips exceed 100 miles, with about 17 percent exceeding 200 miles.

TABLE D.9 TRIP DISTANCE BY WEIGHT CLASS

Trip Distance	Medium	Heavy
<50 mi	78.2%	53.2%
50–100 mi	14.4%	12.8%
100–200 mi	6.2%	11.8%
200–300 mi	1.1%	10.8%
>300 mi	0.2%	4.8%
Total	**100.0%**	**100.0%**

The statewide distribution of stop durations by vehicle weight class is shown in Table D.10. Medium trucks tend to make shorter stops, with 45 percent of medium truck stops less than a half-hour in duration and 28 percent of medium truck stops exceeding 1 hour. 36 percent of heavy truck stops are over two hours in duration, with relatively few stops (9 percent) under 15 minutes. The shorter stops are those where it may be harder to take on a full charge—especially for the heavier vehicles—although a 30–60 minute stop may be sufficient to take on a partial charge (often called "top-up," or opportunity charging) with a high-power charger.

TABLE D.10 POST-TRIP STOP DURATION BY WEIGHT CLASS

Stop Duration	Medium	Heavy
<15 min	24.1%	8.7%
15–30 min	21.0%	16.7%
30 min–1 hr	27.0%	21.6%
1–2 hrs	19.5%	17.2%
>2 hrs	8.4%	35.8%
Total	**100.0%**	**100.0%**

Figure D.4 further breaks out trip length by post-trip stop duration (for all weight classes). Well over half of all trips cluster in a range of 15 minutes to 2 hours stop duration and less than 50 miles in length. These are trips for which a brief "top-up" charge might be feasible if there were a charger at the destination, and for which a full charge between trips is not necessary. Only 11 percent of trips (mostly heavy-duty trucks) have a distance greater than 100 miles and a stop duration less than 2 hours—these might be the hardest trips to serve with a post-trip recharge, except at the highest powered (such as megawatt) chargers. Again, there are important caveats, including 1) many destinations are not likely to have fast charging available (e.g., home or small business deliveries); and 2) a full picture of daily activity would require data on how trips are strung together in a daily tour.

FIGURE D.4 TRIP LENGTH BY POST-TRIP STOP DURATION (PERCENT OF TRIPS)

Medium Duty

		Insufficient time to charge	Possibly enough time to fast charge			Sufficient time to charge	Possibly at home base or truck stop	
	Distance	<15 mins	15-30min	30-45 min	45-60 min	1- 2 hours	> 2 hours	Total
Quick Top up	< 25 miles	0%	25%	22%	9%	9%	7%	72%
Quick Top up	25 - 50 miles	0%	6%	3%	2%	3%	5%	19%
Fast Charging	50 -100 miles	0%	2%	1%	1%	1%	3%	8%
Possible Fast Charging	100 -200 miles	0%	1%	0%	0%	0%	0%	2%
Overnight charging	> 200 miles	0%	0%	0%	0%	0%	0%	0%
	Total	1%	34%	26%	11%	13%	15%	100%

84% of medium duty trips are **short enough** and **stop long** enough for ZEV to charge

Heavy Duty

		Insufficient time to charge	Possibly enough time to fast charge		Sufficient time to charge		Possibly at home base or truck stop	
	Distance	<30 mins	30-45min	45-60 min	1-2 hours	2 - 6 hours	> 6 hours	Total
Quick Top up	< 25 miles	0%	10%	12%	7%	2%	2%	34%
Quick Top up	25 - 50 miles	0%	4%	6%	6%	2%	3%	22%
Fast Charging	50 -100 miles	0%	4%	4%	5%	4%	5%	23%
Possible Fast Charging	100 -200 miles	0%	3%	2%	2%	5%	5%	17%
Overnight charging	> 200 miles	0%	1%	1%	1%	0%	2%	4%
	Total	1%	23%	25%	20%	14%	17%	100%

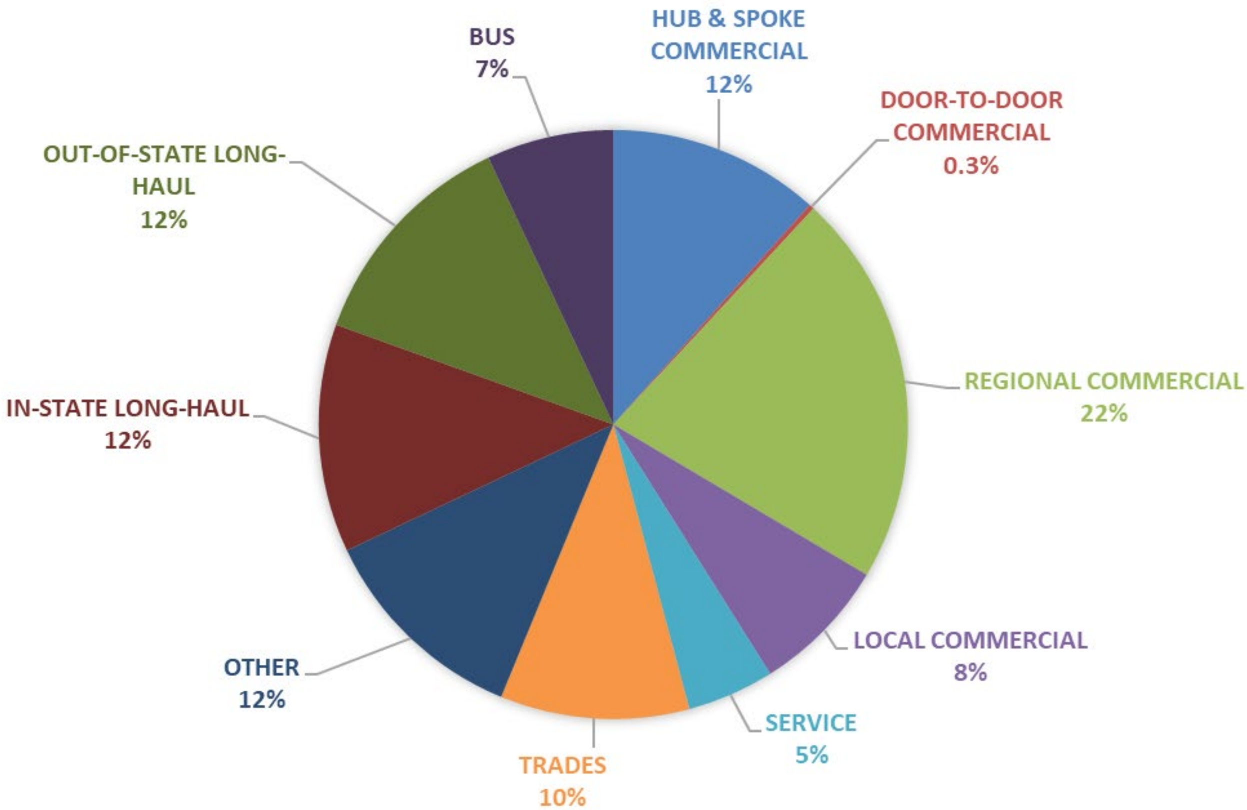
66% of heavy- duty trips are **short enough** and **stop long** enough for ZEV to charge

The LOCUS data and MERI registration data were used in combination with U.S. EPA National Emissions Inventory (NEI) results for Maine to make further inferences about fleet characteristics. In particular, the LOCUS data was used to further disaggregate "Commercial" registered trucks into the following vocational categories (note that the LOCUS Long-Haul category is not included because trucks registered for long-haul use are accounting for separately in the NEI, including out-of-state trucks):

» Regional Commercial
» Local Commercial
» Hub and Spoke Commercial
» Door-to-Door Commercial

LOCUS vocational categories based on trip-ends were used as a proxy for segmenting registered vehicles. Some industry categories defined from MERI were assumed to fall into the Local Commercial category, including construction, home services, and landscaping ("Trades") as well as city/town, state, refuse, and utilities ("Service"). Local Commercial trips from LOCUS were adjusted to remove these categories, to avoid double-counting. Figure D.5 shows the resulting segmentation of vehicle vocations at a statewide level, as expressed in terms of VMT of different vehicle classes.

FIGURE D.5 CONTRIBUTION OF INDUSTRY/VOCATIONAL CLASSES TO MAINE'S MHDV VMT



Source: 2020 Maine registration data and LOCUS Truck data as analyzed by ERG.

D.5 VIUS Data

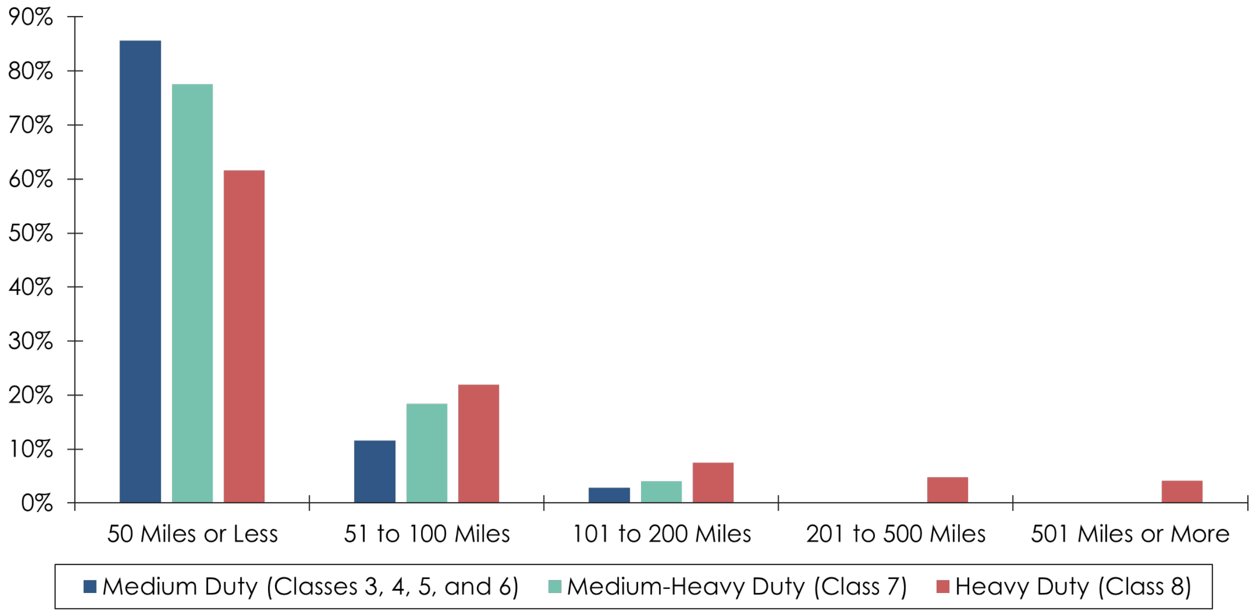
The 2021 U.S. DOT VIUS shows a total of 24,400 medium-duty vehicles (weight class 3–6) and 22,000 heavy-duty vehicles (weight class 7 and 8) with a home base in Maine, covering about 87 percent of registered vehicles (from MERI) in these classes.[87] The VIUS data are based on a nationwide sample of 150,000 vehicles expanded to meet national vehicle totals. The VIUS data suggest that Maine trucks are slightly older and driven slightly less (on average) than trucks nationwide, but with relatively small differences of less than 10 to 20 percent.

Figure D.6 shows the typical operating range of Maine-registered trucks. Over 90 percent of medium-duty and over 80 percent of heavy-duty trucks typically operate within a range of 100 miles or less. This suggests greater potential for ZEV conversion if trucks return to their

87 Home base refers to the location where the vehicle is usually parked when it is not on the road or not in use.

home base on a regular basis for recharging or refueling. That said, operating range does not fully describe daily activity patterns; if the vehicle has a daily distance exceeding its range (even if close to home) and makes only short stops, there will a need for rapid-charging and potentially publicly accessible charging stations to supplement depot charging.

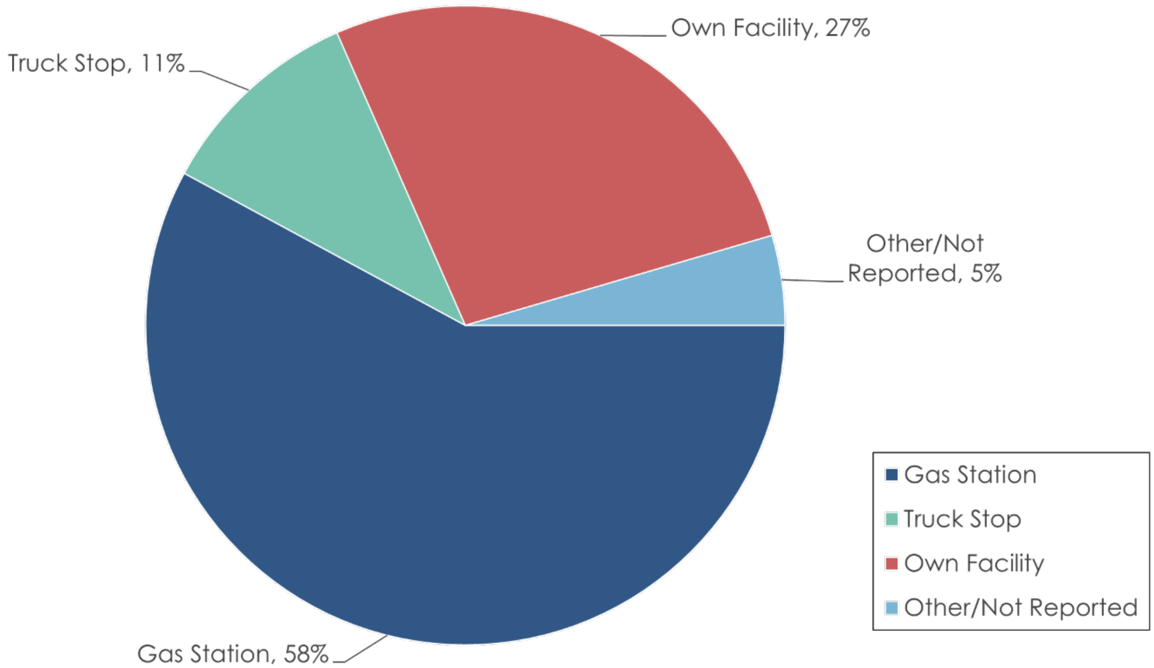
FIGURE D.6 OPERATING RANGE OF MAINE-REGISTERED TRUCKS



Source: U.S. DOT Bureau of Transportation Statistics, 2021 Vehicle Inventory and Use Survey.

Figure D.7 shows the primary fueling location of trucks operating in Maine. While most refuel at a gas station or truck stop, over one-quarter mainly refuel at their own facility. This suggests some potential for adding or converting on-site facility energy delivery to zero-emissions fuels.

FIGURE D.7 MAINE TRUCKS BY PRIMARY FUELING LOCATION



Source: U.S. DOT Bureau of Transportation Statistics, 2021 Vehicle Inventory and Use Survey.

D.6 Conclusions

This appendix describes the use of three data sources to provide a characterization of Maine's MHDV fleet. Some findings are as follows.

- There appear to be substantial market segments that, based on available information, have good potential for electrification. Most of Maine's trucks and buses are engaged in relatively short-distance travel close to home, with daily average travel distances of about 33 miles (school buses) to about 50 miles (MDTs and transit buses) to 100 miles (HDTs); and 80 to 90 percent operating within a typical 100-mile or less range from home. What the available data do not fully show, however, is day-to-day variability in travel distances that may cause a vehicle's electric range to sometimes be exceeded; or the distribution of vehicle activity whereby some vehicles are used much more than average, and others much less.
- The distribution of trip distances and stop durations also suggest that most trips are relatively short, and that a significant fraction of trips have stops long enough to support some degree of mid-route recharging, especially with a fast charger (e.g., 350 kW to 1 MW).

» Maine's MDTs are somewhat, but not substantially, older than the U.S. population on average. This suggests that Maine will not significantly lag behind other States in MDT ZEV introduction just based on fleet turnover rates. In contrast, registered HDTs are on average about 50 percent older than national averages and turnover may lag compared to the Nation as a whole.

» Two-thirds of MHDT trips and about 40 percent of VMT are generated by vocation and weight classes that appear to have good potential for electrification.

D.7 Makes and Models by Vehicle Class

Table D.11 shows the number of registered vehicles by make and model by vehicle weight class for the most common makes/models (over 200 each), with the following weight class definitions:

» Class 3: 10,001–14,000 lb (4,536–6,350 kg)

» Class 4: 14,001–16,000 lb (6,350–7,258 kg)

» Class 5: 16,001–19,500 lb (7,258–8,845 kg)

» Class 6: 19,501–26,000 lb (8,845–11,794 kg)

» Class 7: 26,001–33,000 lb (11,794–14,969 kg)

» Class 8: 33,001 lb and above (14,969 kg and above)

TABLE D.11 NUMBER OF REGISTERED VEHICLES BY MAKE AND MODEL BY VEHICLE CLASS

Class	Vehicle Make	Vehicle Model	Count
3	FORD	F-350	8,723
3	CHEVROLET	Silverado	3,076
3	GMC	Sierra	3,025
3	FORD	E-350	1,133
3	RAM	3500	1,002
3	CHEVROLET	Express	737
3	DODGE	Ram	660
3	GMC	Savana	568
4	FORD	E-450	1,271
4	FORD	F-450	507

Class	Vehicle Make	Vehicle Model	Count
4	ISUZU	NPR/NPR-HD	302
4	CHEVROLET	Express	272
4	FORD	F-Super Duty	242
5	FORD	F-550	2,090
5	RAM	5500	364
5	FORD	F-450	330
6	FREIGHTLINER	M2	417
6	FORD	Motorhome Chassis	342
6	INTERNATIONAL	MA025	309
6	HINO	Conventional Type Truck	307
6	INTERNATIONAL	4700	292
6	FORD	F-650	211
7	FREIGHTLINER	B2 Bus Chassis	959
7	BLUE BIRD	BB Conventional	641
7	FREIGHTLINER	M2	610
7	IC BUS	PB105	605
7	GMC	C7	498
7	INTERNATIONAL	4900	376
7	INTERNATIONAL	MA025	350
7	INTERNATIONAL	MA035	315
7	FORD	F-750	247
7	KENWORTH	T3 Series	207
7	CHEVROLET	C7	206
8	WESTERN STAR	4900	1,112
8	VOLVO TRUCK	VHD	561
8	FREIGHTLINER	M2	536
8	PETERBILT	379	523
8	FREIGHTLINER	Cascadia	476
8	STERLING TRUCK	L9500 series	426
8	INTERNATIONAL	SA525	408
8	WESTERN STAR	4700	363
8	MACK	RD	361
8	PETERBILT	389	355
8	KENWORTH	W9 Series	319
8	KENWORTH	T800	277

Class	Vehicle Make	Vehicle Model	Count
8	KENWORTH	W900	267
8	PETERBILT	567	260
8	VOLVO TRUCK	VNL	257
8	GMC	C7	252
8	MACK	CV	236
8	FORD	LTL9000	220
Total	**All**	**All**	**38,403**

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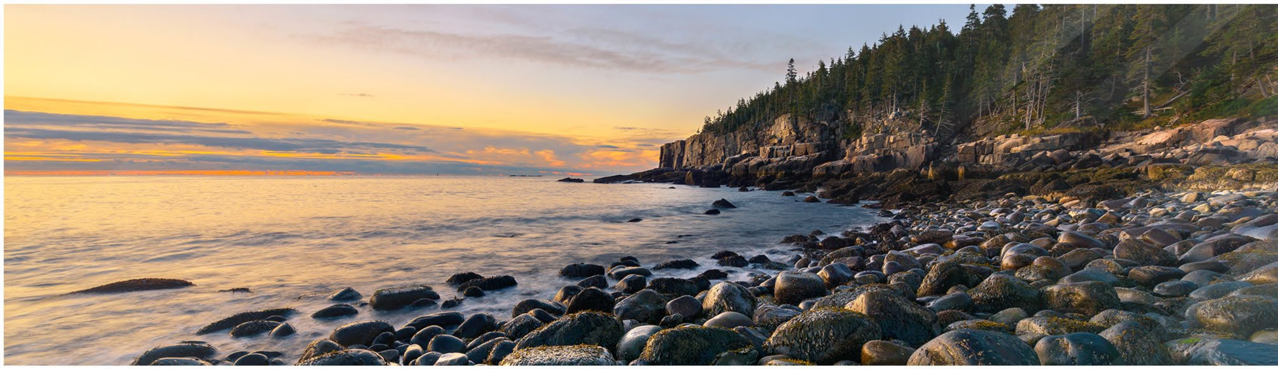

ZERO-EMISSION VEHICLE SCENARIOS

This appendix to the Maine Clean Transportation Roadmap for Medium- and Heavy-Duty Vehicles (MHDV) describes the approach to creating medium- and heavy-duty (MHD) zero emission vehicle (ZEV) scenarios for the roadmap. The purpose is to develop alternative scenarios of MHD ZEV sales and stock by market segment to inform policy development, emissions benefits, and energy demand estimates. The scenarios include discrete forecasts for 2030, 2035, and 2040, as measured against a base year of 2020. Market segmentation and market shares are first discussed, followed by estimates of total vehicle stock.

E.1 Market Segmentation

A "hybrid" market segmentation approach is applied to vehicles registered in Maine, that combines industry data from Maine registration data (MERI database) with vocation/use and vehicle weight class characteristics from Maine-specific telematics data (LOCUS Truck, see further discussion of data sources in Appendix D). This segmentation is shown in Table E.1. The "subcategories" listed are a combination of plate information and industry information as identified from registration data, and vocation/use characteristics as identified from LOCUS data. Vocation/use data based on truck trip-ends are used to segment the "Commercial" plate category reflected in registration data. Table E.1 shows this segmentation and also describes the use characteristics of each category that relate to ZEV potential.

TABLE E.1 MARKET SEGMENTATION

Market Segment	Subcategories	Use Characteristics Related to Electrification Potential
Public and Municipal Services	City/Town[1] State[1] Emergency[1] Education[1] Utilities[1] Refuse[1]	Limited service range Return to base at least daily Lower-speed operations
Transit Bus[1]	–	Limited service range Return to base at least daily Lower-speed operations
School Bus[1]	–	Limited service range Return to base at least daily Lower-speed operations
Commercial: Local	Hub and Spoke[2] Door to Door[2] Local[2]	Limited service range Return to base at least daily Lower-speed operations
Commercial: Regional	Regional[2]	Longer service range (>150 mi) Return to base daily Higher-speed operations
Long-Haul	In-state[1,2] Out-of-state[1,2] Lumber[1] Other Bus[1] Motorhome[1]	Long service range (>250 mi) Inconsistent home base Higher-speed operations

[1] "Industry" determined or inferred from MERI registration data (plate type or fleet owner).

[2] Vocation/use from LOCUS trip-end data. "Long-haul" from registration plate is segmented to in-state and out-of-state based on LOCUS.

These market segments are each further segmented into two weight classes, which are defined as follows:

» Medium-duty vehicle (MDV) = Weight Class 3–6 (10,000–25,999 lb. gross vehicle weight rating or GVWR)

» Heavy-duty vehicle (HDV) = Weight Class 7–8 (>26,000 lb. GVWR)

E.2 Scenario Development

The objectives of developing different scenarios of ZEV market penetration are to:

- Estimate the emissions benefits of different levels of ZEV adoption.
- Estimate the energy/charging demand of different levels of ZEV adoption.
- Identify and focus on market segments with the nearest term electrification potential and most impact (in terms of benefits).

The first three rows in Table E.1 (Public and Municipal Services, Transit Buses, School Buses) have more potential policy levers to accelerate electrification than the other categories, as they are generally under public agency control (directly or through contracts) and can therefore be subject to the alignment of public funding, executive action, or other actions with achieving public policy goals such as emissions reductions. Maine-specific ZEV transition scenarios were developed for these categories, considering both existing or potential policies which accelerate ZEV adoption and what could be realistic within these sectors given anticipated vehicle availability, performance, and costs over the forecasted time horizon.

For the remaining categories that make up private sector vehicles, ZEV transition scenarios were based on available forecasts of sales shares from national studies or other state projections. Sales shares were translated into stock estimates based on Maine-specific fleet turnover characteristics (using registration data). Four scenarios were developed as described further below.

Private Medium and Heavy-Duty Vehicles

The following sections discuss forecasting approaches and scenarios for the private (commercial) sector MHDV vehicle market in the state. The private sector vehicle market segments are listed in the last three rows of Table E.1.

Existing Forecasts

Various Federal studies and other data-driven forecasts were used to inform this roadmap's estimate of the sales and stock of MHD ZEVs through 2040.

The National Renewable Energy Laboratory (NREL) Electrification Futures Study provides detailed yearly estimates for MHDVs by various fuel types.[88] These numbers were released in 2018, and accordingly, do not factor in subsequent regulations and incentive programs such as the Inflation Reduction Act (IRA) and the U.S. Environmental Protection Agency (EPA) Phase 3 greenhouse gas (GHG) emissions rule, which sets declining GHG emissions limits for MHDVs.[89]

The U.S Energy Information Administration's most recent Annual Energy Outlook (2023) factors in projected impacts of the IRA on MHDVs by fuel type, but does not include the EPA Phase 3 rules, finalized in March 2024. Estimates from the Annual Energy Outlook are generally conservative and much lower as compared to other available forecasts. The Energy Information Administration did not release estimates in spring 2024 for the Annual Energy Outlook, noting that they are making substantial updates to the model this year.[90]

The ISO New England's (ISO-NE) Transportation Electrification Forecast, completed as part of their annual 10-year Capacity, Energy, Loads, and Transmission forecast, provides EV sales forecasts specific to Maine, although only for selected vehicle types (medium-duty vans, buses) which are not fully aligned with the market segments in this roadmap.[91]

The EPA Phase 3 GHG Rule Regulatory Impact Analysis (RIA), released in March 2024, estimates the impact of the IRA on MHD ZEV market shares, as well as the impact of the EPA Phase 3 rule itself on market shares. It additionally breaks down sales numbers based on vocations, (e.g., short haul vs. long haul) and based on whether a state has adopted the Advanced Clean Truck (ACT) regulatory emission standards.

Developing a Baseline

The baseline scenario developed for this roadmap reflects a "business as usual" case against which increased benefits from various levels of ZEV adoption are compared. Most of the existing forecasts discussed above either do not factor in the most recent national regulatory

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88 Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. National Renewable Energy Laboratory, 2018. https://www.nrel.gov/docs/fy18osti/71500.pdf.

89 U.S. Environmental Protection Agency (2024). Final Rule: Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3. https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-greenhouse-gas-emissions-standards-heavy-duty.

90 U.S. Energy Information Administration Annual Energy Outlook.

91 Draft CELT 2024 Electrification Adoption Forecasts for Maine, ISO-NE, 2024. transfx2024_draft.pdf.

requirements applying to this sector (i.e., EPA Phase 3 Rule), or are estimates developed to meet a target benchmark (i.e., the emissions benefit outcome is pre-determined, and vehicle stock estimates are designed to fit that outcome).

The EPA Phase 3 RIA presents a Reference Case that refers to a future *without* the Phase 3 rules in place, while factoring in the impact of the IRA on market adoption in MHDV sectors. The reference case provides two estimates for ZEV sales, distinguishing between states which have or have not adopted ACT. For Maine, even with Phase 3 rules in place, the reference scenario may still present a reasonable picture of the future, as manufacturers may comply with Phase 3 rules by selling their mandated share of ZEVs in states which have also adopted ACT and therefore have additional and higher ZEV sales requirements—meeting both sets of regulatory requirements with a disproportionate distribution of vehicles to ACT states. The EPA Phase 3 RIA Reference Case sales estimates therefore form the baseline reference case for emissions modeling for Maine, or the case against which the impacts of other alternative scenarios are measured. The following is an excerpt from the EPA Phase 3 RIA document:[92]

"In modeling heavy-duty ZEV populations in the reference case, a scenario that represents the United States without the final standards, we considered several different factors related to purchaser acceptance of new technologies, along with three factors described below.

- *First, the market has evolved such that early [heavy-duty] (HD) ZEV models are in use today for some applications and HD ZEVs are expected to expand to many more applications. Additionally, manufacturers have announced plans to rapidly increase their investments in ZEV technologies over the next decade.*
- *Second, the IRA and the BIL (Bipartisan Infrastructure Law) provide many monetary incentives for the production and purchase of ZEVs in the heavy-duty market, as well as incentives for electric vehicle charging infrastructure.*
- *Third, there have been actions by states to accelerate the adoption of heavy-duty ZEVs."*

Because the EPA Reference Case captures IRA impacts and estimates different projections for ACT states vs. non-ACT states, this is baseline scenario in the roadmap analysis. While other potential reference case scenarios (e.g., Annual Energy Outlook) show very little MHD ZEV adoption, the EPA reference case is the only available existing forecast which takes into

[92] While this language only refers to heavy-duty vehicles, the EPA phase 3 modeling applies to both medium and heavy-duty vehicles.

consideration *all* current Federal policies while assuming no additional policies or programs in Maine.

Developing Alternative ZEV Scenarios

Three alternative scenarios, each projecting different levels of ZEV penetration in the Maine market, were initially developed as described in Table E.2. Percentages in this table refer to sales or procurements of vehicles (not stock, or total number of vehicles on the road). Note that terminology and vehicle classes may differ among sources, and assumptions had to be made (as noted in the tables) to crosswalk EPA vehicle categories to the roadmap's market segments. A "composite" scenario was later developed that combines market segment-specific assumptions from other scenarios to create a scenario considered to be aggressive yet feasible for Maine.

For the "moderate" scenario, EPA Phase 3 rule implementation forecasts are considered to be appropriate. These forecasts factor in *all* existing nationwide regulations and incentives, and assume that manufacturers will sell ZEVs in Maine in the same proportion as forecasted nationally to comply with the Phase 3 rules, regardless of additional regulatory environments.

For "high" and "advanced" scenarios, vehicle adoption assumptions move from maximizing Federal regulatory compliance pathways to adoption of other technology-advancing regulations, programs, and incentives. For the "high" scenario, the sales forecast assumes that manufacturers sell MHD ZEVs in the same proportions in Maine as they are expected to in states that have adopted the ACT regulation. The "advanced" scenario plays out an increasingly aspirational case where sales percentages are designed to meet a target benchmark (i.e., the emissions benefit outcome is pre-determined, and vehicle stock estimates are designed to fit that outcome). In this scenario, sales meet 100 percent of the goals determined by emissions reduction targets laid out in modeling conducted by the Maine Governor's Energy Office (2024) and in goals advanced in the state's first climate action plan, *Maine Won't Wait* (2020). In years where these goals are lower than sales requirements under ACT, we assume that sales will match the higher of those two levels.

TABLE E.2 DESCRIPTIONS OF SCENARIOS

Scenario	Description
Baseline	**EPA Reference Case—**Business as usual, factoring in IRA. No specific MHD ZEV policy in Maine, and OEMs comply with national targets by increasing sales in states with additional regulatory policies.
Moderate	**National Adopted Policies Scenario—**EPA rules case. Manufacturers sell ZEVs to meet recently adopted national GHG emissions rules, and Maine policies encourage some of those ZEVs to come to Maine.[1]
High	**Advanced States Scenario: ACT Rules—**Maine's supporting policies are sufficient to achieve the benefits of the Advanced Clean Trucks rule adopted to date in 11 states (including Massachusetts, New York, and Vermont), without adopting the rule in Maine.
Advanced	**GEO and Maine Won't Wait Targets—**Maine implements even more ambitious funding, technical support, and/or rules to achieve market shares needed to meet emissions reductions modeled in the 2020 *Maine Won't Wait* climate action plan. This scenario illustrates the level of change that would need to occur in the MHDV sector to meet aggressive emission reduction goals. While achieving these levels of ZEV penetration in this sector will be highly challenging due to economic, political, and readiness factors, this scenario serves as an upper bound to guide the state's ambition. (In cases where ACT shares are higher, the higher value is retained.)

[1] In 2024, the U.S. EPA adopted "Phase 3" Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles, setting declining limits on tailpipe pollution from trucks and buses through model year 2032. EPA has modeled scenarios in which manufacturers sell ZEVs to help comply with those emission reductions; this Maine scenario is based on the EPA national scenarios.

The EPA models sales based on national vehicle regulatory class and on vehicle classes (source types) from the EPA's MOVES model. The ACT regulation also applies to different market segments as defined by the California Air Resources Board. The scenarios developed for this roadmap therefore map market segments and vehicle types to the vocations associated with MOVES. This mapping process is discussed further in Appendix F. Table E.3 shows the general alignment between the roadmap market segments and EPA regulatory categories. The resulting sales projections are shown in complete tables at the end of this document.

TABLE E.3 MAPPING OF COMMERCIAL MARKET SEGMENTS TO EPA REGULATORY CATEGORIES

Market Segment	Vehicle Type	EPA Regulatory Categories
Commercial: Local	Medium Duty	Class 4–5, Single Unit-Short Haul
Commercial: Local	Heavy Duty	Class 8, Combination Short-Haul
Commercial: Regional	Medium Duty	Class 6–7, Combination Long-Haul
Commercial: Regional	Heavy Duty	Class 8, Combination Long-Haul
Commercial: Long-Haul	Medium Duty	Class 6–7, Combination Long-Haul
Commercial: Long-Haul	Heavy Duty	Class 8, Combination Long-Haul

E.3 Public Agency Vehicles

Public and Municipal Services

Public and municipal services vehicles include state- and municipally-owned vehicles as well as vehicles operated by state and municipal contractors and regulated entities, such as refuse collectors and utilities. These vehicle types may be easiest to target for early ZEV adoption given multiple policy avenues for direct influence over purchasing (at a state level), and the potential to influence municipal and contractor purchases through incentives or contract requirements. However, examples of policy or purchase requirements regarding targeted sales shares for public sector MHD vehicles in other jurisdictions are limited. While many other states have public vehicle ZEV transition targets, almost all target light-duty vehicles. There are few MHD ZEV targets for state fleets, and none that distinguish between medium and heavy duty (see Appendix A for further discussion).

In 2020, Maine joined other states as a signatory to the Northeast States for Coordinated Air Use Management (NESCAUM) multi-state MHD ZEV memorandum of understanding (MOU). Under this MOU and in an effort to lead by example, state Government and quasi-Government fleets made a commitment to strive to achieve 30 percent new ZEV procurements by 2030 and 100 percent by 2050.[93]

California's Advanced Clean Fleets (ACF) rule is the most aggressive existing program for public MHD fleet ZEV transition. Under this rule, California's public agencies must have 50 percent of their MHD vehicle procurements be ZEVs starting in 2024 and 100 percent starting in 2027.[94] The ACF sets procurement targets for other large fleet operators based on existing vehicle age and mileage. This complements the ACT regulation, which sets corresponding sales targets for vehicle manufacturers; ACF works to create demand while ACT works to guarantee supply. New York State also commits state agency MHD vehicles to be 100 percent (stock) ZEV by 2040, through an executive order.[95]

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93 Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding. mhdv-zev-mou-20200714.pdf (nj.gov).

94 Rocky Mountain Institute. Understanding California's Advanced Clean Fleet Regulation.

95 No. 22: Leading by Example: Directing State Agencies to Adopt a Sustainability and Decarbonization Program | Governor Kathy Hochul (ny.gov).

These example policy levers, combined with the EPA's reference case projections for Class 6–7 refuse vehicles, give four different scenarios for public and municipal service vehicles shown in Table E.4. While years beyond 2040 are not modeled in this analysis, they are presented for comparison as some 2030, 2035, and 2040 numbers are intermediate estimates based on 2050 numbers from various existing forecasts or targets discussed above.

TABLE E.4 SCENARIOS: PURCHASE SHARES OF PUBLIC AND MUNICIPAL SERVICE VEHICLES

Scenario	2025	2030	2035	2040	2050
Reference (EPA reference case for Class 6–7 refuse trucks)	–	9.2%	15.6%	19.1%	25.7%
Moderate (NESCAUM MOU)	–	30%	40%[1]	50%[1]	100%
High (ACT case)	–	48%	71%	71%	100%[1]
Advanced (California ACF)	50%	100%	100%	100%	100%

[1] CS suggested targets for intermediate or extrapolated years.

School Buses

Maine has a statutory target for 75 percent of its school bus procurements to be zero-emission buses by 2035.[96] California, under ACF, and Delaware (under state-specific policy) also have sales/procurement targets for school buses. California is targeting 100 percent ZEV procurement by 2035. Delaware's target starts at 5 percent procurement in 2025 and gradually increases to 30 percent by 2030. Based on examples from other states, proposed scenarios for Maine are shown in Table E.5. States that have fleet composition target include Connecticut DOT with a target of a 100 percent clean school buses by 2040, while New York is targeting a 100 percent clean fleet by 2035.

TABLE E.5 SCENARIOS: SCHOOL BUS ZEV PURCHASE SHARES

Annual Purchase Sales	2025	2030	2035	2040
Reference (EPA reference case for Class 6–7 school buses)	–	9.2%	15.6%	19.1%
Moderate (Delaware)	5%	30%	50%[1]	75%[1]
High (EPA projections of ACT rules case for school buses in 2030; Maine goal in 2035)	–	47.8%	75%	90%[1]
Advanced (California ACF)	–	75%[1]	100%	100%

[1] CS suggested targets for intermediate and extrapolation years.

[96] https://legislature.maine.gov/statutes/20-a/title20-Asec5401.pdf.

Transit Buses

Multiple state agencies and state transit operators have concrete plans to electrify transit buses in Maine. Maine DOT has its own Bus Electrification Project, targeting carbon neutrality across all state transit fleets by 2045. Through this project, Maine DOT worked with 12 local transit agencies to develop fleet electrification plans. Data from eight plans and their impacts on Maine transit bus stock are included in Table E.6.

The team made the following assumptions while generating ZEV scenarios for transit buses:

- All agencies follow through with the transitions.
- Fleet size remains the same, and all new procurements are used to replace existing non-ZEV bus.
- Hybrid bus procurements outlined in some plans are replaced with ZEV buses.
- 100 percent new procurements (sales) are ZEV from 2025 onward (Advanced scenario).

Other transit agencies with ZEV transition plans include New Jersey Transit and New York City Metropolitan Transportation Authority (NYC MTA). Both agencies have 100 percent ZEV procurement targets, for 2035 and 2030 respectively.[97]

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[97] Ways the U.S. Can Electrify Its Public Vehicle Fleets | World Resources Institute (wri.org).

TABLE E.6 BUS ELECTRIFICATION PROCUREMENT PLANS BY YEAR BY TRANSIT AGENCY IN MAINE[98]

Agency[1]	Existing Fleet	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Bangor	22	1	–	4	2	4	–	–	–	4	–	–	–	2	–	–	–
BSOOB	22	2	4	–	–	–	–	–	–	2	10	–	–	–	–	–	–
Citylink	9	–	–	–	–	–	–	3	–	–	3	3	–	–	–	–	–
Downeast (including 2024 Grant)	69	21	–	–	–	8	10	11	11	4	4	5	–	–	–	–	–
Metro	44	–	–	–	5	–	–	–	11	6	7	2	6	–	–	7	–
RTP	26	10	9	7	–	–	–	–	–	–	–	–	–	–	–	–	–
SPBS	7	–	3	–	2	–	–	–	–	–	1	2	–	–	–	–	–
YCCAC	30	20	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	229	54	27	11	9	12	10	14	22	16	25	12	6	2	0	7	0
Cumulative Totals	–	54	81	92	101	113	123	137	159	175	200	212	218	220	220	227	227
Stock Share	–	**24%**	**35%**	**40%**	**44%**	**49%**	**54%**	**60%**	**69%**	**76%**	**87%**	**93%**	**95%**	**96%**	**96%**	**99%**	**99%**

[1] BSOOB = Biddeford Saco Old Orchard Beach Transit; RTP = Regional Transportation Program (Lakes Region); SPBS = South Portland Bus Service; YCCAC = York County Community Action Corporation.

[98] MaineDOT Climate Initiative—Electrification | MaineDOT.

Other states have set targets based on total fleet composition (stock). While our methodology focuses on sales instead of stock targets, it is helpful to contextualize the Maine bus electrification program's impact in comparison to other states. The NYC MTA targets 100 percent of its fleet to be ZEVs by 2040, while Maryland targets a 50 percent ZEV fleet by 2030. Massachusetts and Vermont have a 100 percent ZEV fleet target by 2050. Table E.7 lists the stock shares from other state targets.

TABLE E.7 TRANSIT BUS FLEET ZEV SHARE GOALS

Annual Stock Share	2030	2035	2040	2045	2050
MassDOT/VTrans[1,2]	20%	–	75%	–	100%
Maryland DOT[3]	50%	–	–	–	–
Maine Bus electrification plan (assuming the plan is expanded to all transit bus operators in the state)	54%	93%	99%	–	–
NYC MTA[4]	–	–	100%	–	–

[1] The Electrification of Vermont's Public Transit Fleet | Agency of Transportation.

[2] LBE Priorities and Efforts: Clean Transportation | Mass.gov.

[3] MDOT MTA LAUNCHES PHASED PLAN FOR CONVERSION TO ZERO-EMISSION BUS FLEET | Maryland Transit Administration.

[4] MTA Zero-Emission Bus Fleet Transition.

Using targets from other states as suggestions, as well as data from Maine's existing transit electrification plans, sales (procurement) share targets were developed for transit buses for each of the scenarios as shown in Table E.8. Note that years beyond 2040 are not modeled in this analysis, but are presented for comparison as some 2030, 2035, and 2040 numbers are intermediate estimates based on 2050 numbers from the various sources.

TABLE E.8. SCENARIOS: TRANSIT BUS ZEV PROCUREMENT

Annual purchases share (sales)	2025	2030	2035	2040	2045	2050
Reference EPA reference case for Class 6–7 transit buses	–	9.2%	15.6%	19.1%	22.4%	25.7%
Moderate	–	15%[1]	30%[1]	50%[1]	75%	100%
High NJ Transit	–	50%	100%	100%	100%	100%
Advanced Assumes all future procurements are ZEV to achieve 100 percent ZEV fleets by 2035–2040	100%	100%	100%	100%	100%	100%

[1] CS suggested intermediate targets.

Projections of Total Vehicle Stock

The above scenarios are presented in terms of market shares for new vehicle sales or procurements. These shares are applied to existing and projected vehicle populations to develop estimates of ZEV vehicle stock shares based on fleet turnover assumptions built into the EPA MOVES model; this enables consistency with biennial emissions modeling conducted by the State of Maine, and therefore with statutory emissions reduction targets applying to the state.[99] Future year total vehicle stock (2030, 2035, 2040) is inflated from base year (2020) levels using a growth factor. Table E.9 shows options that were considered for growth factors.

TABLE E.9 MHDV GROWTH FACTOR OPTIONS

Factor	Basis Years	Annual Growth	Source
Freight volumes	2019–2050	1.7%	U.S. DOT Freight Analysis Framework, from Department of Transportation Integrated Freight Strategy (IFS) 2024
Employment	2013–2022	0.8%	Maine IFS 2024
GDP	2013–2022	2.4%	Maine IFS 2024
Population	2020–2040	0.2%	Maine demographics, cited in IFS 2024
MDV Stock	2020–2040	2.4%	Consultants for Maine Governor's Energy Office
HDV Stock	2020–2040	1.0%	Consultants for Maine Governor's Energy Office
MDV Stock	2022–2040	2.7%	U.S. DOE AEO 2023
HDV Stock	2022–2040	1.1%	U.S. DOE AEO 2023

Considering these various sources, the growth rates consistent with the freight volume growth in Maine as per the U.S. Department of Transportation Freight Analysis Framework, from the 2024 Maine Integrated Freight Strategy, was used. These values approximately correspond to the average of the MHD vehicle forecasts of the DOE Annual Energy Outlook, while being based on Maine specific freight growth data.

[99] Maine Department of Environmental Protection (2024). 10th Report on Progress on Greenhouse Gas Reduction Goals.

E.4 MHDV Stock and VMT Projections

By Vehicle Vocation (Source Type) from the MOVES Model

ZEV sales shares were translated into ZEV stock and VMT by scenario and year using the U.S. Environmental Protection Agency (EPA) vehicle emissions model MOVES4 with Maine-specific input data, as used by the Maine Department of Environmental Protection (DEP) for emissions modeling. The MOVES4 data and application are described in more detail in Appendix F.

Starting with 2020 county-level databases from Maine DEP, MHDV stock and VMT were corrected for COVID-related reductions in truck activity.[100] Once corrected, the simple annual growth rate (from a 2019 base) of 1.7 percent was applied to vehicle stock in Maine. Combining this growth projection with a 14 percent COVID adjustment results a growth in MHDV stock of 23 percent from 2020 to 2030, 34 percent from 2020 to 2035, and 45 percent from 2020 to 2040. These factors were applied to MOVES stock (by vocation/source type) and VMT (by Federal Highway Administration Highway Performance Monitoring System category) for each of Maine's 16 counties.

Table E.10 and Table E.11 show the resulting statewide MHDV stock and VMT for projection years for Maine Class 2b–8 MHDVs by MOVES vocation/source type. By default, MOVES assumes that the share of Light Commercial Trucks that are Class 2b–3 will shift to light-duty trucks over time, resulting in the reductions shown for this type of vehicle. While the stock projections include only trucks registered in Maine, VMT projections include all travel in Maine, including from trucks registered out-of-state. Note that, in the below analysis, the stock totals are higher than the totals shown in the roadmap for Class 3–8 trucks, since Class 2b trucks are also included in the MOVES categories. Other minor differences in the stock totals are due to differences in how data was processed by Maine DEP for the MOVES source type categories, in comparison to the processing completed by the project team for the roadmap market segmentation.

[100] Federal Highway Administration VMT data for Maine found a 14 percent drop in VMT between 2019 and 2020.

TABLE E.10 MHDV STOCK PROJECTIONS BY MOVES SOURCE TYPE

MOVES Source Type	CY 2020	CY 2030	CY 2035	CY 2040
Bus	3,954	4,844	5,290	5,733
Combination Long-Haul	4,325	5,298	5,787	6,271
Combination Short-Haul	12,724	15,587	17,025	18,450
Motorhome	3,378	4,138	4,520	4,898
Refuse	833	1,020	1,115	1,208
Single Unit Long-Haul	1,172	1,436	1,568	1,699
Single Unit Short-Haul	34,774	42,598	46,528	50,422
Light Commercial	22,093	19,880	19,002	18,981
Total	**83,253**	**94,801**	**100,834**	**107,663**

TABLE E.11 MHDV VMT PROJECTIONS (MILLION MILES)

MOVES Source Type	CY 2020	CY 2030	CY 2035	CY 2040
Bus	93.7	114.8	125.4	135.9
Combination Long-Haul	310.4	380.2	415.3	450.1
Combination Short-Haul	251.5	308.1	336.5	364.7
Motorhome	17.7	21.7	23.7	25.7
Refuse	17.3	21.3	23.2	25.2
Single Unit Long-Haul	26.6	32.6	35.6	38.6
Single Unit Short-Haul	487.5	597.2	652.3	706.9
Light Commercial	239.8	216.5	206.9	210.8
Total	**1,444.7**	**1,692.4**	**1,818.9**	**1,957.8**

By Roadmap Vocation and Weight Class Segments

MOVES stock and emissions projections were allocated into the vocation and weight class segments selected for the roadmap as a basis for analyzing the emissions impact of selected MHDV electrification scenarios. This was accomplished by first splitting MOVES source types into Class 3–6 MDV and Class 7–8 HDV weight class segments, then allocating source types by MDV/HDV into roadmap truck vocations.

Splitting MOVES source types to Class 3–6 MDV and Class 7–8 HDV categories required the following steps:

» Remove Class 2b vehicles from MOVES estimates, which account for 41 percent of Maine commercial trucks in the 8,501–14,000 lb. Gross Vehicle Weight category per registration data.

» Assign all MOVES Class 3–5 vehicles to the MDV category.

» Assign 43 percent of MOVES Class 6–7 vehicles to the MDV category and 57 percent to the HDV category, based on Maine registration data (see further discussion in Appendix D).

» Assign all MOVES Class 7–8 to the HDV category.

Vehicle stock and associated emissions, grouped by MOVES source type and MDV/HDV, were then allocated to the roadmap truck vocation using allocation factors shown in Table E.12 and Table E.13. Allocations used for emissions differ from those used for stock because they remove the contribution of out-of-state trucks traveling in Maine; this step was not necessary for stock estimates based on Maine State registration data. Bus, refuse truck, motorhome, and long-haul source types map directly to vocational categories used in the roadmap. Class 3 light commercial trucks, single unit short-haul and combination short-haul source types were distributed among the public, local commercial, and regional commercial vocations using allocation factors derived from registration organization categories and LOCUS trips (for stock) or VMT (for VMT and emissions), as discussed in Appendix D. Long-haul VMT and emissions were reduced 50 percent to remove out-of-state trucks from these estimates, based on LOCUS origin-destination data.

TABLE E.12 ALLOCATION FACTORS FOR MAPPING MOVES SOURCE TYPE STOCK TO ROADMAP MARKET SEGMENTS

Market Segment	Light Comm and Short Haul	Other Bus	Transit Bus	School Bus	Refuse	Motor-home	Long Haul
Medium-Duty (Class 3–6)							
Public	6%	–	–	–	100%	–	–
Local Commercial	89%	–	–	–	–	–	–
Regional Commercial	5%	–	–	–	–	–	–
Long Haul	–	100%	–	–	–	100%	100%
Transit Bus	–	–	100%	–	–	–	–
School Bus	–	–	–	100%	–	–	–

Market Segment	Light Comm and Short Haul	Other Bus	Transit Bus	School Bus	Refuse	Motor-home	Long Haul
Heavy-Duty (Class 7–8)							
Public	13%	–	–	–	100%	–	–
Local Commercial	64%	–	–	–	–	–	–
Regional Commercial	23%	–	–	–	–	–	–
Long Haul	–	100%	–	–	–	100%	100%
Transit Bus	–	–	100%	–	–	–	–
School Bus	–	–	–	100%	–	–	–

TABLE E.13 ALLOCATION FACTORS FOR MAPPING MOVES SOURCE TYPE EMISSIONS TO ROADMAP MARKET SEGMENTS

Market Segment	Light Comm and Short Haul	Other Bus	Transit Bus	School Bus	Refuse	Motor-home	Long Haul
Medium-Duty (Class 3–6)							
Public	6%	–	–	–	100%	–	–
Local Commercial	86%	–	–	–	–	–	–
Regional Commercial	8%	–	–	–	–	–	–
Long Haul	–	50%	–	–	–	50%	50%
Transit Bus	–	–	100%	–	–	–	–
School Bus	–	–	–	100%	–	–	–
Heavy-Duty (Class 7–8)							
Public	8%	–	–	–	100%	–	–
Local Commercial	43%	–	–	–	–	–	–
Regional Commercial	49%	–	–	–	–	–	–
Long Haul	–	50%	–	–	–	50%	50%
Transit Bus	–	–	100%	–	–	–	–
School Bus	–	–		100%	–	–	–

Composite Scenario and Summary of Scenarios

Table E.14 summarizes market shares for new vehicle sales or procurements in 2030, 2035, and 2040. Table E.15 summarizes the resulting stock shares, Table E.16 shows total ZEV stock, and Table E.17 shows total MHDV stock in each year and market segment.

A "composite" scenario is also shown in these tables. This scenario mixed different levels of ZEV adoption across different years, depending on market segments and operational cycles. The guidelines for this composite scenario are:

» Public and municipal service vehicles (including transit and school buses, state and municipal fleets, utilities, and refuse trucks): aligned with High scenario in 2030, increasing to the Advanced scenario by 2040. These vehicles tend to operate locally under conditions that may be more suitable for electrification, and also may have more opportunities for leveraging public policy and funding than commercial vehicles.

» Commercial vehicles (all distance ranges): aligned with the Moderate scenario in 2030, increasing to the High scenario by 2040. The more conservative levels for this sector reflect the greater diversity of vehicle uses (including regional and long-haul) and the greater challenge of reaching a large number of relatively small fleet operators with varying degrees of financial and technical capacity.

TABLE E.14 MHD ZEV SALES SHARES BY SCENARIO AND MARKET SEGMENT

Segment	Class	Base 2030	Base 2035	Base 2040	Mod. 2030	Mod. 2035	Mod. 2040	High 2030	High 2035	High 2040	Adv. 2030	Adv. 2035	Adv. 2040	Comp. 2030	Comp. 2035	Comp. 2040
Public	MD	9%	16%	19%	30%	40%	50%	48%	71%	71%	100%	100%	100%	30%	71%	100%
Local	MD	12%	21%	25%	27%	58%	58%	64%	94%	94%	64%	94%	94%	27%	58%	94%
Regional	MD	3%	4%	5%	7%	19%	19%	40%	47%	47%	30%	71%	79%	7%	19%	47%
Long Haul	MD	1%	2%	2%	4%	16%	16%	17%	25%	25%	23%	71%	79%	4%	16%	25%
Transit Bus	MD	9%	16%	19%	15%	30%	50%	50%	100%	100%	100%	100%	100%	50%	100%	100%
School Bus	MD	9%	16%	19%	30%	50%	75%	48%	75%	90%	75%	100%	100%	75%	100%	100%
Public	HD	9%	16%	19%	30%	40%	50%	48%	71%	71%	100%	100%	100%	30%	71%	100%
Local	HD	4%	5%	6%	14%	43%	43%	40%	48%	48%	38%	66%	74%	14%	43%	48%
Regional	HD	4%	5%	6%	14%	43%	43%	40%	48%	48%	38%	66%	74%	14%	43%	48%
Long Haul	HD	1%	2%	2%	4%	16%	16%	17%	25%	25%	22%	66%	74%	4%	16%	25%
Transit Bus	HD	9%	16%	19%	15%	30%	50%	50%	100%	100%	100%	100%	100%	50%	100%	100%
School Bus	HD	9%	16%	19%	30%	50%	75%	48%	75%	90%	75%	100%	100%	75%	100%	100%
All	**All**	**6%**	**13%**	**16%**	**21%**	**46%**	**48%**	**49%**	**70%**	**70%**	**55%**	**84%**	**87%**	**23%**	**51%**	**73%**

TABLE E.15 MHD ZEV STOCK SHARES BY SCENARIO AND MARKET SEGMENT

Segment	Class	Base 2030	Base 2035	Base 2040	Mod. 2030	Mod. 2035	Mod. 2040	High 2030	High 2035	High 2040	Adv. 2030	Adv. 2035	Adv. 2040	Comp. 2030	Comp. 2035	Comp. 2040
Public	MD	3%	7%	11%	4%	13%	21%	6%	17%	28%	9%	39%	61%	7%	24%	38%
Local	MD	3%	7%	11%	4%	13%	20%	6%	17%	27%	6%	36%	56%	6%	22%	35%
Regional	MD	3%	7%	11%	4%	13%	20%	6%	17%	27%	4%	27%	47%	4%	18%	30%
Long Haul	MD	2%	5%	9%	3%	10%	16%	6%	18%	29%	3%	27%	46%	3%	17%	29%
Transit Bus	MD	2%	6%	12%	9%	32%	50%	13%	38%	67%	15%	68%	116%	20%	63%	106%
School Bus	MD	2%	7%	12%	9%	33%	52%	11%	35%	55%	13%	52%	80%	15%	60%	95%
Public	HD	1%	2%	4%	2%	8%	14%	4%	12%	19%	6%	25%	38%	5%	18%	29%
Local	HD	1%	2%	4%	2%	7%	12%	3%	10%	16%	2%	14%	25%	2%	11%	19%
Regional	HD	1%	2%	4%	2%	7%	12%	3%	10%	16%	2%	14%	25%	2%	11%	19%
Long Haul	HD	0%	1%	2%	1%	7%	13%	2%	9%	15%	2%	24%	39%	1%	12%	21%
Transit Bus	HD	2%	3%	5%	5%	13%	21%	6%	16%	28%	7%	28%	48%	9%	26%	43%
School Bus	HD	2%	6%	11%	8%	28%	46%	10%	30%	48%	12%	45%	70%	13%	53%	83%
All	**All**	**2%**	**5%**	**8%**	**3%**	**11%**	**18%**	**5%**	**15%**	**24%**	**5%**	**29%**	**47%**	**5%**	**20%**	**32%**

TABLE E.16 MHD ZEV STOCK (VEHICLES) BY SCENARIO AND MARKET SEGMENT

Segment	Class	Base 2030	Base 2035	Base 2040	Mod. 2030	Mod. 2035	Mod. 2040	High 2030	High 2035	High 2040	Adv. 2030	Adv. 2035	Adv. 2040	Comp. 2030	Comp. 2035	Comp. 2040
Public	MD	76	192	330	117	370	627	154	491	853	231	1,116	1,850	195	669	1,150
Local	MD	1,031	2,599	4,448	1,546	4,810	8,128	2,021	6,388	11,085	2,201	13,817	22,695	2,028	8,288	14,099
Regional	MD	59	149	255	89	276	466	116	366	636	82	590	1,090	89	389	713
Long Haul	MD	70	207	380	116	392	696	196	724	1,271	98	1,071	2,035	108	665	1,284
Transit Bus	MD	3	11	24	14	58	104	21	69	139	24	125	240	32	115	219
School Bus	MD	40	121	235	153	582	1,011	181	619	1,065	218	928	1,546	238	1,080	1,842
Public	HD	29	81	152	78	330	576	136	449	772	230	968	1,579	186	698	1,196
Local	HD	109	302	554	238	1,014	1,805	457	1,436	2,462	339	2,009	3,789	327	1,550	2,921
Regional	HD	38	106	195	84	357	635	161	506	867	120	707	1,334	115	546	1,028
Long Haul	HD	25	97	182	67	556	1,053	136	722	1,225	134	1,842	3,161	84	898	1,735
Transit Bus	HD	8	13	21	18	54	89	24	64	119	27	113	205	35	104	187
School Bus	HD	46	134	257	171	640	1,107	202	681	1,166	244	1,020	1,692	268	1,187	2,015
All	**All**	**1,533**	**4,013**	**7,034**	**2,692**	**9,438**	**16,297**	**3,806**	**12,515**	**21,661**	**3,948**	**24,307**	**41,217**	**3,704**	**16,188**	**28,389**

TABLE E.17 TOTAL MHDV STOCK (VEHICLES) BY MARKET SEGMENT

Segment	Class	2020	2030	2035	2040
Public	MD	2,176	2,661	2,843	3,055
Local	MD	28,808	35,505	37,969	40,774
Regional	MD	1,652	2,036	2,177	2,338
Long Haul	MD	2,881	3,485	3,963	4,447
Transit Bus	MD	109	159	183	207
School Bus	MD	1,210	1,628	1,786	1,944
Public	HD	2,942	3,660	3,891	4,134
Local	HD	11,329	13,706	14,412	15,203
Regional	HD	3,989	4,825	5,074	5,353
Long Haul	HD	5,409	7,428	7,793	8,172
Transit Bus	HD	278	380	406	431
School Bus	HD	1,577	2,069	2,252	2,432
All	**All**	**62,360**	**77,542**	**82,750**	**88,489**

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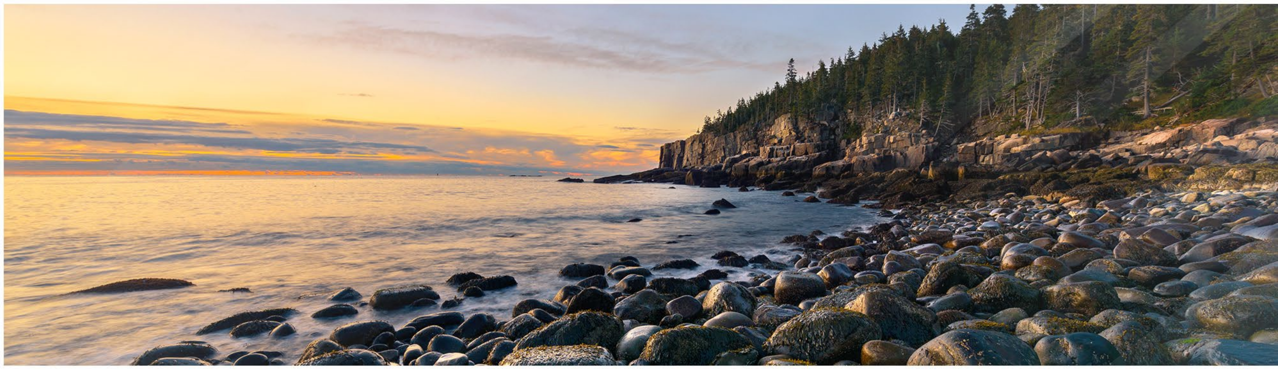

EMISSIONS ANALYSIS

F.1 Overview

This appendix to the Maine Clean Transportation Roadmap for Medium and Heavy-Duty Vehicles (MHDV) evaluates the greenhouse gas (GHG) and criteria pollutant emission reductions for a baseline or "business-as-usual" (BAU) zero-emission vehicle (ZEV) adoption scenario and four increasingly ambitious adoption scenarios defined for the project (see Appendix E). It outlines the methods used to project MHDV stock and activity by the vocation and weight class categories defined in this roadmap, run MOVES for the baseline and electrification scenarios, and process results. For each modeled scenario, the ZEV sales percentage, ZEV stock estimates, GHG emissions, and criteria pollutant emissions are presented.

This work was conducted by team member ERG, and involved estimating MHDV stock (both zero emissions and conventional) for calendar years (CY) 2030, 2035, and 2040; running the U.S. Environmental Protection Agency (EPA) vehicle emissions model MOVES4 using Maine-specific input data; and processing emission results into MHDV vocation and weight class categories used for defining roadmap electrification scenarios.

MOVES modeling for these analyses used county-level databases (CDB) developed by Maine Department of Environmental Protection (DEP) for the 2020 National Emissions Inventory (NEI). MOVES CDBs house necessary input data about vehicle stock, age distribution, activity levels (primarily vehicle miles traveled, or VMT), fuel properties (such as the sulfur or biodiesel content of on-road diesel sold in Maine), and meteorology (including temperature and humidity data in Maine). Because the 2020 CDBs were developed for MOVES3, an older version of EPA's model, ERG first converted the databases to MOVES4 using a conversion script published by EPA. A set of unique CDBs were developed for 2030, 2035, and 2040, creating 48 CDBs in all (16 counties x 3 years). MOVES4 was run to produce emissions and ZEV stock per year for each scenario.[101]

Criteria pollutant reductions and monetized health benefits resulting from these reductions were estimated for the entire State, and for a subset of census tracts identified as disadvantaged communities by the Federal Government using nationally-consistent data sets.

Appendix E describes how MOVES was used to translate sales projections into stock and VMT projections for the baseline and for all scenarios.

F.2 Business-As-Usual or Baseline Scenario

Transportation sources accounted for 51 percent of Maine's GHG emissions in 2021.[102] Of transportation emissions, commercial MHDVs contribute about 27 percent; this relative contribution is expected to grow over time, as emissions from cars and light-trucks are reduced through existing emissions standards and accelerated electrification. To assess future GHG emissions from MHDVs, and provide a baseline for estimating emission reductions associated with varying degrees of electrification, ERG developed a baseline emissions estimate for the business-as-usual, or reference, scenario selected for the roadmap. Data sources used to develop this baseline estimate included MOVES, Maine-specific fleet and activity inputs developed by Maine DEP for the 2020 NEI, and input files generated by the EPA for its Phase 3 emissions rule.[103,104] Analysis was then conducted at the county level for 2030, 2035, and 2040 using the Maine CDBs. As shown in Appendix E, by 2040 an estimated 7,000 MHDVs would be electrified under the baseline scenario, with nearly two-thirds these being in the MDV Local Commercial category.

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[101] ZEVs were modeled in MOVES as electric vehicles (EVs), but could also represent hydrogen fuel-cell vehicles, as MOVES assigns a zero tailpipe emission rate to both EVs and hydrogen fuel cell vehicles.

[102] Maine Department of Environmental Protection (2024). 10th Report on Progress on Greenhouse Gas Reduction Goals.

[103] The MOVES database table *SampleVehiclePopulation* developed by EPA for the Phase 3 Reference Case was inserted into the MOVES default database.

[104] U.S. EPA, "Regulatory Impact Analysis: Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards Regulatory Impact Analysis," March 2024, EPA-420-R-24-006.

GHG emissions in million metric tons of CO_2 equivalent (CO_2e)—the sum of CO_2 plus CH_4, and N_2O, weighted in MOVES by their respective 100-year global warming potentials—are shown for the baseline scenario in Table F.1. These emissions are from trucks registered in Maine that could be influenced by state initiatives to advance adoption of zero-emissions MHDVs. HDVs contribute about two-thirds of overall MHDV emissions, primarily from the Local, Regional, and Long-Haul categories.

TABLE F.1 MHDV BAU GHG PROJECTIONS (MMTCO$_2$E)

Market Segment	CY 2020	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)				
Public	0.027	0.029	0.029	0.029
Local Commercial	0.341	0.371	0.365	0.367
Regional Commercial	0.033	0.036	0.036	0.036
Long Haul	0.019	0.024	0.025	0.027
Transit Bus	0.008	0.011	0.011	0.012
School Bus	0.027	0.031	0.031	0.031
Heavy-Duty (Class 7–8)				
Public	0.070	0.078	0.078	0.080
Local Commercial	0.217	0.230	0.229	0.232
Regional Commercial	0.246	0.260	0.259	0.263
Long Haul	0.282	0.308	0.315	0.329
Transit Bus	0.022	0.026	0.026	0.027
School Bus	0.035	0.040	0.039	0.039
Total MHDV	**1.33**	**1.44**	**1.44**	**1.47**

F.3 MHDV ZEV Scenarios

Reductions in GHG and criteria pollutant emissions, including nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and volatile organic compounds (VOC), were modeled for four MHDV electrification scenarios: Moderate, High, Advanced, and a Composite scenario which considers accelerated ZEV adoption levels across certain public sector and municipal vehicle vocations (see Appendix E). Data used for the Moderate and High scenarios includes input files used by the U.S. EPA for its Phase 3 emissions rule. The Moderate scenario is based directly on EPA's modeling of the Phase 3 rule, and the High scenario is based on EPA's modeling of the Phase 3 rule in States which have also adopted the Advanced Clean Trucks (ACT) regulation. The MOVES database table developed by EPA for these scenarios was converted to the input needed for county-level runs, known as the Alternative Fuel and Vehicle Technology table (AVFT). MOVES was run in the same manner as the baseline scenario for 2030, 2035, and 2040, to produce ZEV stock and total emissions by MOVES source type and regulatory class. These results were post-processed into the roadmap vocational and weight categories, and also to reflect emission reductions from Class 3 MDVs that were not included in EPA's Phase 3 rule modeling. For the Moderate scenario, 32 percent of Class 3 sales were ZEV MY 2030, based on EPA light-truck GHG emission standards.[105] For the High scenario, ZEV sales percentage was increased to 55 percent by MY 2030 based on alignment with ACT. Advanced and composite scenarios were modeled by interpolating between results of the MOVES baseline runs and MOVES results for a "full electrification" upper-bound scenario. This approach provided a flexible means to quickly generate results for alternative scenarios using the roadmap vocation and weight categories. For calendar years 2030, 2035, and 2040, interpolation used as endpoints the range of ZEV sales percentages in model years 2030, 2035 and 2040 for the baseline case by roadmap category (Table F.1and 100 percent EV sales.

GHG emissions are presented in the following sections for each scenario. For all scenarios, it is important to note that relative emission benefits would continue to increase beyond 2040, as the fleet continues to turn over to ZEVs. Per the MOVES model, it would take 30 years for ZEV percentage of stock to match the ZEV sales percentage in a given model year—for example, if ZEVs were 25 percent of sales in 2030 and every year beyond, it would not be until 2060 that the entire vehicle stock reached a level of 25 percent ZEVs.

Moderate Scenario Results

GHG emissions for the Moderate scenario are shown in Table F.2. MHDV ZEV stock grows to about 16,300 by 2040, an increase of approximately 9,000 ZEVs from the baseline. Under this scenario, GHGs would be reduced 21 percent by 2040.

105 U.S. EPA (2021). Final Rule to Revise Existing National GHG Emissions Standards for Passenger Cars and Light Trucks Through Model Year 2026.

TABLE F.2 MODERATE SCENARIO GHG PROJECTIONS ($MMTCO_2E$)

Market Segment	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)			
Public	0.028	0.025	0.024
Local Commercial	0.357	0.319	0.298
Regional Commercial	0.035	0.031	0.029
Long Haul	0.023	0.022	0.022
Transit Bus	0.010	0.009	0.007
School Bus	0.029	0.022	0.017
Heavy-Duty (Class 7–8)			
Public	0.076	0.067	0.062
Local Commercial	0.224	0.197	0.182
Regional Commercial	0.254	0.223	0.206
Long Haul	0.306	0.284	0.273
Transit Bus	0.026	0.023	0.021
School Bus	0.037	0.028	0.022
Total MHDV	**1.40**	**1.25**	**1.16**
Reduction from BAU (MMT)	0.04	0.19	0.31
Reduction from BAU (%)	-2.8%	-13.5%	-21.0%

High Scenario Results

GHG emissions for the High scenario are shown in Table F.3. MHDV ZEV stock grows to about 22,000 by 2040, an increase of approximately 15,000 EVs from BAU. Under this scenario, GHGs would be reduced 30 percent by 2040.

TABLE F.3 HIGH SCENARIO GHG PROJECTIONS ($MMTCO_2E$)

Market Segment	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)			
Public	0.027	0.022	0.019
Local Commercial	0.343	0.283	0.246
Regional Commercial	0.033	0.028	0.024
Long-Haul Commercial	0.022	0.020	0.018
Transit Bus	0.010	0.008	0.005
School Bus	0.028	0.021	0.016

Market Segment	CY 2030	CY 2035	CY 2040
Heavy-Duty (Class 7–8)			
Public	0.073	0.062	0.055
Local Commercial	0.213	0.179	0.161
Regional Commercial	0.241	0.203	0.183
Long Haul	0.302	0.277	0.269
Transit Bus	0.025	0.022	0.019
School Bus	0.036	0.027	0.021
Total MHDV	**1.35**	**1.15**	**1.04**
Reduction from BAU (MMT)	0.09	0.29	0.43
Reduction from BAU (%)	-6.3%	-20.2%	-29.5%

Advanced Scenario Results

GHG emissions are shown in Table F.4. MHD ZEV stock grows to about 41,000 by 2040, an increase of approximately 34,000 ZEVs from BAU. Under this scenario, GHGs would be reduced 61 percent by 2040.

TABLE F.4 ADVANCED SCENARIO GHG PROJECTIONS (MMTCO$_2$E)

Market Segment	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)			
Public	0.025	0.012	0.007
Local Commercial	0.336	0.161	0.101
Regional Commercial	0.035	0.022	0.015
Long Haul	0.024	0.017	0.013
Transit Bus	0.009	0.006	0.003
School Bus	0.027	0.016	0.007
Heavy-Duty (Class 7–8)			
Public	0.068	0.040	0.024
Local Commercial	0.219	0.159	0.117
Regional Commercial	0.248	0.180	0.133
Long Haul	0.301	0.198	0.143
Transit Bus	0.025	0.016	0.007
School Bus	0.035	0.020	0.010
Total MHDV	**1.35**	**0.85**	**0.58**
Reduction from BAU (MMT)	0.09	0.60	0.89
Reduction from BAU (%)	-6.5%	-41.4%	-60.5%

Composite Scenario Results

Composite scenario results are shown in Table F.5. MHD ZEV stock grows to about 35,000 by 2040, an increase of approximately 28,000 EVs from the baseline. Under this scenario, GHGs would be reduced 43 percent by 2040, with local commercial MDVs alone contributing about one-third of this reduction.

TABLE F.5 COMPOSITE SCENARIO GHG PROJECTIONS (MMTCO$_2$E)

Market Segment	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)			
Public	0.028	0.018	0.007
Local Commercial	0.362	0.260	0.101
Regional Commercial	0.036	0.035	0.026
Long Haul	0.024	0.026	0.025
Transit Bus	0.010	0.006	0.003
School Bus	0.027	0.016	0.007
Heavy-Duty (Class 7–8)			
Public	0.075	0.052	0.024
Local Commercial	0.227	0.188	0.164
Regional Commercial	0.257	0.213	0.186
Long Haul	0.308	0.292	0.272
Transit Bus	0.026	0.016	0.007
School Bus	0.035	0.020	0.010
Total MHDV	**1.42**	**1.14**	**0.83**
Reduction from BAU (MMT)	0.03	0.30	0.64
Reduction from BAU (%)	-2.0%	-21.0%	-43.4%

Full Electrification Sensitivity Case

The full electrification case assumed 100 percent ZEV sales by MY 2030 for all classes; this was not modeled as a realistic policy scenario, but rather to provide an upper bound under which to develop the Advanced and Composite scenarios. GHG results for this case are shown in Table F.6; under this case, GHGs would be reduced 74 percent by 2040.

TABLE F.6 MHDV 100 PERCENT ZEV SALES SENSITIVITY CASE GHG PROJECTIONS (MMTCO$_2$E)

Market Segment	CY 2030	CY 2035	CY 2040
Medium-Duty (Class 3–6)			
Public	0.025	0.012	0.007
Local Commercial	0.312	0.147	0.080
Regional Commercial	0.030	0.014	0.008
Long Haul	0.021	0.013	0.008
Transit Bus	0.009	0.006	0.003
School Bus	0.026	0.016	0.007
Heavy-Duty (Class 7–8)			
Public	0.068	0.040	0.024
Local	0.198	0.116	0.071
Regional	0.224	0.131	0.080
Long Haul	0.271	0.135	0.074
Transit Bus	0.025	0.016	0.007
School Bus	0.033	0.020	0.010
Total MHDV	**1.24**	**0.66**	**0.38**
Reduction from BAU (MMT)	0.20	0.78	1.09
Reduction from BAU (%)	-14.1%	-54.0%	-74.2%

F.4 Energy Consumption Results

Total energy consumption results for all scenarios are shown in Table F.7, in million British thermal units (MMBTU). A reduction in total energy consumption for electrification scenarios reflects the high energy efficiency of ZEVs relative to diesel and gasoline vehicles. Under the composite scenario, the MHDV sector would consume 22 percent less energy by 2040. The contribution of MHD ZEVs to reduced energy consumption is shown in Table F.8; this information is used as the basis for estimating electricity demand from charging.

TABLE F.7 MHDV TOTAL ENERGY CONSUMPTION PROJECTIONS (MMBTU)

Calendar Year	BAU	Moderate	High	Advanced	Composite
2020	21,594,726	21,594,726	21,594,726	21,594,726	21,594,726
2030	22,154,699	21,807,691	21,426,449	21,381,482	21,914,152
2035	22,455,930	20,984,686	20,208,009	17,585,910	19,989,129
2040	23,197,060	20,942,324	19,899,004	16,205,893	18,185,866
2040 Reduction from BAU (MMBTU)		2,254,737	3,298,057	6,991,168	5,011,194
2040 Percent Reduction (%)		-10%	-14%	-30%	-22%

TABLE F.8 MHDV EV ENERGY CONSUMPTION PROJECTIONS (MMBTU)

Calendar Year	BAU	Moderate	High	Advanced	Composite
2020	4,091	4,091	4,091	4,091	4,091
2030	129,057	309,914	583,409	552,012	251,473
2035	350,139	1,446,270	1,936,337	3,515,512	1,848,220
2040	591,539	2,417,025	3,018,493	5,637,251	3,843,889

F.5 Criteria Pollutant Results

Statewide Results

Electrification of Maine's MHDV fleet will reduce harmful emissions of PM, NO_x, and VOC. Emissions of these pollutants were estimated from the MOVES runs described above for the baseline and accelerated electrification scenarios. Exhaust VOC emissions from MOVES were increased 5 percent to account for evaporative emissions, which only occur on gasoline trucks during summer months. Statewide results are shown in Table F.9–Table F.11. Unlike GHGs, the baseline case already shows significant reduction in criteria pollutants over time as the fleet turns over and new vehicles adhere to stringent Federal PM, NO_x, and VOC emission standards already in place. However, by 2040, the MHD ZEV scenarios could further reduce $PM_{2.5}$ by 47 percent, NO_x by 42 percent, and VOC by 54 percent.

TABLE F.9 MHDV $PM_{2.5}$ PROJECTIONS (TONS)

Calendar Year	BAU	Moderate	High	Advanced	Composite
2020	150.8	150.8	150.8	150.8	150.8
2030	34.5	34.3	34.0	34.0	34.4
2035	19.1	18.1	17.5	15.8	17.4
2040	10.9	9.2	8.4	5.8	7.2
2040 Reduction from BAU (Tons)		1.7	2.5	5.1	3.7
2040 Percent Reduction (%)		-15%	-23%	-47%	-34%

TABLE F.10 MHDV NO_X PROJECTIONS (TONS)

Calendar Year	BAU	Moderate	High	Advanced	Composite
2020	5,334	5,334	5,334	5,334	5,334
2030	2,541	2,523	2,509	2,494	2,526
2035	1,691	1,608	1,553	1,395	1,541
2040	1,471	1,274	1,199	849	1,025
2040 Reduction from BAU (Tons)		197	272	622	446
2040 Percent Reduction (%)		-13%	-19%	-42%	-30%

TABLE F.11 MHDV VOC PROJECTIONS (TONS)

Calendar Year	BAU	Moderate	High	Advanced	Composite
2020	533	533	533	533	533
2030	304	298	292	291	300
2035	246	223	209	167	206
2040	217	181	161	101	134
2040 Reduction from BAU (Tons)		37	56	117	84
2040 Percent Reduction (%)		-17%	-26%	-54%	-38%

The monetized health benefits that would result from these reductions were estimated using EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) web tool.[106] Accounting for additional reductions in $PM_{2.5}$ and ozone alone, the Composite scenario could save Maine people between \$3.7 and \$4.6 million dollars in 2040.

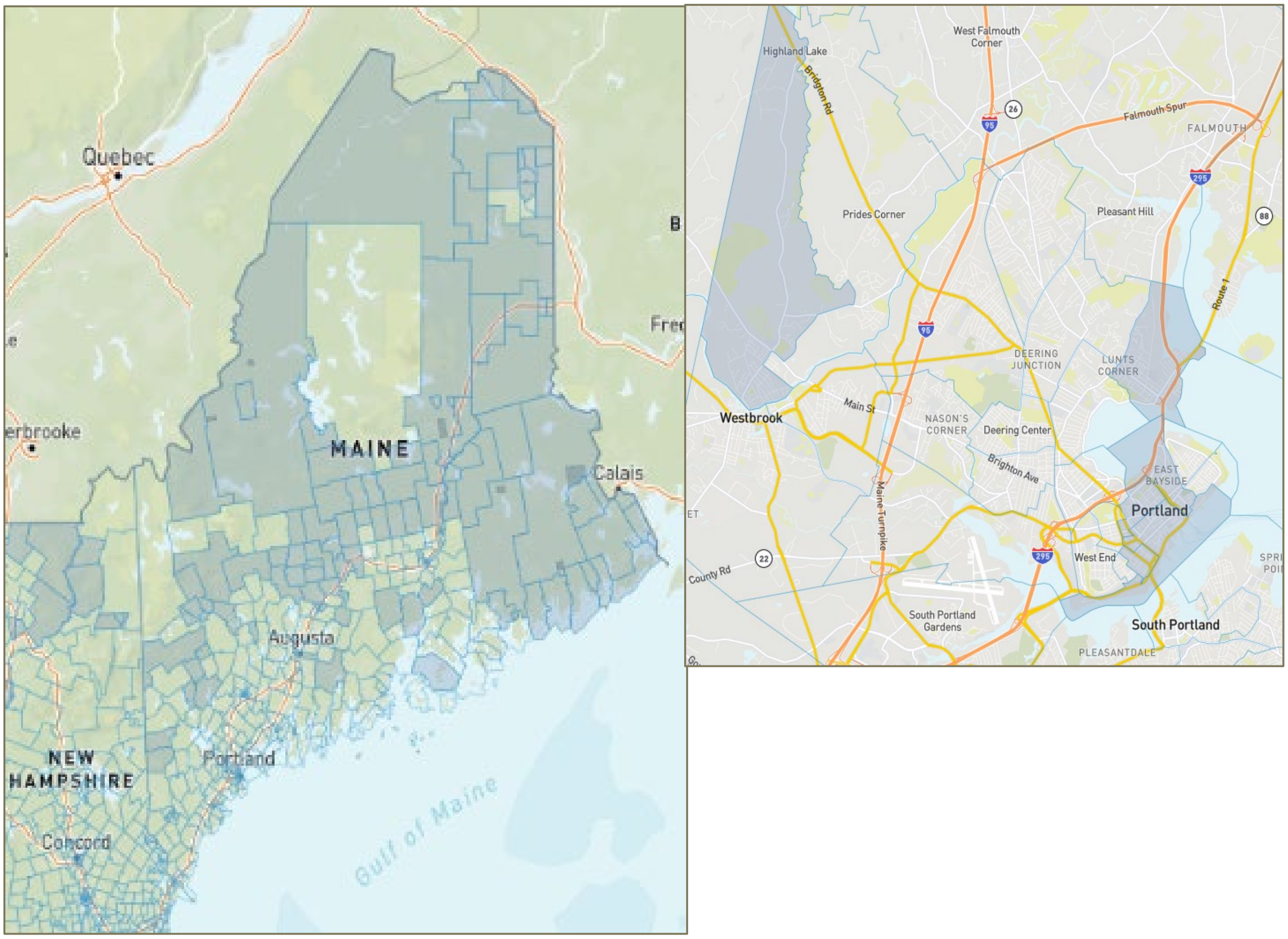
Emissions Benefits in Disadvantaged Communities

This roadmap sought to begin to understand whether and how the benefits of clean trucks would accrue in disadvantaged communities. The Federal Climate and Economic Justice Screening Tool (CEJST) was used to identify census tracts in Maine classified as disadvantaged, as based on nationally-consistent census-tract level data.[107] Of Maine's 358 census tracts, 33 percent are disadvantaged, shown in Figure F.1 as shaded areas. A zoom-in of disadvantaged census tracts in the Portland area is shown on the right, including areas in the I-295 corridor.

[106] U.S. EPA, COBRA Web Edition https://cobra.epa.gov/ accessed 10/29/24.

[107] White House Council on Environmental Quality Climate and Economic Justice Screening Tool https://screeningtool.geoplatform.gov/en/ accessed 10/28/24.

FIGURE F.1 DISADVANTAGED COMMUNITIES IN MAINE PER CEJST (SHADED AREAS)



LOCUS data on trip destination by census tract was used as the best available surrogate for truck travel at the census tract; LOCUS data includes trips with very short stop durations (under five minutes). While trip destination data does not represent traffic from trucks passing *through* a census tract (e.g., on I-295 passing through Portland), it does account for trucks registered in other locales which traveling to the area of interest, unlike registration data. Per LOCUS, 27.5 percent of MHDV trips ended in a disadvantaged census tract in 2023. This figure was used to allocate statewide criteria pollutant benefits from Table F.11 to disadvantaged communities in Maine, with results for 2040 shown in Table F.12. Reductions associated with the Composite scenario translate to health benefits between $1.0–1.3 million for Maine residents residing in disadvantaged communities.

TABLE F.12 2040 CRITERIA POLLUTANT REDUCTIONS IN DISADVANTAGED COMMUNITIES (TONS)

Pollutant	Moderate	High	Advanced	Composite
$PM_{2.5}$	0.5	0.7	1.4	1.0
NO_x	54.2	74.9	171.1	122.7
VOC	10.0	15.0	32.0	23.0

F.6 Conclusions

MHDVs are a significant contributor to Maine's transportation emissions, and the contribution of this vehicle segment will grow over time as light-duty vehicles rapidly decarbonize. This analysis shows that meaningful GHG reductions, reductions of criteria pollutants, and health benefits are achievable in Maine by 2040 across a range of electrification scenarios, with benefits continuing to accrue beyond 2040. Specific subsectors of MHDVs, including MDV local commercial trucks, contribute a significant portion of overall benefits for these scenarios. Under the Composite scenario, total GHGs from MHDVs would be reduced over 40 percent by 2040, with about one-third coming from the MDV local commercial sector. This Composite scenario would see nearly 30,000 MHD ZEVS on the roads in Maine by 2040, with reductions in PM, NO_x, and VOC leading to statewide health benefits of $3.7 million–$4.6 million in 2023 dollars. Based on LOCUS telematics data, about one-quarter of statewide benefits would be realized in Maine's disadvantaged communities. Further analysis could focus on the reduction in "hot spot" emissions and exposure in areas through which a disproportionate concentration of MHDVs pass through, such as the I-295 corridor in Portland.

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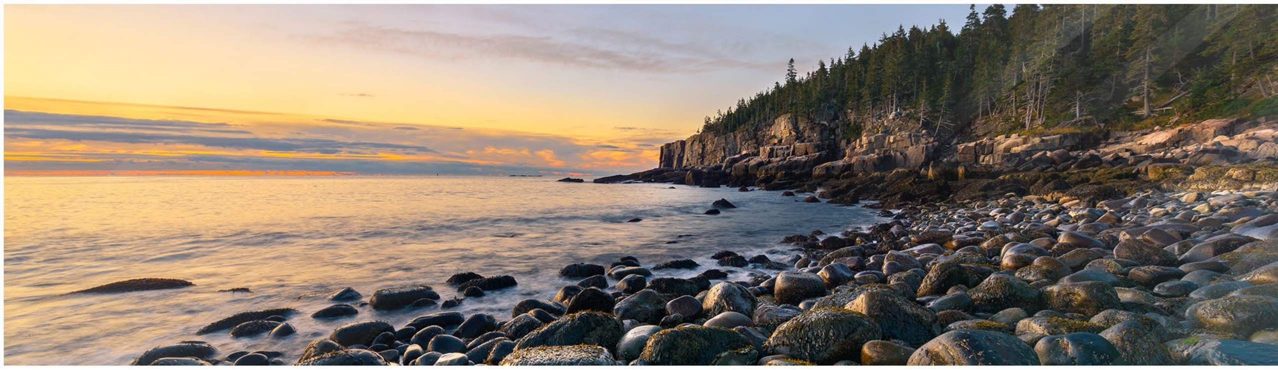


ESTIMATION OF CHARGING DEMAND AND INFRASTRUCTURE COSTS

This appendix to the Maine Clean Transportation Roadmap for Medium- and Heavy- Duty Vehicles describes the methodology for forecasting electricity demand and associated infrastructure costs for future scenarios for medium and heavy-duty (MHD) zero emission vehicles (ZEV) in Maine.

G.1 Method

The following steps were taken to forecast electricity demand and infrastructure costs.

» Identify analysis years—selected as 2030, 2035, and 2040 for the ZEV market penetration scenarios (see Appendix E) and emissions analysis (see Appendix F).

» Estimate the number of ZEVs in Maine's fleet by market segment across each analysis year and ZEV scenario—this information was taken from the scenarios developed according to the methodology outlined in Appendix E.

» Obtain estimates of total ZEV energy consumption by market segment from the emissions analysis conducted for the roadmap (see Appendix F) using the U.S. Environmental Protection Agency (EPA) MOVES emissions model, which also provides energy estimates. The average energy consumption rates (kWh per mile) associated with ZEVs from the MOVES model are compared to other sources to evaluate consistency.

» Identify the fraction of ZEVs in each market segment which are assumed to be battery electric vehicles (BEV) versus hydrogen fuel cell EV (FCEV). Adjust for the share of BEV versus FCEVs to estimate BEV energy consumption by market segment.

- Allocate energy consumption by type of charging (at the private depot versus at publicly available charging, by charge power level ranging from Level 2 to megawatt charging) based on expected charging preferences and patterns from other research and from outreach to Maine fleet operators.
- Estimate the number of ports needed by type of charger (private versus public, by power level) for ZEV scenarios in each forecast year, based on the projected vehicle stock for each market segment and the estimated number of chargers (ports) needed per vehicle by power level and location type.
- Identify typical infrastructure costs for public and private sites based on number of ports and power demand by power level, and apply unit costs to estimate total statewide costs under ZEV scenarios in each forecast year.
- Estimate charging revenues based on typical commercial site and public charging rates per kilowatt-hour.
- Develop daily temporal distributions (load profiles) to assist in identifying maximum loads, based on LOCUS Truck data, which also provides information on trip-ends by time of day. Compare the LOCUS-based profiles with data from other sources.

The remainder of this appendix describes the key data sources and assumptions that were used to apply the above procedure.

G.2 Key Assumptions

Energy Rates

We use energy rates from the EPA MOVES model, using the same runs as conducted for the emissions analysis completed for this roadmap (see Appendix F). Other sources also cite various energy rates, as shown in Table G.1, including EPRI, National Grid based on Rocky Mountain Institute (RMI) data, ISO-New England, and the California Air Resources Board (CARB). These estimates vary for reasons, including differences in vehicle class definitions and duty cycles. MOVES rates are somewhat higher than other sources, but the rates for short-haul trucks are lower than for long-haul trucks, which is expected given the greater battery capacity requirements and higher operating speeds for long-haul operation. For comparison, the CARB rates are based on short-haul applications (drayage trucks and yard tractors). The ISO-NE estimates are for delivery vehicles only, which are normally short-haul. Other sources do not clearly specify assumptions about the mix of short-haul versus long-haul use. Using MOVES rates provides for maximum consistency with the emissions analyses conducted.

TABLE G.1 ENERGY CONSUMPTION RATES (KWH/MI)

Source	MDV	HDV	Transit Bus	School Bus	Notes
MOVES: short-haul	1.27/1.31	2.76/2.87	2.03/2.06	1.46/1.49	2030/2040 values. Based on Maine MOVES runs by project team. MDV = single-unit, HDV = combination.
MOVES: long-haul	2.34/2.37	4.38/4.55	–	–	
EPRI (2024)[1]	1.1	1.8	–	–	Presentation for Maine GOPIF, July 2024, as used in the eRoadMap.
National Grid/RMI	1.3	2.5	–	–	RMI, as cited in National Grid (2022).
ISO-NE (2023)	1.9–2.1	NA	3.1–4.5	2.4–3.7	MDV for medium-duty delivery vehicle. Ranges are temperature-dependent.
ICCT (2023)	1.12/1.06	2.16/2.05	1.18/1.14	1.26/1.20	2030/2040 values.
CARB (2018)	–	2.1–2.4	1.5–2.3	–	Range of individual vehicle values from CARB (2018).

[1] A full set of references is provided at the end of this appendix.

Battery-Electric versus Fuel-Cell Electric Vehicles

While it is likely that short-haul MHD ZEVs will be mainly battery-electric, there is still uncertainty regarding trucks used in long-haul applications regarding the degree to which battery-electric versus hydrogen fuel cell technology will dominate the market. Most sources project a mix of these technologies.

The National Grid (2022) Electric Highways study states that, "The National Renewable Energy Laboratory considers that, by 2050, the MD truck stock will include 66 percent BEVs and 16 percent fuel cell electric vehicles (FCEVs); the HD truck stock will consist of 56 percent BEVs and 16 percent FCEVs. A report by the Mission Possible Partnership, and sponsored in part by RMI, shows that, by 2050, FCEVs make up almost no share of U.S. regional MHDV sales and 32 percent of long-haul MHDV sales, with the vast majority of other sales being battery-electric." The referenced NREL study shows a majority of sales of HD ZEVs for long-haul use through 2050 being FCEVs (estimated 50–60 percent), with short-haul HD ZEVs and MD ZEVs being mainly (over 80 percent) battery-electric.[108]

[108] Numbers were not available in the public materials, so the estimates are read from the figure.

For this study we apply FCEV shares by market segment as shown in Table G.2.

TABLE G.2 HYDROGEN FUEL CELL SHARES OF MHD ZEV MARKET

Market Segment	MDV	HDV
Public and Municipal Service	0%	0%
Local	0%	20%
Regional	20%	20%
Long Haul	20%	60%
Transit Bus	0%	0%
School Bus	0%	0%

Type of Charging

We allocate charging by type (depot versus public, by charge power level) at a statewide level, since we do not have sufficient data to make location-specific charging projections.

ICCT (2022) estimates that, in the U.S. market by 2040, an estimated fleet of 4.7 million battery-electric trucks will require approximately 2.3 million chargers, with 91 percent being overnight private depot charging, 3 percent being depot charging accessible to the public, and 6 percent being fast (350 kW) and ultra-fast (1 MW) public charging services. Public chargers are roughly equally split between fast and ultra-fast by 2040.

ICCT (2023) provides additional estimates of the share of energy by power type, broken out by vehicle category. These estimates show the share of energy provided by each type of charger/location, rather than the share of the number of chargers provided in the 2022 study. Note that ICCT assumes that depot chargers for most MHDVs are Level 3 chargers (50 to 150 kW).

Atlas Public Policy (2021) also assumes that 75–90 percent of fleet vehicle charging is done at depots, with 10–25 percent of charging done on-road at publicly accessible locations.

For this study, we proportion total energy use by charger and location type based on a combination of these sources, with different assumptions for each market segment, as shown in Table G.3.

TABLE G.3 SHARE OF POWER SUPPLIED BY CHARGER AND LOCATION TYPE

Market Segment	Weight Class	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
Public and Municipal Service	MD (3–6)	96%	–	–	4%	–
Local	MD (3–6)	96%	–	–	4%	–
Regional	MD (3–6)	75%	–	–	8%	17%
Long Haul	MD (3–6)	–	–	75%	8%	17%
Transit Bus	MD (3–6)	–	100%	–	–	–
School Bus	MD (3–6)	100%	–	–	–	–
Public and Municipal Service	HD (7–8)	–	77%	–	6%	17%
Local	HD (7–8)	–	77%	–	6%	17%
Regional	HD (7–8)	–	82%	–	1%	16%
Long Haul	HD (7–8)	–	–	82%	1%	16%
Transit Bus	HD (7–8)	–	100%	–	–	–
School Bus	HD (7–8)	100%	–	–	–	–
Weighted Average	**MD + HD**	**44%**	**39%**	**5%**	**4%**	**9%**

Number of Chargers per Vehicle

We developed estimates of the number of chargers per vehicle (or vehicles served by each charger) at depot sites based on estimates of average daily energy demand by market segment, and assessment of how many chargers would be needed to meet that demand given assumptions regarding typical operating cycles for that market segment. Since costs increase rapidly with charger power level, an effort was made to assign the minimum charger power level needed to serve a particular market segment, relying on assumptions about managed charging and additional operational efficiencies.

In our analysis, a typical school bus requires between 85 and 92 kWh per day of energy (to travel about 60 miles a day at about 1.5 kWh/mile). A Level 2 charger providing 19.2 kW of power can fully charge a bus in about 5 hours. Since most school buses dwell for at least 12 hours overnight, we assume that a single charger can serve at least two buses (not taking into account additional charging capability midday, between school bus runs). This could be accomplished either with a "smart charger" that allows two vehicles to charge from a single port, or by alternating charging nights if daily vehicle range allowed. A transit bus, requiring an average of 277 to 351 kWh of energy per day, would require a higher power charger

(50 to 100 kW), as a full recharge would require 15 to 19 hours on a Level 2 charger; again, however, two transit buses could likely share one higher-powered charger.

In this analysis, we assume that no more than two vehicles can share a single charger (0.5 ports per vehicle). Many Maine fleets are likely to be relatively small, and it may be necessary to have more than the theoretical minimum number of chargers per vehicle to account for varying load situations and charger downtime.

Table G.4 shows the average daily power requirement and the assumed number of depot chargers per vehicle by market segment. The number of hours per day to fully charge the vehicle is shown for comparison for each power level and vehicle type. Power requirements are shown for 2030, but show little variation in 2035 and 2040. Level 2 chargers are assumed to provide 19 kW and Level 3 chargers to provide 100 kW of charging capacity.

TABLE G.4 POWER REQUIREMENTS (2030) AND DEPOT PORTS PER VEHICLE

Market Segment	Weight Class	kWh/veh/day	Hrs/day with Level 2	Hrs/day with Level 3	Hrs/day with 350 kW	Ports per Vehicle: Level 2	Ports per Vehicle: Level 3	Ports per Vehicle: 350 kW
Public	MD (3–6)	73	3.8	0.9	0.2	0.5	–	–
Local	MD (3–6)	68	3.6	0.8	0.2	0.5	–	–
Regional	MD (3–6)	115	6.1	1.4	0.4	1	–	–
Long Haul[1]	MD (3–6)	49	2.6	0.6	0.2	–	–	–
Transit Bus	MD (3–6)	277	14.6	3.3	0.9	–	0.5	–
School Bus	MD (3–6)	85	4.5	1.0	0.3	0.5		–
Public	HD (7–8)	241	12.7	2.8	0.8	–	0.5	–
Local	HD (7–8)	262	13.8	3.1	0.9	–	0.5	–
Regional	HD (7–8)	843	44.4	9.9	2.8	–	–	1
Long Haul[1]	HD (7–8)	428	22.6	5.0	1.4	–	–	–
Transit Bus	HD (7–8)	351	18.5	4.1	1.2	–	0.5	–
School Bus	HD (7–8)	92	4.8	1.1	0.3	0.5		–

[1] Long Haul power consumption is lower than Regional power consumption because only in-state long-haul travel is included. As discussed above, long-haul trucks are only assumed to use public charging, not depot charging.

For publicly accessible charging sites, the number of ports required was estimated based on the total energy consumption by type of port (150 kW, 350 kW, or 1 MW) and an average daily utilization rate.[109] The utilization rate was assumed to be 30 percent in 2035 and beyond, but only 15 percent in 2030 as some infrastructure may need to be built out initially even when demand is limited. Atlas (2021) assumes 20–40 percent utilization of long-haul truck parking chargers, based on truck parking utilization studies in Florida and Texas showing 40–70 percent space utilization, and adjusted for other requirements such as maneuvering. For comparison, for depot charging, ICCT (2022) assumes 8 hours (i.e., 1/3 of the day) are available for overnight charging events, a utilization rate of 33 percent.

The number of ports required is therefore be calculated as:

> Ports = Total annual energy demand (kWh) * share of energy demand by port type (%) / [average charge power by port type (kW) * 24 * 365 * utilization rate]

Finally, we assume the average charge power level is 85 percent of the nominal charge power level, or 110 kW for a 150 kW charger, 300 kW for a 350 kW charger, and 850 kW for a 1 MW charger. Not all vehicles will charge at the full power level, and charge power may also be scaled down as battery capacity is approached.

Costs of Charging Infrastructure

To estimate the total cost of public charging infrastructure to support MHD ZEVs, cost estimates were researched for four components:

- Charging station equipment (includes hardware and software).
- Installation and customer-side infrastructure (includes cabling, permitting, platforms, etc.).
- Utility-side make-ready (includes transformer upgrades, cabling, and power line connection upgrades as needed).
- Annual maintenance costs.

The first two sets of costs were estimated per port, with the third set of costs estimated per kW of installed capacity. Note that make-ready costs can vary **widely**. Discussion with Maine utilities suggested that transformer upgrades are often needed, with the exception of sites with four or fewer Level 2 chargers. Existing power capacity serving a site can vary widely,

[109] Overnight charging could be provided in many cases with lower-power Level 3 chargers in the range of 50 to 100 kW. This analysis assumes public fast chargers have a minimum of 150 kW nominal capacity consistent with National Electric Vehicle Infrastructure (NEVI) Program requirements for fast chargers along Alternative Fuel Corridors.

and costs can increase significantly if connection to a three-phase power line or upgrade to this connection is needed.

Maintenance costs were assumed to be 10 percent of annual charging station hardware costs per year. This is based on recommendations provided by stakeholders contacted in the development of the Massachusetts NEVI Plan (MassDOT, 2022).

Costs for depot charging station equipment are assumed to be included in total cost of ownership calculations, influencing purchase decisions for ZEVs and necessary to include in vehicle transition costs and to estimate any per-vehicle incentives necessary to accelerate ZEV transition. Make-ready costs to support private depot charging were estimated separately for illustrative purposes, as utilities have programs to partially cover these costs in some States. In Maine, there is currently no provision for utilities to cover make-ready costs; all make-ready costs would need to be borne by the site host or charging provider.

Cost estimates for charging equipment were based on literature sources. Cost estimates for make-ready work were based on a combination of literature sources, information from pilot projects by Maine's utilities, and other pilot project data from New York and California available to the project team. The available sources were somewhat inconsistent as to what was considered as charging equipment versus make-ready. Some sources also differentiated between customer-side and utility-side make-ready costs, which at the current time is not a relevant distinction in Maine. Given the considerable uncertainty in costs, especially make-ready costs, both a "low" and "high" cost scenario were developed to illustrate what a range might mean for overall costs. The assumptions used in this study are shown in Table G.5. Data sources and key assumptions are discussed further below.

TABLE G.5 CHARGING COSTS BY TYPE OF SITE AND POWER LEVEL

Cost Element and Scenario	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
Nominal power level (kW)	19	100	150	350	1,000
Low Cost Scenario					
Charging station equipment (per port)	$1,500	$25,000	$55,000	$130,000	$300,000
Installation and customer-side infrastructure (per port)	$1,000	$10,000	$17,000	$39,000	$75,000
Utility-side make-ready (per kW)	$142	$183	$183	$300	$400

Cost Element and Scenario	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
High Cost Scenario					
Charging station equipment (per port)	$5,000	$65,000	$75,000	$190,000	$400,000
Installation and customer-side infrastructure (per port)	$4,900	$27,500	$42,500	$57,000	$100,000
Utility-side make-ready (per kW)	$258	$283	$283	$500	$500

Cost Data Sources

EVAdoption.com, based on Cleantek, provides cost estimates for 50 kW to 350 kW chargers. We use these as a partial basis for the 100 kW, 150 kW, and 350 kW low and high costs.

Atlas (2021) provides hardware cost estimates for 150 kW, 350 kW, and 2 MW DCFC. For this study, we interpolated between the 350 kW and 2 MW estimates to arrive at 1 MW cost estimates. Atlas assumes that hardware costs decline by 3 percent per year between 2020 and 2030 (based on ICCT, 2019); this study does not deflate costs as we anticipate that supply chain constraints in the early years of MHD ZEV rollout may keep costs high. Combined hardware and installation costs are shown in Table G.6. Based on ICCT (2019) we estimate installation to be about 40 percent of hardware costs for a 150 kW charger and 30 percent for a 350 kW charger, averaged across different site sizes (Table G.7); we estimate these costs at 25 percent for a 1 MW charger.

TABLE G.6 DCFC INFRASTRUCTURE COSTS (ESTIMATED FROM ATLAS/ICCT)

Nominal Power Level	Hardware per port, 2020	Hardware per port, 2030 cost (2020 $)	Hardware + install (2020)[1]
150 kW	$85,000	$50,000	$119,000
350 kW	$140,000	$100,000	$182,000
1 MW[1]	$350,000	$350,000	$437,500
2 MW	$600,000	$440,000	$750,000

[1] Values estimated by CS from Atlas data.

TABLE G.7 HARDWARE AND INSTALLATION COSTS (ICCT)

ICCT (2019)	150 kW charger	350 kW charger
Hardware	$75,000	$140,000
Installation—1 per site	$48,000	$66,000
Installation—2 per site	$38,000	$52,500

ICCT (2019)	150 kW charger	350 kW charger
Installation—3–5 per site	$28,300	$39,100
Installation—6+ per site	$18,600	$25,700
Installation—average[1]	$30,270	$41,790
Hardware + Installation[1]	$105,270	$181,790
Installation—% of hardware[1]	40%	30%

[1] Values computed by CS from ICCT data.

RMI (2020) provides hardware cost estimates in the same range as ICCT, as shown in Table G.8

TABLE G.8 HARDWARE COSTS (RMI)

Hardware Cost	150 kW charger	350 kW charger
Low	$76,000	$128,000
High	$100,000	$150,000

The following sources were consulted for infrastructure costs, in addition to the Cleantek source documented above.

Avangrid (2024), which owns Central Maine Power, provided the following estimates from early DCFC projects, which are summarized and converted into per kW costs in Table G.9:

» Installation costs of DCFC (L3) = $55,000–$85,000, including transformer ($20,000–$35,000). labor ($25,000) and materials ($10,000–$25,000). Typically four plugs were installed with a total capacity of 600 kW.

» Installation costs of 24 Level 2 charging plugs = Range of $700–$7,000 per plug (average $2,700). Transformer costs are the main component. The average cost is equivalent to about $142 per kW.

» A >150kW DCFC installation will likely increase the cost by $35,000 for a 1500 kVA transformer.

» Three-phase line extensions can get expensive but are site (based on design) and therefore difficult to estimate. Some projects may also require that the circuit be fed from another sub-station that has capacity, which adds significant costs.

TABLE G.9 DCFC INSTALLATION COSTS (AVANGRID)

DCFC	Per site	Per plug[1]	Per kW[1]
150 kW Installation—low	$55,000	$13,750	$92
150 kW Installation—high	$85,000	$21,250	$142
>150 kW Installation—low[1]	$90,000	$22,500	$94
>150 kW Installation—high[1]	$120,000	$30,000	$125

[1] Values calculated by CS from a small sample of EV charging sites in Avangrid service territories. Per-kW values for >150 kW installation are based on a 240 kW charger.

Central Maine Power (2019) provided median costs for hardware and installation for four-plug Level 2 sites as shown in Table G.10.

TABLE G.10 LEVEL 2 HARDWARE AND INSTALLATION COSTS (CMP)

Element	Per site	Per plug	Per kW[1]
Installation	$19,632	$4,908	$256
Hardware	$16,615	$4,154	$216
Total	$36,713	$9,178	$478

[1] Values computed by CS from CMP data.

Versant (2024) provided costs for installation of six 240 kW level 3 fast chargers at their facilities. The total cost was about $843,000 or $140,000 per charger, including $91,000 for charger hardware and $49,000 for labor, site work, and other materials including switch gear, transformers, and miscellaneous electrical material. This is equivalent to about $585 per installed kW.

Synapse (2023) identifies make-ready costs from New York State pilots, as shown in Table G.11. These costs can be traced to data from deployments conducted between 2013 and 2017 as documented in NYDPS (2020) and NYSERDA (2019). The study notes that the average per-port cost for Level 2 installations was around $9,000, of which $5,000 was for the make-ready aspect of the installation. For Level 3 DC fast charging equipment, the study assumed that equipment would be able to deliver up to 50 kW, with a total cost of $75,000 and a make-ready cost of $50,000. Inflation would increase these values by about 30 percent if converted into 2024 dollars.

TABLE G.11 MAKE-READY COSTS, NEW YORK STATE (SYNAPSE/NYDPS/NYSERDA)

By Region	Con Ed	National Grid (West)	By Power Level (Upstate)	50 KW	L2
Average kW/vehicle	64	188	kW	50	19
Cost per vehicle	$36,350	$63,420	Cost per charger	$50,000	$5,000
Cost per kW[1]	$568	$337	Cost per kW[1]	$1,000	$263

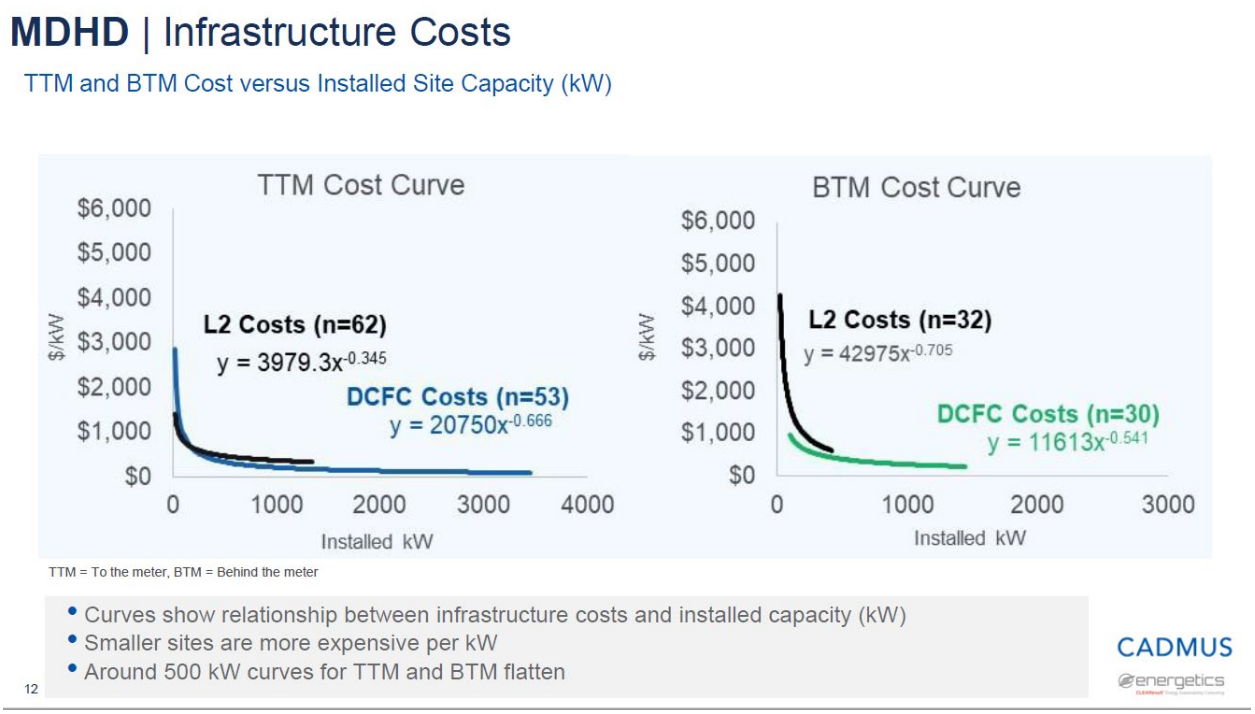
[1] Values computed by CS from study data.

Cadmus provided unpublished cost data for two California pilot programs as shown in Table G.12. Cadmus also provided data from over 150 MHDV sites comparing the cost per installed kW for Level 2 and DCFC as a function of installed kW, as shown in Figure G.1. This data shows a declining cost per kW as the supplied power increases, and also lower costs per kW for Level 3 than for Level 2 charging. These cost curves are for fleets who needed upgrades and therefore enrolled in California utility programs, so there is likely a self-selection effect whereby more expensive sites are included in this dataset.

TABLE G.12 MAKE-READY COSTS, CALIFORNIA (CADMUS)

Program	Southern California Edison Charge Ready Transport Program	PG&E EV Fleet
Sites	16	20
Vehicle Mix	10 school bus sites, three transit bus sites, two medium-duty sites, and one heavy-duty sites	20 school bus sites
Charger Power	Mix of L2 and DCFC	All L2 except for one mixed site
Avg. Installed Capacity (kW)	225	168
Avg. Number of Ports	6.1	8
Cost per Site	$195,420	$226,209
Cost per kW	$1,269	$1,886
Cost per Vehicle	$25,180	$14,076

FIGURE G.1 COST PER INSTALLED KW



Level 2 costs from the literature sources described above (used for the "high" estimates) were judged to be higher than necessary, considering the increasingly widespread availability of low-cost charging units and potentially low installation cost if the required electrical infrastructure already exists. A market review was therefore used to estimate a "low" cost for Level 2 chargers, with a focus on higher-power Level 2 chargers (19.2 kW) that are likely to be used in commercial MHDV applications. For example, in October 2024, GM was advertising a 19.2 kW Wi-Fi-enabled, wall-mounted charger for $1,299.

For comparison, Table G.13 converts costs assumed for this study, for all the cost categories, into per-port and per-kW costs.

TABLE G.13 CHARGING COSTS BY TYPE OF SITE AND POWER LEVEL

Cost Element and Scenario	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
Nominal power level (kW)	19	100	150	350	1,000
Low					
Charging station hardware (per kW)	$79	$250	$367	$371	$300
Installation and local infrastructure (per kW)	$221	$433	$550	$671	$700
Utility-side make-ready (per kW)	$142	$183	$183	$300	$400
Total per kW	**$442**	**$866**	**$1,099**	**$1,343**	**$1,400**

Cost Element and Scenario	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
High					
Charging station hardware (per kW)	$263	$650	$500	$543	$400
Installation and local infrastructure (per kW)	$521	$933	$783	$1,043	$900
Utility-side make-ready (per kW)	$258	$283	$283	$500	$500
Total per kW	**$1,042**	**$1,866**	**$1,566**	**$2,086**	**$1,800**
Low					
Charging station hardware (per port)	$1,500	$25,000	$45,000	$130,000	$300,000
Installation and local infrastructure (per port)	$1,000	$10,000	$15,000	$39,000	$75,000
Utility-side make ready (per port)	$2,698	$18,300	$27,450	$105,000	$400,000
Total per port	**$5,198**	**$53,300**	**$87,450**	**$274,000**	**$775,000**
High					
Charging station hardware (per port)	$5,000	$65,000	$75,000	$190,000	$400,000
Installation and local infrastructure (per port)	$4,900	$27,500	$42,500	$57,000	$100,000
Utility-side make ready (per port)	$4,902	$28,300	$42,450	$175,000	$500,000
Total per port	**$14,802**	**$120,800**	**$159,950**	**$422,000**	**$1,000,000**

TABLE G.14 DATA SOURCES FROM WHICH VALUES SHOWN IN TABLE G.5 WERE DERIVED

Cost Element and Scenario	Level 2 Depot	50–150 kW Depot	150 kW Public	350 kW Public	1 MW Public
Low Cost Scenario					
Charging station equipment	Market research	EVAdoption	EVAdoption	EVAdoption	Atlas
Installation and customer-side infra.	Team estimates	EVAdoption	EVAdoption	EVAdoption	Atlas/ICCT
Utility-side make-ready	Avangrid	Avangrid	Avangrid	Avangrid	Avangrid
High Cost Scenario					
Charging station equipment	NYSERDA	EVAdoption	ICCT, RMI, EVAdoption	EVAdoption	Atlas
Installation and customer-side infra.	CMP	Avangrid	Avangrid	EVAdoption	Atlas/ICCT
Utility-side make-ready	CMP	Avangrid	Avangrid	EVAdoption, NYSERDA	EVAdoption, NYSERDA

Charging Revenues

In 2023, Hatch completed a series of electric bus transition plans for Maine's transit operators. Those plans include:

- Bus Electrification Transition Plan for Bangor Community Connector, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for BSOOB, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for CityLink, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for DTI, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for Portland METRO, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for RTP, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for SPBS, Hatch Consulting, 2023.
- Bus Electrification Transition Plan for YCCAC, Hatch Consulting, 2023.

Those plans estimated charging costs based on daily kWh of energy used and monthly demand charges. For this study, the total monthly cost was estimated (daily kWh cost * 30 + monthly demand charge) for each operator and service evaluated, and converted into an average cost per kWh consumed over the month. This calculation was done both for current electricity rates **and** for current or proposed EV-specific rates in the respective utility territory. Costs per kWh were then averaged to estimate an overall average cost per kWh. Note that these estimated costs may not be directly representative of costs for other truck and bus fleets (beyond transit buses), which may incur costs specific to their use patterns and service territory.

TABLE G.15 BUS CHARGING COSTS

Operator	Electricity Rate	Daily kWh	Daily Charge	Monthly Charge	Total Monthly	$/kWh
Bangor	Current	3,038	$321	$9,630	$19,260	$0.21
	New	3,038	$321	$3,444	$13,074	$0.14
Portland Metro	Current	9,807	$1,287	$8,688	$47,298	$0.16
	New	9,807	$1,287	$1,636	$40,246	$0.14
	Current	1,222	$160	$5,547	$10,347	$0.28
	New	1,222	$160	$1,463	$6,263	$0.17
Citylink	Current	2,613	$343	$5,242	$15,532	$0.20
	New	2,613	$343	$1,383	$11,673	$0.15

Operator	Electricity Rate	Daily kWh	Daily Charge	Monthly Charge	Total Monthly	$/kWh
BSOOB	Current	3,397	$453	$2,751	$16,341	$0.16
	New	3,397	$453	$425	$14,015	$0.14
	Current	1,167	$156	$7,484	$12,164	$0.35
	New	1,167	$156	$1,156	$5,836	$0.17
York County	Current	878	$115	$1,631	$5,081	$0.19
	New	878	$115	$430	$3,880	$0.15
	Current	246	$32	$1,481	$2,441	$0.33
	New	246	$32	$391	$1,351	$0.18
South Portland	Current	2,233	$293	$4,276	$13,066	$0.20
	New	2,233	$293	$1,128	$9,918	$0.15
RTP	Current	444	$58	$932	$2,672	$0.20
	New	444	$58	$246	$1,986	$0.15
DTI	Current	5,556	$586	$2,023	$19,603	$0.12
	New	5,556	$586	$347	$17,927	$0.11
	Current	399	$42	$2,232	$3,492	$0.29
	New	399	$42	$798	$2,058	$0.17
Average	**Current**	–	–	–	–	**$0.22**
	New	–	–	–	–	**$0.15**

The range of $0.15 to $0.22 per kWh brackets the value of $0.18 per kWh assumed by CALSTART for the case studies conducted for this project (see Appendix B). The $0.18 per kWh value is based on Versant's Business Eco Rate of $0.12 per kWh plus demand charges of $10 over 20 kW from national data built into CALSTART's CHARIOT web tool.

G.3 References

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