Southern New England Clean Trucks Program

An Analysis of the Impacts of Zero-Emission Medium- and Heavy-Duty Trucks on the Environment, Public Health, Industry, and the Economy

MJB & A
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Acknowledgments

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MJB&A, an ERM Group company, provides strategic consulting services to address energy and environmental issues for the private, public, and nonprofit sectors. MJB&A creates value and addresses risks with a comprehensive approach to strategy and implementation, ensuring clients have timely access to information and the tools to use it to their advantage. Our approach fuses private sector strategy with public policy in air quality, energy, climate change, environmental markets, energy efficiency, renewable energy, transportation, and advanced technologies. Our international client base includes electric and natural gas utilities, major transportation fleet operators, investors, clean technology firms, environmental groups, and government agencies. Our seasoned team brings a multi-sector perspective, informed expertise, and creative solutions to each client, capitalizing on extensive experience in energy markets, environmental policy, law, engineering, economics, and business. For more information, we encourage you to visit our website, www.mjbradley.com.

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Introduction

M.J. Bradley & Associates was commissioned by the Natural Resources Defense Council and the Union of Concerned Scientists to evaluate the costs and benefits of state-level requirements for manufacturers that the Southern New England states (Massachusetts, Connecticut, and Rhode Island) could adopt to increase sales of no- and low-emission medium- and heavy-duty (M/HD) trucks and buses. The analysis examines all on-road vehicles registered in Southern New England with greater than 8,501 pounds gross vehicle weight, encompassing vehicle weight classes from Class 2b though Class 8. This is a diverse set of mostly commercial vehicles that includes heavy-duty pickups; school and shuttle buses; sanitation, construction, and other types of work trucks; and freight trucks ranging from local delivery vans to tractor-trailers that weigh up to 80,000 pounds when loaded.

Collectively the Southern New England M/HD fleet includes almost 532,200 vehicles that annually travel more than 8.5 billion miles and consume almost 1.0 billion gallons of petroleum-based fuels.

In Southern New England, M/HD vehicles are currently responsible for a disproportionate amount of pollution from on-road vehicles. Despite making up only 6 percent of the on-road fleet, M/HD vehicles emit estimated 11.4 million metric tons (MMT) of greenhouse gas (GHG) emissions annually—approximately 22 percent of all GHGs from the on-road vehicle fleet.[1] In Southern New England M/HD vehicles are also responsible for 48 percent of the nitrogen oxide (NOx) and 41 percent of the particulate matter (PM) emitted by on-road vehicles, both of which contribute to poor air quality and resulting negative health impacts in many urban areas, including low-income and disadvantaged communities that are often disproportionately affected by emissions from freight movement due to their proximity of transportation infrastructure to the communities.[2]

1 The remainder of emissions are from passenger cars and light trucks. This includes tailpipe emissions and "upstream" emissions from fuel production and transport.

2 In this report all references to PM are particulate matter with mean aerodynamic diameter less than 2.5 microns ($PM_{2.5}$).

trucks and buses emit higher levels of air pollution, which can lead to even greater health concerns in populations more directly exposed to diesel emissions.[3] Communities located adjacent to ports and related goods-movement infrastructure (e.g., warehouses, logistics centers, rail yards, etc.) experience higher levels of truck traffic, both from surrounding thruways and on local streets, which exacerbates health concerns. Since these emissions are local in their effects, policies to reduce transportation emissions from medium- and heavy-duty vehicles can improve the health and well-being of communities in urban areas or around transportation corridors, which are often home to people of color or low income or those who are otherwise vulnerable or disadvantaged. But to ensure reductions in those communities, program requirements on truck manufacturers, such as the Advanced Clean Truck and Heavy-Duty Omnibus Rules discussed below, would need to be accompanied by additional policies designed specifically with these communities in mind.

For the study of Southern New England region—including Massachusetts, Connecticut, and Rhode Island—MJB&A modeled three Clean Truck policy scenarios with increasing levels of ambition. Results for the individual states can be found in the appendices, with the regional results based on the combined state results presented in the main body of this report. Under the least aggressive scenario—adoption of California's Advanced Clean Truck (ACT) rule (allowable under the Clean Air Act) by the states in the region—estimated cumulative net societal benefits total almost $12.1 billion (in constant 2020$) through 2050, compared with the baseline scenario.[4] These net societal benefits include the monetized value of climate and public health benefits resulting from reduced GHG, NOx, and PM emissions in the region, including up to 113 fewer premature deaths and 113 fewer hospital visits from breathing polluted air. Net societal benefits also include net cost savings to fleets from operating zero-emission trucks, and savings to all residential and commercial electricity customers due to lower electric rates made possible by the additional electricity sales for electric vehicle charging. Under the ACT scenario, by 2050 annual cost savings for Southern New England fleets are estimated to be $243 million, and annual bill savings for electric utility customers in the region could reach an estimated $197 million.[5]

The most aggressive policy scenario (100 x 40 ZEV + Clean Grid, discussed below) results in turnover of virtually the entire Southern New England M/HD fleet to zero-emission vehicles (ZEVs) by 2050, together with a shift to cleaner electricity generation sources. Cumulative net societal benefits through 2050 increase to more than $23.4 billion under this scenario, and there will be an estimated 333 fewer premature deaths and 334 fewer hospital visits. In 2050 estimated annual fleet cost savings also increase, to $562 million, and electric customer annual bill savings increase to an estimated $303 million.

Implementation of the modeled scenarios will require significant changes to the national economy, as manufacturing of internal combustion engine vehicles is replaced by manufacturing of electric and fuel cell vehicles, and production and sale of petroleum fuels is replaced by increased production and sale of electricity and hydrogen. This analysis indicates that this transition will have positive macroeconomic effects, including increased net jobs and gross domestic product (GDP), as well as increased wages for the new jobs that will be added, relative to the jobs that will be replaced.

Compared with the baseline scenario, net national job gains under the most aggressive policy scenario total 1,537 in 2035. This will be accompanied by a $418 million increase in 2035 GDP, rising to a $592 million increase in 2040. Average wages for the new jobs created under the ZEV transition are expected to be, on average, more than twice as high as average wages for the jobs that will be replaced.

3 MJB&A, *Newark Community Impacts of Mobile Source Emissions: A Community-Based Participatory Research Analysis*, November 2020, http://www.njeja.org/wp-content/uploads/2021/04/NewarkCommunityImpacts_MJBA.pdf.

4 All values cited in this report are in constant 2020$, unless otherwise stated.

5 The modeling tools used for this analysis could not apportion these estimated benefits to individual communities within the states.

Policy Scenarios

This report summarizes the projected environmental and economic effects of Southern New England adopting policies requiring manufacturers to sell a greater number of M/HDV low- and no-emission vehicles over the next 30 years. Three specific Clean Truck policy scenarios, representing increasing levels of ambition, were evaluated.

- **ACT Rule:** Southern New England states adopt requirements analogous to those adopted by California under the Advanced Clean Trucks Rule, which requires an increasing percentage of new trucks purchased in the region to be ZEVs beginning in the 2025 model year. The percentage of new vehicles that must be ZEV varies by vehicle type, but for all vehicle types the required ZEV percentage increases each model year between 2025 and 2035 (see Figure 1).

- **ACT Rule plus NOx Omnibus Rule:** In addition to adopting the ACT Rule, Southern New England states adopt requirements analogous to those adopted by California under the Heavy-Duty Omnibus Rule (referred to herein as the NOx Omnibus Rule). This rule requires an additional 75 percent reduction in nitrogen oxide (NOx) emissions from the engines in new gasoline and diesel trucks sold between model year 2025 and 2026, and a 90 percent reduction for trucks sold beginning in the 2027 model year.[6]

- **100 x 40 ZEV + Clean Grid:** In addition to adopting the ACT and NOx Omnibus Rules, Southern New England states take further actions to ensure more rapid and continued increases in new ZEV sales, such that virtually all new trucks are ZEV by 2040 (see Figure 1), with Class 2b–3 achieving 100 percent ZEV sales in 2038 and Class 4–8 (non-tractors) achieving 100 percent ZEV sales in 2035. In addition, an aggressive federal Clean Energy Standard is assumed to ensure that electricity generation in the state is virtually carbon free and 53 percent renewable by 2050. State-specific, renewable portfolio standards that could increase the renewable electricity levels even more were not analyzed as part of this study.

All three of these Southern New England policy scenarios are compared with a baseline "business as usual" scenario in which all new trucks sold in the region continue to meet existing EPA NOx emission standards and ZEV sales increase only marginally, never reaching more than 1 percent of new vehicle sales each year.[7]

The analysis assumes that M/HD annual vehicle miles traveled (VMT) in Southern New England will continue to grow by approximately 0.5 percent annually through 2050, as projected by the Energy Information Administration (EIA), as the economy and population continue to grow. The modeled policy scenarios do not include freight system enhancements or mode shifting to slow the growth of, or reduce, M/HD truck miles; this would be expected to provide additional emission reductions.

The analysis was conducted using MJB&A's STate Emission Pathways (STEP) Tool. The climate and air quality impacts of each policy scenario were estimated on the basis of changes in M/HD fleet fuel use and include both tailpipe emissions and "upstream" emissions from production of the transportation fuels used in each scenario. These include petroleum fuels used by conventional internal combustion engine vehicles (gasoline, diesel, natural gas) and electricity and hydrogen used by ZEVs, which are assumed to include both battery electric (EV) and hydrogen fuel cell electric (FCV) vehicles.

6 Reductions are relative to current federal EPA new engine emission standards. This rule does not require additional PM reductions but includes anti-backsliding provisions to ensure that PM emissions do not increase compared with engines designed to meet current federal standards.

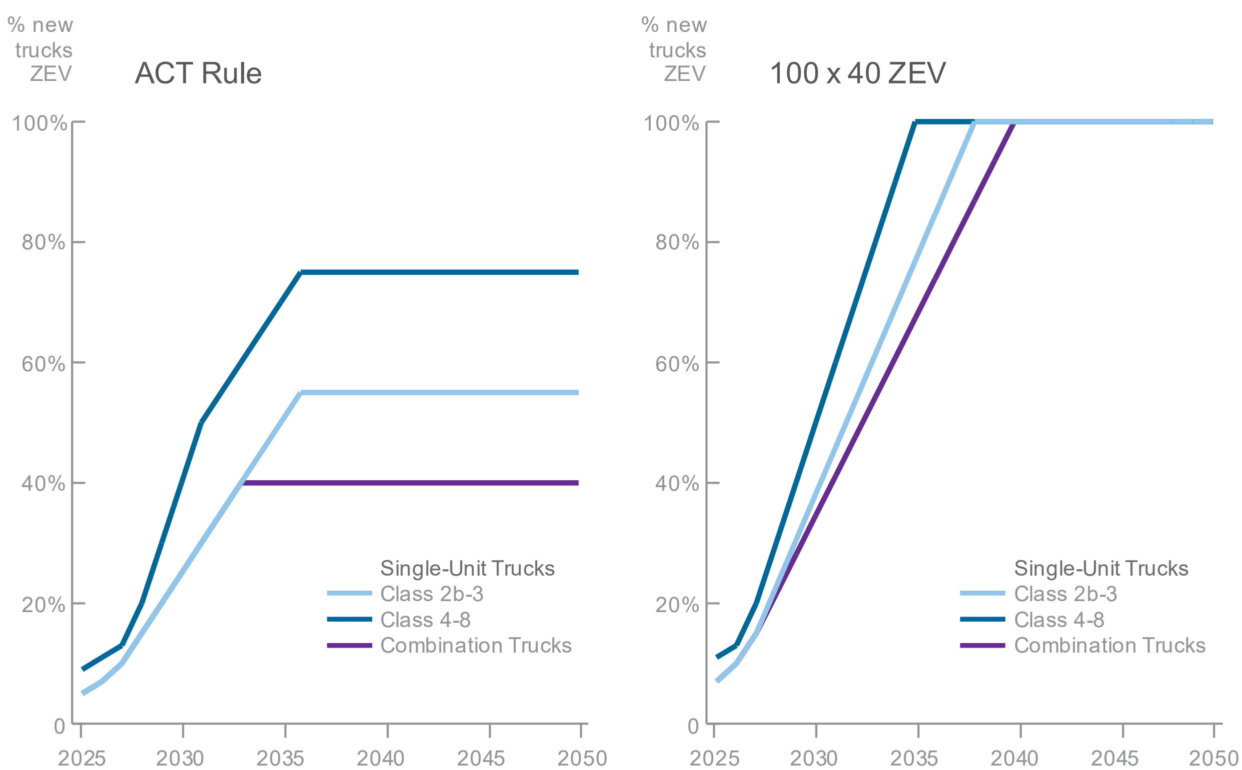
7 The baseline ZEV sales assumptions are consistent with projections in the Energy Information Administration's Annual Energy Outlook 2021.

To evaluate climate impacts, the analysis estimated changes in all combustion related GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To evaluate air quality impacts, the analysis estimated changes in total nitrogen oxide (NOx) and particulate matter (PM) emissions and resulting changes in ambient air quality and health metrics such as premature deaths, hospital visits, and lost workdays.

The economic analysis estimated the change in annual M/HD fleet-wide spending on vehicle purchase, charging/fueling infrastructure to support ZEVs, vehicle fuel, and vehicle and infrastructure maintenance under each scenario. Currently ZEVs are more expensive to purchase than equivalent gasoline and diesel vehicles, but they have lower fuel and maintenance costs. Over time the incremental purchase cost of ZEVs is also projected to fall. Technologies required to meet the more stringent NOx standards of the NOx Omnibus Rule are also projected to increase purchase costs for compliant vehicles.

On the basis of estimated changes in fleet spending, the analysis estimated the macroeconomic effects of each scenario on national jobs, wages, and gross domestic product (GDP).

Figure 1 Annual Zero-Emission Vehicle Sales in Clean Truck Policy Scenarios



The analysis also estimated the impact of each scenario on Southern New England's electric utilities, including the total regional change in power demand (kW) and energy consumption (kWh) for M/HD EV charging, as well as the additional revenue and net revenue that would be received by the region's electric utilities for providing this power. On the basis of projected utility net revenue, the analysis estimates the potential effect on regional electricity rates for residential and commercial customers.

In addition, the analysis estimated the total number of vehicle chargers that will be required to support the increase in M/HD EVs under each scenario—both depot-based chargers and shared public chargers—compared with the existing charging network in the region.

For a full description of the modeling approach and sources of assumptions used for this analysis, see the report: *Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies and Assumptions*, May 2021 (https://mjbradley.com/clean-trucks-analysis).

The Southern New England electric grid mix and energy cost assumptions used can also be found in the Appendix to this report.

Southern New England Results

The sections below detail the results of the Southern New England Clean Trucks analysis, beginning with a description of the current Southern New England Medium/Heavy-Duty Vehicle (M/HDV) fleet and the projected fleet under each modeled policy scenario. This is followed by a summary of the environmental and public health benefits of each scenario and the economic impacts of the modeled fleet transitions.

Southern New England M/HD Vehicle Fleet

Table 1 summarizes the current M/HD fleet in Southern New England, broken down by the four major vehicle types used to frame the Clean Trucks analysis.

Table 1 Current Southern New England M/HD Fleet

Vehicle Type		No. of Vehicles	Annual VMT (billion miles)	Annual Fuel (million gallons)
Heavy-Duty Pickup and Van **Class 2b**	 	169,751	1.91	102
Bus **Class 3–8**	  	31,702	0.57	72
Single-Unit Work and Freight Truck **Class 3–8**	     	288,946	3.55	437
Combination Truck **Class 7–8**		41,806	2.51	367
TOTAL		**532,205**	**8.54**	**978**

Approximately 32 percent of the in-use M/HD fleet are Class 2b vehicles (8,500–10,000 in gross vehicle weight rating, GVWR), which are mostly heavy-duty pickup trucks and vans.[8] These vehicles account for 22 percent of annual M/HD miles and 10 percent of annual fuel use. Approximately 6 percent of the fleet are buses, which account for 7 percent of annual VMT and 7 percent of annual fuel use. This includes relatively small shuttle buses (class 3–5) as well as school buses, transit buses, and intercity/charter coach buses.[9] Fifty-four percent of the fleet are single-unit freight and work trucks, which account for 42 percent of annual VMT and 45 percent of annual fuel use. These vehicles come in a wide variety of sizes (Class 3–8) and have a wide variety of uses, from vans and box trucks used to deliver freight, to sanitation and construction trucks, to boom-equipped utility trucks. Only 8 percent of the fleet are combination truck-tractors, but these vehicles account for 29 percent of annual VMT and 38 percent of annual fuel use, since approximately two-thirds of these vehicles are used primarily for long-distance freight hauling and typically log many more daily and annual miles than other M/HD vehicles.

Today less than 1 percent of the national M/HD fleet is powered by electricity or alternative fuels (natural gas and propane). Approximately 64 percent of the fleet have diesel engines and 36 percent use gasoline.[10] The largest Class 7 and 8 vehicles are almost all diesel, while almost 50 percent of the smaller Class 2b–5 trucks have gasoline engines, with most of the remainder diesel.

Figure 2 summarizes the modeled turnover of the Southern New England in-use fleet to zero-emission and low-NOx trucks under the three Clean Truck policy scenarios. Fleet turnover to new trucks is based on historical average turnover rates and projected fleet growth rates, along with the new vehicle ZEV purchase percentages shown in Figure 1. Approximately 6.1 percent of existing Class 2b trucks and 4.7 percent of Class 3–8 trucks and buses are retired each year and replaced with new vehicles.[11] The ACT + NOx Omnibus scenario and the 100 x 40 ZEV + Clean Grid scenario further assume that all new vehicles purchased in 2024 and later years that are not ZEV will have low-NOx engines compliant with the NOx Omnibus standards.

As shown, under the ACT Rule policy scenario, 33.7 percent of the in-use M/HD fleet will turn over to ZEV by 2040, and 59.2 percent are ZEV by 2050; all of these ZEVs are assumed to be electric vehicles. Under the ACT + NOx Omnibus policy scenario, the same percentage of the fleet turns over to ZEV, but the remaining internal combustion engine vehicles in the fleet turn over to low-NOx engines by 2044. Under the 100 x 40 ZEV + Clean Grid policy scenario, 52.6 percent of the in-use fleet turns over to ZEV by 2040 and 95.3 percent do so by 2050. This scenario assumes that new ZEVs will include both EV and fuel cell vehicles powered by hydrogen. In 2050, 5.3 percent of in-use ZEVs are assumed to be FCV and 90.0 percent are EV.

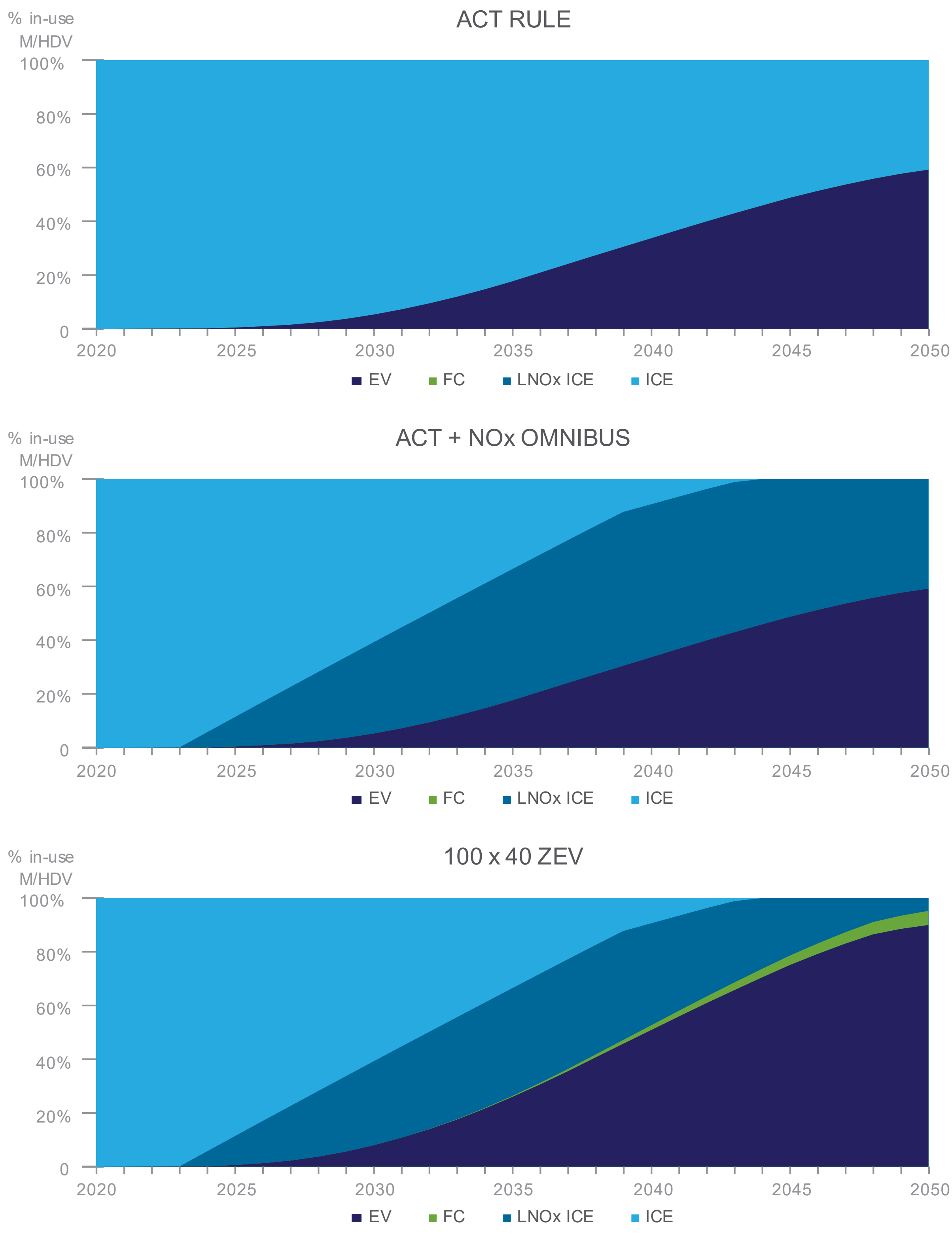
8 A very small percentage of these vehicles are large SUVs.

9 Note that the ACT Rule does not include ZEV requirements for transit buses, as these vehicles are covered by a separate Innovative Clean Transit regulation in California.

10 These figures are based on state registration data collected by IHS Markit.

11 This is a long-term average. Actual annual turnover is highly correlated to economic conditions and can vary widely from year to year.

Figure 2 Fleet Turnover to Low-NOx and Zero-Emission Vehicles in Clean Truck Policy Scenarios



EV (battery electric vehicle); FC (fuel cell vehicle); LNOx ICE (low-NOx internal combustion engine vehicle); ICE (conventional internal combustion engine vehicle)

Changes in Fleet Fuel Use

Under all modeled Clean Truck policy scenarios, a significant portion of the Southern New England M/HD fleet is assumed to turn over to EV and FCV trucks and buses. This will result in replacement of petroleum fuels—primarily gasoline and diesel fuel—with electricity and hydrogen.[12]

Under the baseline scenario, total petroleum fuel use by the Southern New England M/HD fleet in 2050 is projected to be 790 million gallons. Under the ACT Rule policy scenario, petroleum fuel use in 2050 falls to an estimated 380 million gallons (-52 percent), and cumulative reductions in diesel and gasoline use by the M/HD fleet total 5.1 billion gallons between 2020 and 2050. This petroleum fuel is replaced by 88.5 million megawatt-hours (MWh) of electricity between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 7.61 million MWh, a 9 percent increase to estimated baseline electricity use by Southern New England residential and commercial customers that year (83.9 million MWh).

Adding the NOx Omnibus Rule to the ACT Rule does not result in additional reductions in petroleum fuel use.

Under the 100 x 40 ZEV + Clean Grid scenario, estimated petroleum fuel use by the M/HD fleet in 2050 falls to 50 million gallons (-92 percent), and cumulative reductions in diesel and gasoline use by the M/HD fleet total 8.5 billion gallons between 2020 and 2050. This petroleum fuel is replaced by 130.4 million MWh of electricity and 1.1 billion kilograms of hydrogen between 2020 and 2050. Electricity use for M/HD EV charging in 2050 is estimated to be 11.4 million MWh, and 14 percent increase to estimated baseline electricity use by Southern New England residential and commercial customers that year.

Public Health and the Environment

The modeled Clean Trucks policy scenarios produce significant reductions in NOx, PM, and GHG emissions from the M/HD fleet, even after accounting for the emissions from producing the electricity and hydrogen needed to power ZEVs. NOx and PM reductions will improve air quality resulting in public health benefits from reduced mortality and hospital visits.

Air Quality Impacts

Figures 3 and 4 show estimated annual M/HD fleet NOx and PM emissions, respectively, under the baseline scenario and the modeled Clean Truck policy scenarios. Under the baseline scenario, annual M/HD fleet NOx emissions are projected to fall by 47 percent and annual fleet PM emissions are projected to fall 74 percent through 2045, as the current fleet turns over to new gasoline and diesel trucks with cleaner engines that meet more stringent EPA new engine emissions standards. After 2045 baseline annual NOx and PM emissions are then projected to start rising again as annual fleet VMT continues to grow.

12 A small number of M/HD trucks and buses in Southern New England currently use natural gas.

Figure 3 Projected M/HD Fleet NOx Emissions

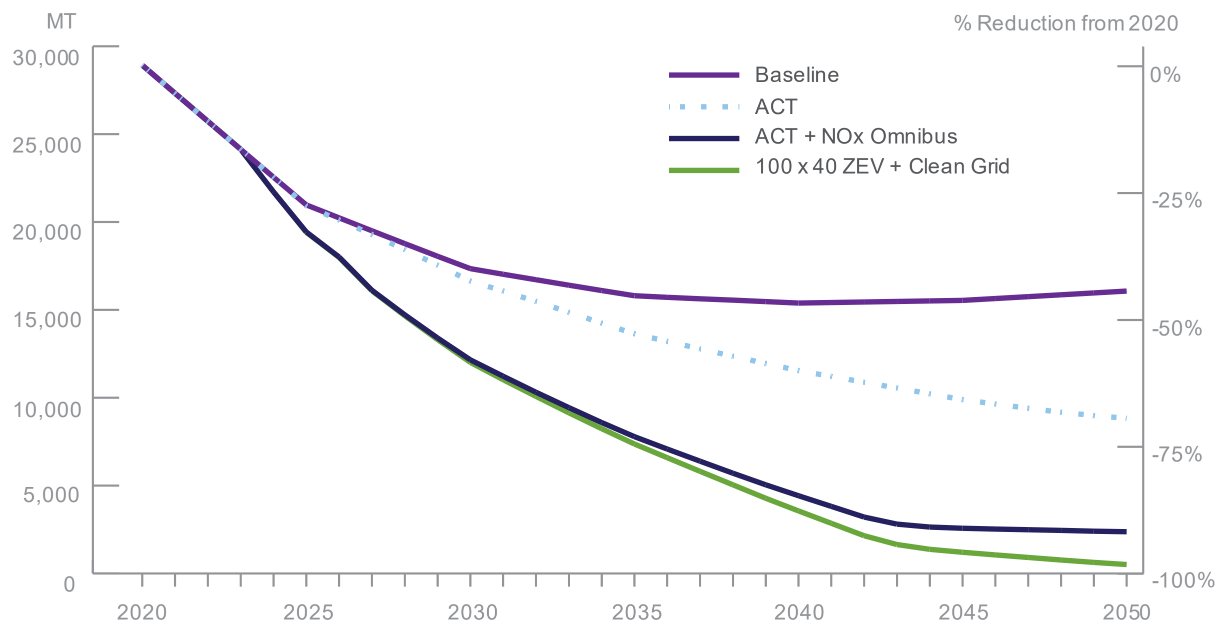
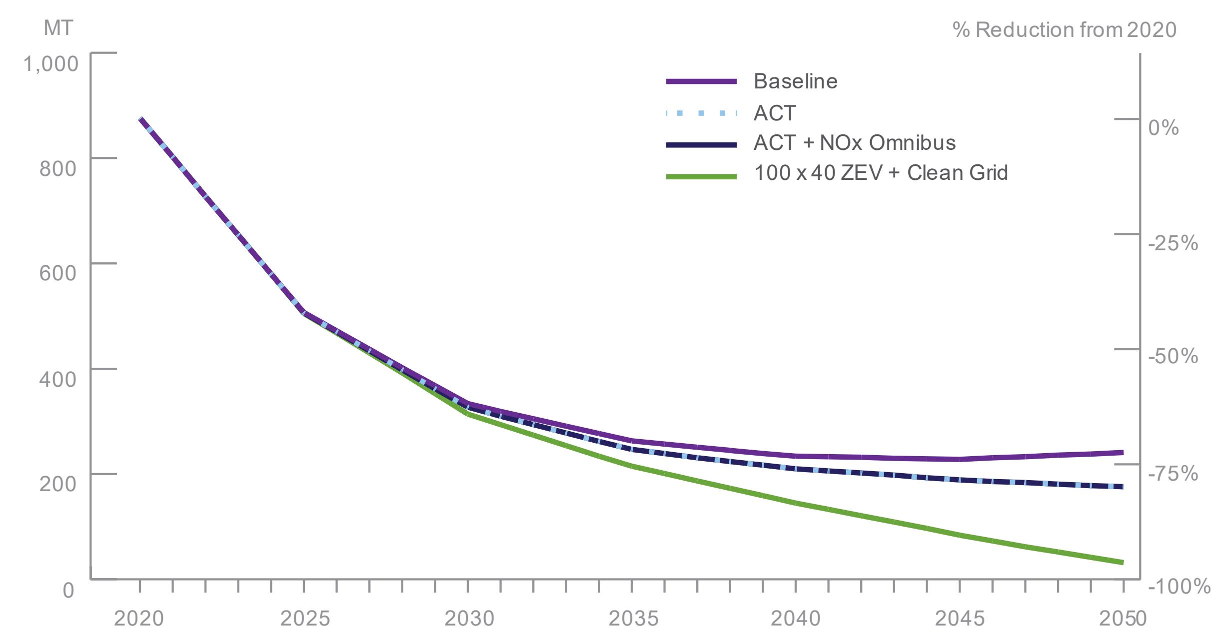


Figure 4 Projected M/HD Fleet PM Emissions



Compared with the baseline, by 2050 the ACT rule is estimated to reduce annual fleet NOx and PM emissions by 45 percent and 27 percent, respectively, as diesel and gasoline trucks are replaced with electric vehicles. Adding the NOx Omnibus Rule will further reduce annual fleet NOx emissions due to turnover of the diesel and gasoline portion of the fleet to new vehicles with low-NOx engines; by 2050 annual NOx emissions are projected to be 85 percent lower than under the baseline if both the ACT and NOx Omnibus Rules are implemented.

As shown in Figures 3 and 4, the 2050 emission levels are dramatically lower for all scenarios compared to today's (2021) levels. The ACT + NOx Omnibus scenario, for example, contributes to reductions that are 92 percent lower in nitrogen oxide (NOx) and 80 percent lower in PM in 2050 compared to today's levels. The 100 x 40 ZEV + Clean Grid scenario has the lowest fleet emissions due to replacement of virtually all gasoline and diesel trucks and buses with EVs and FCVs by 2050, when annual NOx and PM emissions are estimated to be 97 percent and 87 percent lower, respectively, than baseline emissions.

Over the next 30 years, cumulative NOx and PM emission reductions from the ACT Rule (compared with the baseline scenario) total 83,500 metric tons (MT) and 626 MT, respectively. Additional cumulative NOx reductions from the NOx Omnibus Rule are estimated at 151,600 MT over the same time. Cumulative NOx and PM emission reductions from the 100 x 40 ZEV + Clean Grid scenario (compared with the baseline) are projected to total 254,900 MT and 2,160 MT, respectively.

Public Health Benefits

The reduced annual NOx and PM emissions under the Clean Truck policy scenarios will reduce ambient particulate levels in the air, which will reduce the negative health effects on Southern New England residents breathing in these airborne particles.[13] Estimated public health impacts include reductions in premature mortality and fewer hospital admissions and emergency room visits for asthma. There will also be reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and fewer restricted activity days and lost workdays. Cumulative estimated reductions in these health outcomes in Southern New England under the modeled Clean Truck policy scenarios are shown in Table 2; these benefits were estimated using the U.S. Environmental Protection Agency's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool.

Table 2 Cumulative Public Health Benefits of Clean Truck Policy Scenarios, 2020–2050

Health Metric	ACT Rule	ACT + NOx Omnibus	100 x 40 ZEV + Clean Grid
Avoided Premature Deaths	113	269	333
Avoided Hospital Visits[a]	113	271	334
Avoided Minor Cases[b]	64,821	153,423	189,962
Monetized Value, 2020$ (millions)	$1,326	$3,143	$3,888

a Includes hospital admissions and emergency room visits.

b Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

13 PM is directly emitted to the atmosphere from combustion sources as solid particles. NOx is emitted from combustion sources as a gas but contributes to the formation of secondary particles via chemical reactions in the atmosphere. Both direct and secondary particles have negative health effects when taken into the lungs.

The monetized value of cumulative public health benefits from the ACT Rule over the next 30 years totals more than $1.3 billion. Adding the NOx Omnibus Rule would increase the monetized value of cumulative net public health benefits to $3.1 billion. The monetized value of cumulative public health benefits under the 100 x 40 ZEV + Clean Grid policy scenario totals $3.9 billion through 2050.

Climate Benefits

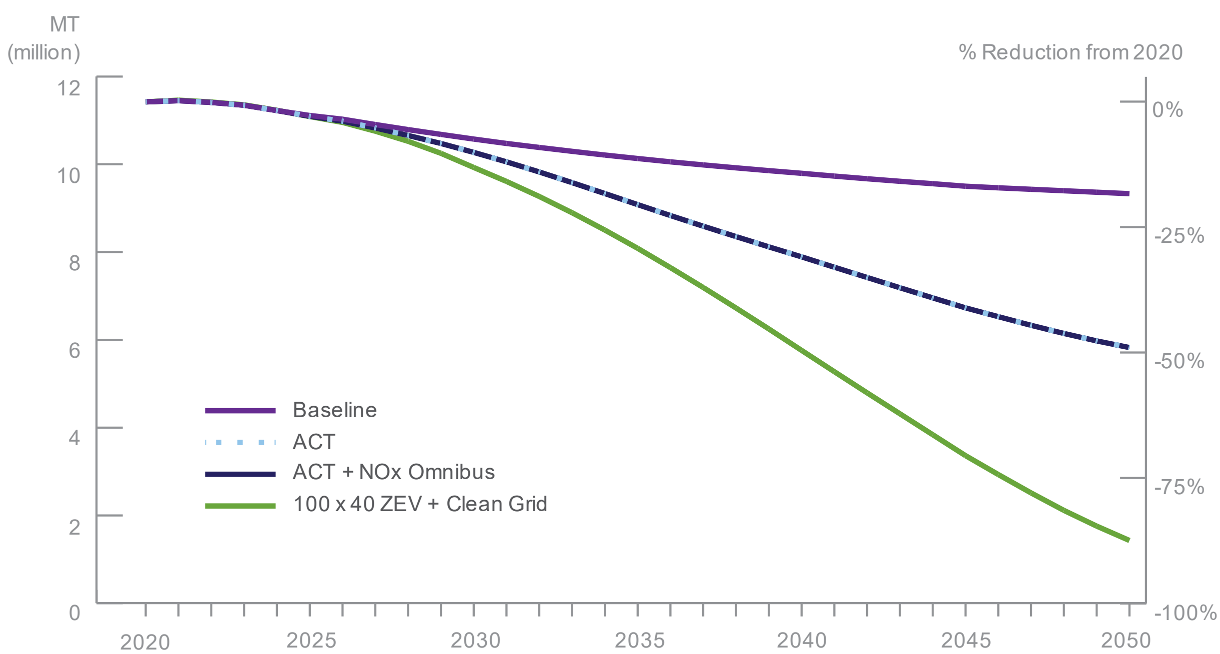
Figure 5 illustrates estimated annual M/HD fleet GHG emissions under the baseline scenario and the modeled Clean Truck policy scenarios. As shown, under the baseline scenario annual M/HD fleet GHG emissions are projected to fall by 18 percent through 2050 as the current fleet turns over to new, more efficient gasoline and diesel trucks that meet more stringent EPA new engine and vehicle emission standards.

Compared with the baseline, by 2050 the ACT rule is estimated to further reduce annual fleet GHG emissions by 38 percent, as diesel and gasoline trucks are replaced with electric vehicles; adding the NOx Omnibus Rule does not produce additional fleet GHG emissions beyond those achieved by the ACT Rule.

As shown in Figure 5, the 2050 GHG emission level for the ACT + NOx scenario is significantly lower compared to today's (2021) levels by 49 percent.

The 100 x 40 ZEV + Clean Grid scenario has the lowest fleet emissions due to replacement of virtually all gasoline and diesel trucks and buses with EV and FCV by 2050, when annual fleet GHG emissions are estimated to be 85 percent lower than baseline emissions.

Figure 5 Projected M/HD Fleet GHG Emissions



Over the next 30 years, cumulative GHG emission reductions from the ACT Rule (compared with the baseline scenario) total 40.5 million MT. Cumulative GHG emission reductions from the 100 x 40 ZEV + Clean Grid scenario (compared with the baseline) are projected to total 87.5 million MT. These estimates of GHG reductions from each policy scenario account for reductions in petroleum fuel use (gasoline, diesel fuel) by the M/HD fleet as well as increased emissions from electricity and hydrogen production to fuel the EVs and FCVs that will replace gasoline and diesel trucks and buses.

Using the social cost of greenhouse gases as estimated by the federal government's Interagency Working Group, these estimated cumulative GHG reductions have a monetized value of $8.4 billion for the ACT Rule policy scenario and $15.6 billion for the 100 x 40 ZEV + Clean Grid policy scenario.[14] The social value of GHG reductions represents potential societal cost savings from avoiding the negative effects of climate change.[15]

The assumed grid mix for electricity production each year is shown in the Appendix for each state in Southern New England. For the baseline, ACT Rule, and ACT+ NOx Omnibus scenarios, this analysis conservatively uses a business-as-usual (BAU) grid mix, while the 100 x 40 ZEV + Clean Grid scenario assumes a "decarbonized" grid mix. In 2020 the average BAU grid mix for the region is 5.7 percent coal-fired generation, 69.7 percent natural gas–fired generation, and 24.7 percent "zero-emitting" generation sources.[16] By 2050 the zero-emitting portion of the BAU grid mix increases to 81.7 percent while the coal portion increases slightly to 5.9 percent and natural gas falls to 12.4 percent. Considering just renewable resources, the percentages are 44.0 percent in 2030, 57.1 percent in 2040, and 66.3 percent in 2050, with the remainder of zero-emitting sources nuclear.

Under the 100 x 40 ZEV + Clean Grid scenario, zero-emitting generation for the region, on average, increases to 89.5 percent in 2030, 93.7 percent in 2040, and 100 percent in 2050. Considering just renewable resources, the percentages are 72.4 percent in 2030, 77.0 percent in 2040, and 81.9 percent in 2050. It is noted that additional state policies, such as Renewable Portfolio Standards, could potentially increase the renewable percentages even higher, but these were not considered in this analysis.

Economic Impacts

This section summarizes projected economic impacts of the modeled Clean Truck policy scenarios, including changes in annual operating costs for Southern New England fleets; impacts to Southern New England electric utilities and their customers; net societal benefits; and macroeconomic effects on jobs, wages, and gross domestic product from the transition to low-NOx and zero-emission trucks and buses. This section also estimates the required public and private investment in electric vehicle charging infrastructure to support the electric M/HD fleet under each scenario.

Costs and Benefits to Fleets

For all the modeled Clean Truck policy scenarios, this analysis estimated annual incremental costs associated with purchase and use of M/HD ZEVs compared with baseline conventional vehicles with combustion engines that operate on petroleum fuels (gasoline, diesel). These costs include the incremental purchase cost

14 For the social cost values used, see MJB&A, *Clean Trucks Analysis: Costs & Benefits of State-Level Policies to Require No- and Low-Emission Trucks, Technical Report—Methodologies & Assumptions*, May 2021, https://mjbradley.com/clean-trucks-analysis.

15 The Interagency Working Group developed GHG social cost estimates using a range of discount rates. These values are based on the 95th percentile results using a 3 percent discount rate, which is in the middle of the range of estimated values. The monetized value of cumulative GHG reductions under each policy scenario would be 72 percent lower if using the lowest published social cost values, and three times greater if using the highest published values.

of the new ZEVs added each year (instead of new combustion vehicles), the cost of installing the charging and hydrogen fueling infrastructure required by these new ZEVs, and net fuel and maintenance costs for all ZEVs in the fleet, both those newly purchased each year and those purchased in prior years and still in use.

Net fuel costs include reductions in purchases of diesel fuel and gasoline (due to fewer combustion vehicles), offset by the increased purchase of electricity and hydrogen to power ZEVs. Net maintenance costs include net savings in annual vehicle maintenance for the ZEVs in the fleet compared with combustion vehicles, offset by annual costs to maintain the charging and hydrogen fueling infrastructure needed to support in-use ZEVs.

Figure 6 Projected Lifetime Incremental Costs for Southern New England ZEVs Compared with Combustion Vehicles

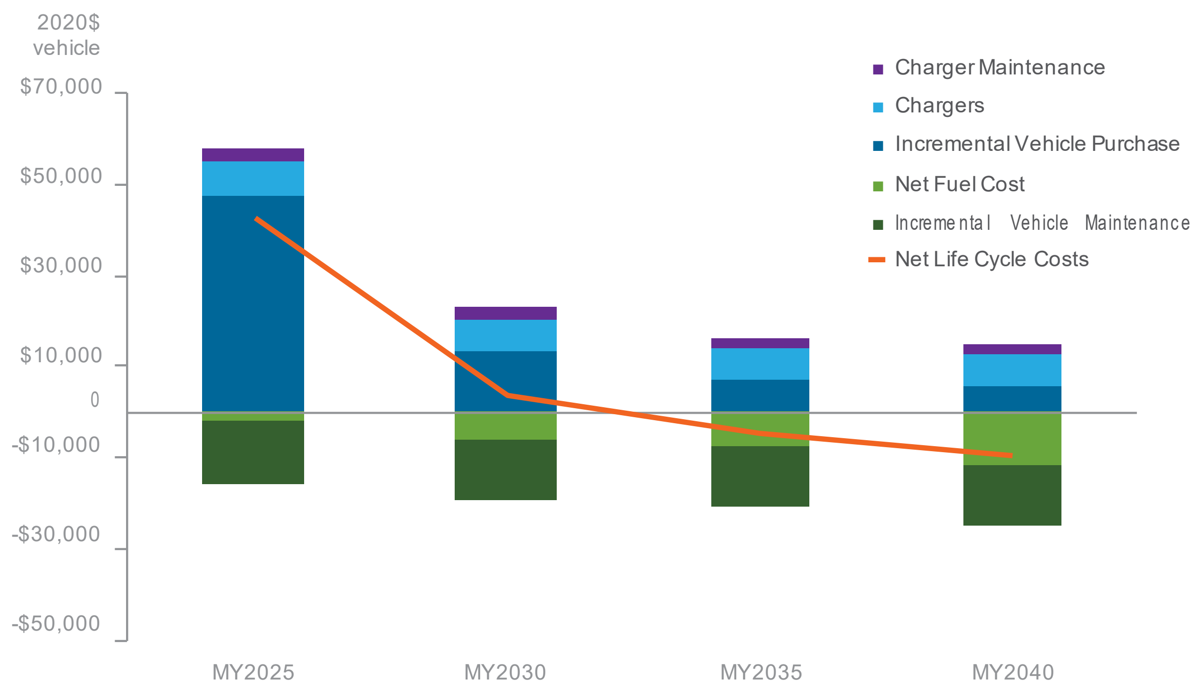


Figure 6 shows projected average lifetime incremental costs for new ZEVs purchased in Southern New England compared with lifetime costs for combustion vehicles purchased in the same model year; the bars show fleet average values for all Class 2b–8 ZEVs purchased each year under the 100 x 40 ZEV scenario. Incremental fuel and maintenance costs are discounted lifetime costs, assuming 21-year vehicle life, and 6 percent annual discount rate. Vehicle financing, which is often used by fleets when purchasing vehicles, was not considered in this analysis.

As shown, the average M/HD ZEV in Southern New England is projected to produce at least $15,000 in discounted fuel and maintenance cost savings over its lifetime. For ZEVs purchased in the very near term, this savings may not be enough to offset the projected incremental cost of vehicle purchase and fueling infrastructure for some ZEVs, resulting in net increased lifetime costs compared with those of combustion vehicles. However, by 2035 incremental ZEV purchase costs are projected to fall significantly, such that the average ZEV will reach lifetime cost parity with combustion vehicles, when discounted lifetime fuel and maintenance savings are considered. By 2040, the average ZEV purchased that year is projected to produce almost $10,000 in discounted lifetime net savings (2020$) compared with the costs of an equivalent combustion vehicle.

It is important to reiterate that the values in Figure 6 are fleet average values, which mask a significant amount of variability across vehicle types and among different fleets of the same vehicle type. Also, it is important to note that the utility impact analysis (in the next section) indicates that the cost of providing power to charge M/HD EVs is lower than expected utility revenue under current rate structures. This suggests that Southern New England states could consider changes to rates that would not only be fairer for fleets, but also lower electricity costs for M/HD EV charging, thus reducing net fleet operating costs further than estimated here. However, this would reduce the potential benefits that would accrue to other ratepayers from M/HD vehicle charging (see discussion below).

M/HD ZEVs in some fleets will likely achieve lifetime cost parity with combustion vehicles much earlier than 2030, while others may lag. In addition, this analysis, and the values shown in Figure 6, assume no government incentives for vehicle purchase or development of fueling infrastructure. If existing and potential incentives are considered, or policies such as improved electricity rates for fleets, then actual net costs to fleets will be lower, resulting in cost parity sooner.

Electric Utility Impacts

Current annual electricity sales to residential and commercial customers in Southern New England total 74.2 million MWh and are projected to grow to 83.8 million MWh in 2050.[16]

Under the ACT Rule policy scenario, additional annual electricity sales for M/HD EV charging are estimated to total 0.7 million MWh in 2030, rising to 7.6 million MWh in 2050. This incremental load represents 2.8 percent and 30.4 percent of the total electricity demand in 2030 and 2050, respectively. Incremental monthly peak charging demand under this scenario is estimated at 174 MW in 2030, rising to 2,240 MW in 2050.

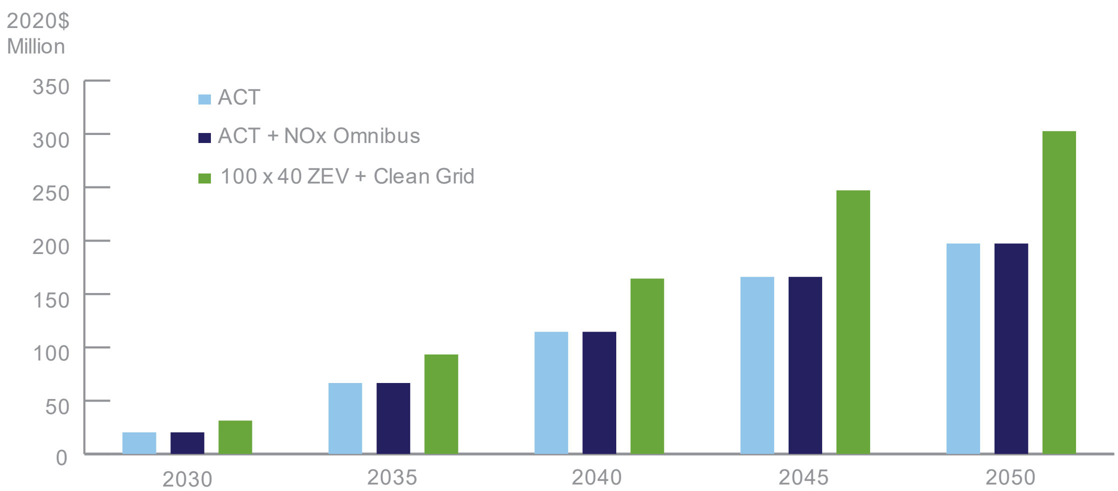
Under the 100 x 40 ZEV policy scenario, incremental peak charging demand is estimated at 265 MW in 2030, rising to 3,300 MW in 2050, and annual incremental electricity sales are estimated to be 1.1 million MWh in 2030, rising to 11.4 million MWh in 2050 (3.9 percent and 41.9 percent of the total electricity demand, respectively).

This analysis estimated the revenue that Southern New England electric utilities would receive from these incremental electricity sales, the marginal generation and transmission costs of providing this power, and the net revenue that utilities would earn (net revenue = revenue – marginal cost). The estimated marginal cost includes costs associated with procuring the necessary additional peak generation and transmission capacity to serve the load ($/MW) as well as marginal generation and transmission energy costs ($/MWh).

Figure 7 summarizes estimated annual utility net revenue from M/HD EV charging under the modeled Clean Truck policy scenarios. Under the ACT Rule scenario, annual utility net revenue is projected to be $20.2 million in 2030, rising to $114.5 million in 2040 and $197.2 million in 2050. Under the 100 x 40 ZEV scenario, utility net revenue is projected to be $31.2 million in 2030, rising to $164.3 million in 2040 and $302.6 million in 2050.

16 This growth assumption is from the EIA 2021 Annual Energy Outlook. It does not include sales to large industrial customers.

Figure 7 Projected Annual Utility Net Revenue From M/HD EV Charging



In general, a utility's costs to maintain its distribution infrastructure increase each year with inflation, and these costs are passed on to utility customers in accordance with rules established by the public utility commissions for Massachusetts, Connecticut, and Rhode Island[17] via periodic increases in residential and commercial electric rates. However, projected utility net revenue from increased electricity sales for M/HD EV charging would lower distribution rates ($/kWh), since fixed annual distribution system costs would be spread over a larger base of energy sales.

This analysis indicates that under the 100 x 40 ZEV scenario, by 2050 incremental utility net revenue from M/HD EV charging could potentially reduce average residential and commercial electricity rates in Southern New England by as much as 2.4 percent ($0.0070/kWh in 2020$). This could save the average Southern New England household $52 per year and the average commercial customer $220 per year on their electricity bills (2020$).[18]

Jobs, Wages, and GDP

The transition from gasoline and diesel M/HD vehicles to ZEVs will have significant impacts on the U.S. economy, with substantial job gains in many industries (e.g., battery and electric component manufacturing, charging infrastructure construction, electricity generation), accompanied by fewer jobs in other industries (e.g., engine manufacturing, oil exploration and refining, gas stations, auto repair shops).[19]

This analysis used the IMPLAN model to estimate these macroeconomic effects of the modeled Southern New England Clean Truck policy scenarios based on estimated changes in spending in various industries (relative to the baseline scenario). These estimates of spending changes by industry were developed from the fleet cost analysis. For example, under the modeled Clean Truck policy scenarios, more money will be spent to manufacture batteries and electric drive components for ZEVs, but less will be spent to manufacture gasoline and diesel engines, and transmissions. Similarly, less money will be spent by fleets to purchase petroleum fuels, but more will be spent to purchase electricity and hydrogen.

17 In Connecticut, rates are regulated by the Public Utilities Regulatory Authority, in Massachusetts rates are regulated by the Department of Public Utilities, and in Rhode Island rates are regulated by the RI Public Utilities Commission.

18 Figures are based on average annual electricity use of 7,370 kWh per housing unit and 31,170 kWh per commercial customer in Southern New England.

19 For example, in-state charging infrastructure is estimated to increase by 686 jobs in 2045 under the most aggressive scenario.

The IMPLAN analysis also includes the effects of induced economic activity due to consumers having more money to spend, thanks to return of utility net revenue in the form of lower electric rates, and net fleet cost savings returned as lower shipping costs for goods, resulting in lower consumer prices for those goods.

The IMPLAN analysis was run at the national level, but assuming only the industry spending changes (from application of the policy scenarios) occurring due to M/HD vehicle purchase and use in Southern New England. Estimated national effects would be significantly greater if the modeled policy scenarios were applied to the entire U.S. M/HD fleet.

Table 3 offers a summary of estimated macroeconomic effects of the modeled Clean Truck scenarios on jobs, GDP, and wages.

Compared with the baseline scenario, adoption of the ACT + NOx Omnibus policy scenario in Southern New England will increase national net jobs through at least 2045, while the 100 x 40 ZEV + Clean Grid scenario will increase national net jobs through 2040. The loss in 2045 is largely due to the reductions in spending on diesel fuel and decreases in the costs of M/HDV ZEVs over time, resulting in decreased spending and investments in the out years. Both scenarios also increase annual GDP in all years. For both scenarios in all years, the average wages for new jobs added to the economy are more than twice the average wages for jobs that are replaced. This is because the largest number of added jobs are in electrical component manufacturing and in construction of charging infrastructure, requiring many well-paid electricians and electrical engineers, while the largest job losses are in vehicle repair—due to lower maintenance required by ZEVs—as well as relatively low-paid retail workers at gas stations.

Table 3 Macroeconomic Effects of Southern New England Clean Truck Policy Scenarios

Metric		ACT + NOx Omnibus		100 x 40 ZEV + Clean Grid	
		2035	2045	2035	2045
Net Change in Jobs		1,203	335	1,537	(4)
Net Change in GDP 2020$ (million)		$302	$425	$418	$592
Average Annual Compensation	Added Jobs	$101,097	$101,589	$102,056	$101,051
	Replaced Jobs	$44,649	$46,374	$45,039	$46,805

Today many components used in electric and fuel cell vehicles—most notably batteries, but also many electric drivetrain components—are manufactured outside the United States and imported for final vehicle assembly. The percentage of imported content is higher for ZEV drivetrains today than for conventional drivetrains (gasoline and diesel engines, and transmissions). The scale of U.S. macroeconomic effects from the modeled Clean Truck policy scenarios will depend on how the nascent M/HD ZEV industry develops; for this analysis, MJB&A assumed that all incremental spending on ZEV batteries and electric drivetrain components would be in the United States, with no imported content. As such, the results summarized in Table 3 represent a high-end estimate of what is possible from the ZEV transition, with the right federal and state policy supports in place to incentivize development of U.S.-based ZEV component manufacturing. If vehicle manufacturers continue to rely primarily on imported batteries and electric drivetrain components, the net job and GDP gains will be lower than those summarized here.

This macroeconomic analysis only includes direct, indirect, and induced impacts from changes in M/HD vehicle manufacturing and use, and from consumer re-spending of net utility revenue and fleet cost savings returned as lower prices for electricity and shipped goods. It does not include any effects on freight industry growth and investment due to lower operating costs, or any macroeconomic effects associated with the estimated climate and air quality (health) benefits of the modeled Clean Truck policy scenarios.

Required Public and Private Investments

On the basis of a detailed charging model that considers typical daily usage patterns for different vehicle types, this analysis assumes that most M/HD ZEVs in Southern New England will use overnight charging at their place of business, though about 10 percent will need to rely on a publicly accessible network of higher-power chargers.[20] The exception are combination trucks, 70 percent of which are assumed to require high-power public chargers since they are used primarily for long-haul freight operations.

Table 4 summarizes estimated charging infrastructure required to support M/HD electric trucks and buses under the Clean Truck policy scenarios.

Table 4 Projected Charging Infrastructure Required for Clean Truck Policy Scenarios

Metric		ACT Rule			100 x 40 ZEV		
		2035	2045	2050	2035	2045	2050
Cumulative Charge Ports	Depot	77,285	227,725	283,915	116,536	364,019	452,174
	Public 150 kW	1,072	3,140	3,944	1,581	4,850	6,084
	Public 500 kW	608	1,605	2,017	895	3,238	4,400
Cumulative Investment, 2020$ (million)	Depot	$423	$1,186	$1,577	$638	$1,926	$2,606
	Public	$270	$707	$936	$396	$1,299	$1,799

Depot chargers will need to be 10–50 kW per port depending on vehicle type. The smaller 150 kW public chargers are needed primarily to support single-unit freight trucks, while the higher-capacity 500 kW public chargers are needed mostly for combination trucks.

As of June 2021, there were 192 publicly accessible charging stations in Southern New England with a total of 653 direct current fast-charging (DCFC) ports (>50 kW).[21] Two-thirds of these DCFC ports are Tesla superchargers that can be used only by Tesla owners. In Southern New England, there are only 221 DCFC ports fully available to any vehicle.

Under the ACT Rule policy scenario, Southern New England's fleet owners will have to invest an average of $63 million per year (2020$) between 2025 and 2050 to purchase and install depot-based charging infrastructure. The government and private investors will need to invest an average of $37 million per year over the same time period to build out a publicly accessible charging network across the region to serve the EV M/HD truck fleet.

20 See the methodology report for a detailed discussion of M/HD EV charging needs.

21 These numbers are from the U.S. Department of Energy's Alternative Fuel Data Center public charger database.

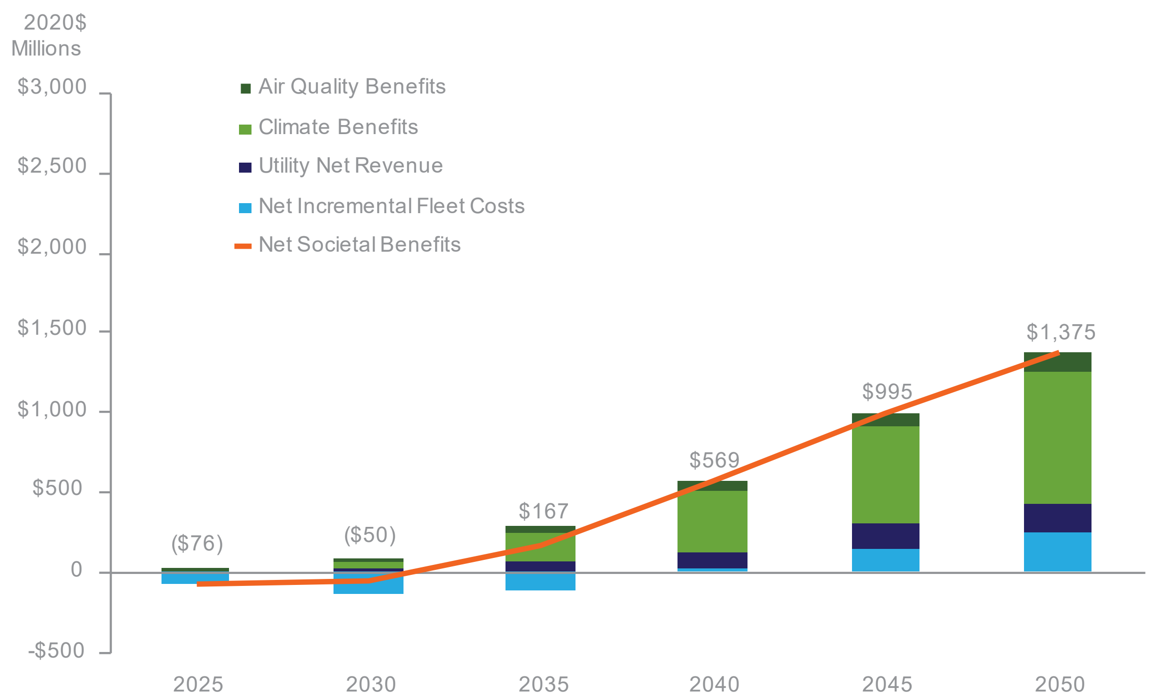
Under the 100 x 40 ZEV scenario, fleet investments in depot charging infrastructure from 2025 to 2050 will need to increase to an average of $104 million per year, and public and private investments in the public charging network will need to rise to an average of $72 million per year.

Net Societal Benefits

The net societal benefits from the modeled Southern New England Clean Truck policy scenarios include the monetized value of public health and climate benefits, net cost savings for fleets, and net utility revenue from electricity sales for EV charging.

Figures 8–10 present projected annual net societal benefits under the ACT Rule, ACT + NOx Omnibus Rule, and 100 x 40 ZEV + Clean Grid scenarios, respectively. Under all three Clean Truck policy scenarios, near-term fleet costs are higher than fleet costs under the baseline.[22] However, after approximately 2030 all policy scenarios show annual net societal benefits, despite net fleet costs, due to growing utility net revenue in addition to public health and climate benefits. After approximately 2035 there is an annual net savings in fleet costs from operating ZEVs instead of diesel and gasoline trucks, and net societal benefits grow quickly.[23]

Figure 8 Projected Annual Net Societal Benefits From ACT Rule Policy Scenario



22 If an individual truck owner finances a vehicle, it would better equalize payments for increased vehicle price and fuel savings, resulting in a better balancing of cash flow. On a net fleet-wide basis, however, the cost of financing reduces total net fleet savings.

23 Note that fleet-wide annual net savings under the Clean Truck policy scenarios lag average ZEV life-cycle cost parity to combustion vehicles by about 5 years. This is because even after life-cycle cost parity is achieved, most ZEVs will still have higher up-front purchase costs (vehicle plus charger) than combustion vehicles; these higher costs are then paid back over the next few years via fuel and maintenance cost savings.

Figure 9

Projected Annual Net Societal Benefits From ACT + NOx Omnibus Policy Scenario

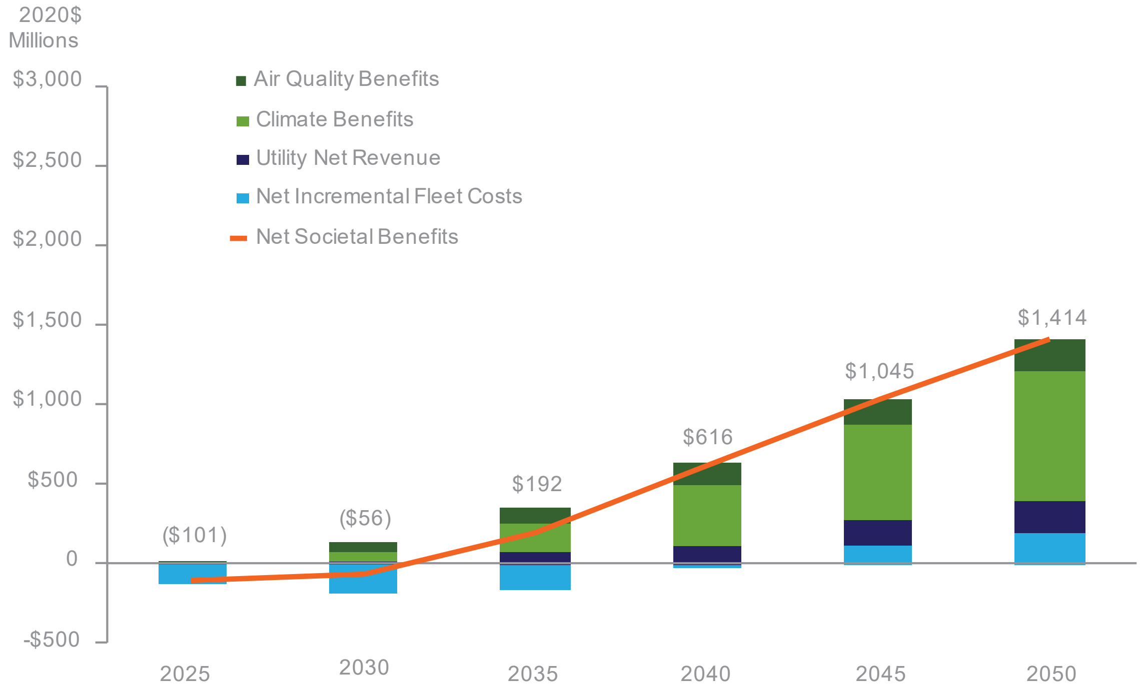
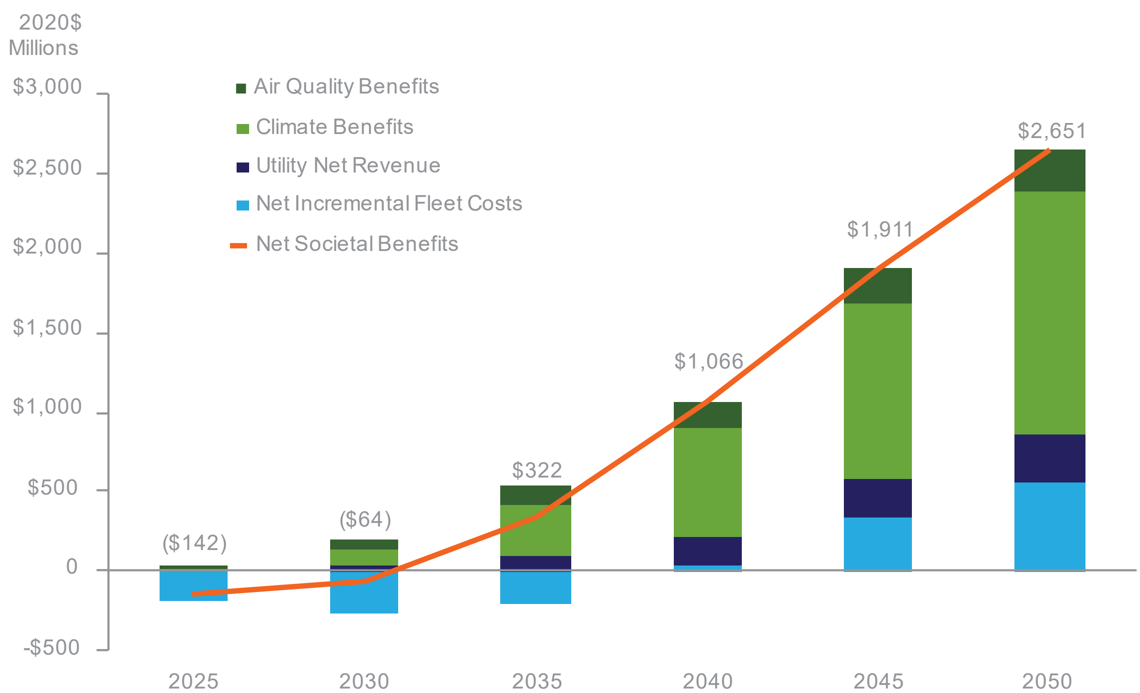


Figure 10

Projected Annual Net Societal Benefits From 100 x 40 ZEV + Clean Grid Policy Scenario



Under the ACT Rule scenario, by 2050 annual net societal benefits are estimated to be $1.4 billion, including $240 million in net fleet savings and $197 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $12.1 billion between 2020 and 2050.

Under the ACT + NOx Omnibus scenario, by 2050 annual net societal benefits are estimated to be $1.4 billion, including $205 million in net fleet savings and $197 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $12.7 billion between 2020 and 2050.

Under the 100 x 40 ZEV + Clean Grid scenario, by 2050 annual net societal benefits are estimated to be $2.7 billion, including $562 million in net fleet savings and $303 million in utility net revenue. Cumulative estimated societal net benefits under this scenario total $23.4 billion between 2020 and 2050.

APPENDIX A: Southern New England Energy Cost Assumptions and Supplemental Material

Figure A1 Southern New England Average Fuel Costs

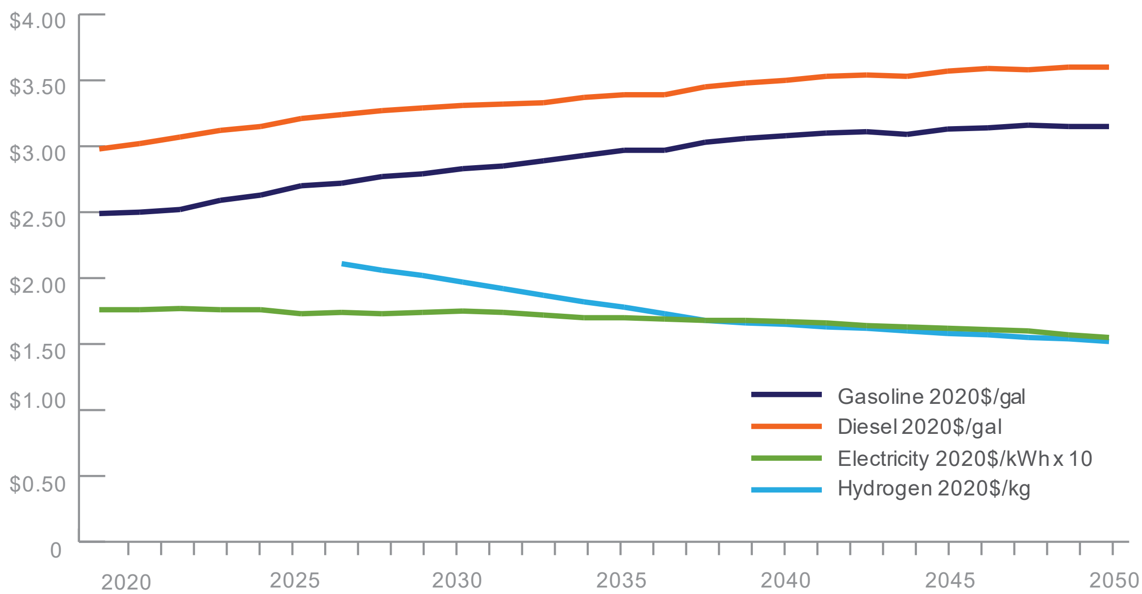


Table A1 M/HDV In-Use ZEVs Population

M/HDV In-Use ZEVs	2025	2030	2035	2040	2045	2050
Baseline	680	1,242	1,829	2,617	3,338	4,015
ACT	2,598	29,406	100,378	194,751	288,226	359,366
ACT + NOx OMN	2,598	29,406	100,378	194,751	288,226	359,366
100x40 ZEV + Clean Grid	3,460	44,069	148,817	301,926	460,979	575,490
Total M/HDV Fleet (ZEV + ICE)	549,894	561,956	574,323	587,006	600,014	613,360

Table A2 Net Incremental Fleet Benefits

2020$ (millions)	2025	2030	2035	2040	2045	2050
ACT	($81)	($132)	($117)	$18	$144	$243
ACT + NOx OMN	($124)	($193)	($162)	($20)	$106	$205
100x40 ZEV + Clean Grid	($180)	($270)	($201)	$48	$335	$562

Table A3

Average Southern New England Household and Commercial Customer Electric Bill Savings in 2050

2020$	Household	Commercial Customer
ACT	$34	$143
ACT + NOx OMN	$34	$143
100x40 ZEV + Clean Grid	$52	$220

APPENDIX B: Results from Massachusetts Analysis

Table B1 Current Massachusetts M/HD Fleet

Vehicle Type	No. of Vehicles	Annual VMT (billion miles)	Annual Fuel (million gallons)
Heavy-Duty Pickup and Van **Class 2b** 	137,232	1.55	82.5
Bus **Class 3–8** 	19,338	0.35	43.9
Single-Unit Work and Freight Truck **Class 3–8** 	160,211	1.97	242.2
Combination Truck **Class 7–8** 	21,201	1.27	186.2
TOTAL	**337,982**	**5.132**	**554.8**

Table B2 Current Massachusetts M/HD Fleet's Share of Total Transportation Emissions

	M/HDV share of total on-road fleet
Greenhouse Gas Emissions	20%
NOx Emissions	46%
PM Emissions	40%
Share of On Road Vehicles	7%

Table B3 Projected M/HD Fleet Petroleum Fuel and Electricity Usage

	2050 M/HDV Petroleum Fuel Use (million Gallon)	Fuel Saved 2020-2050 (million Gallon)	2050 Residential and Commercial Electricity Use (million MWh)
Baseline	440	-	49
ACT and ACT + NOx Omnibus	210	2,900	53 (+8%)
100 x 40 + Clean Grid	34	4,800	55 (+13%)

Figure B1 Projected M/HD Fleet NOx Emissions

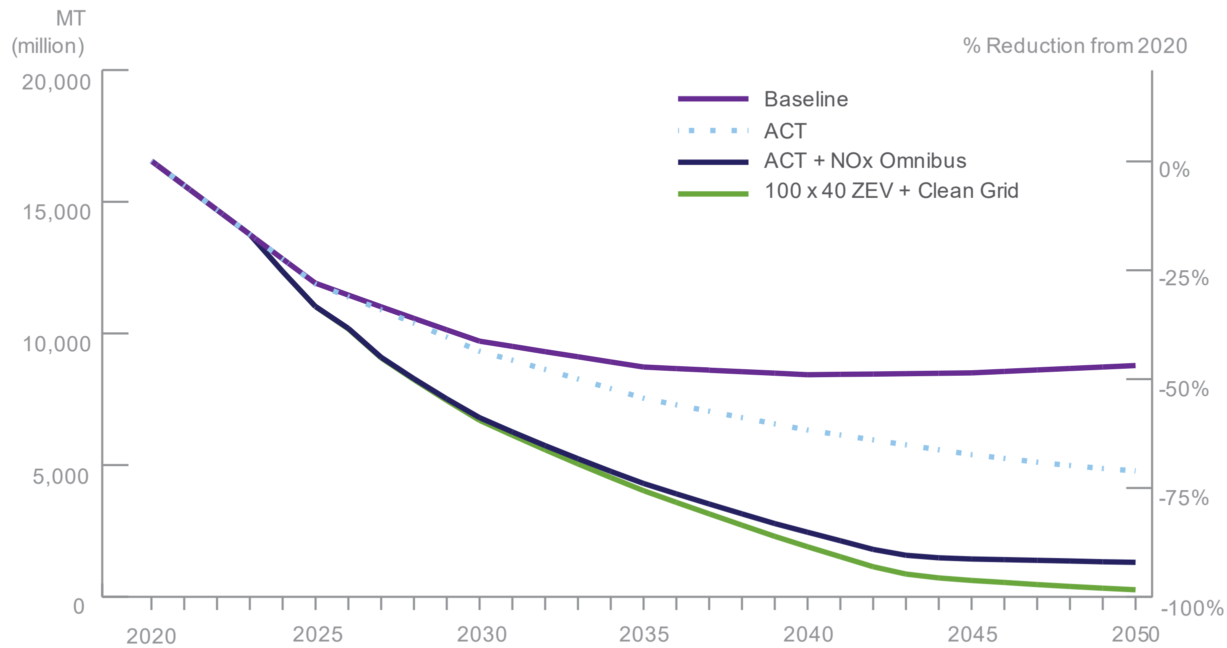


Figure B2 Projected M/HD Fleet PM Emissions

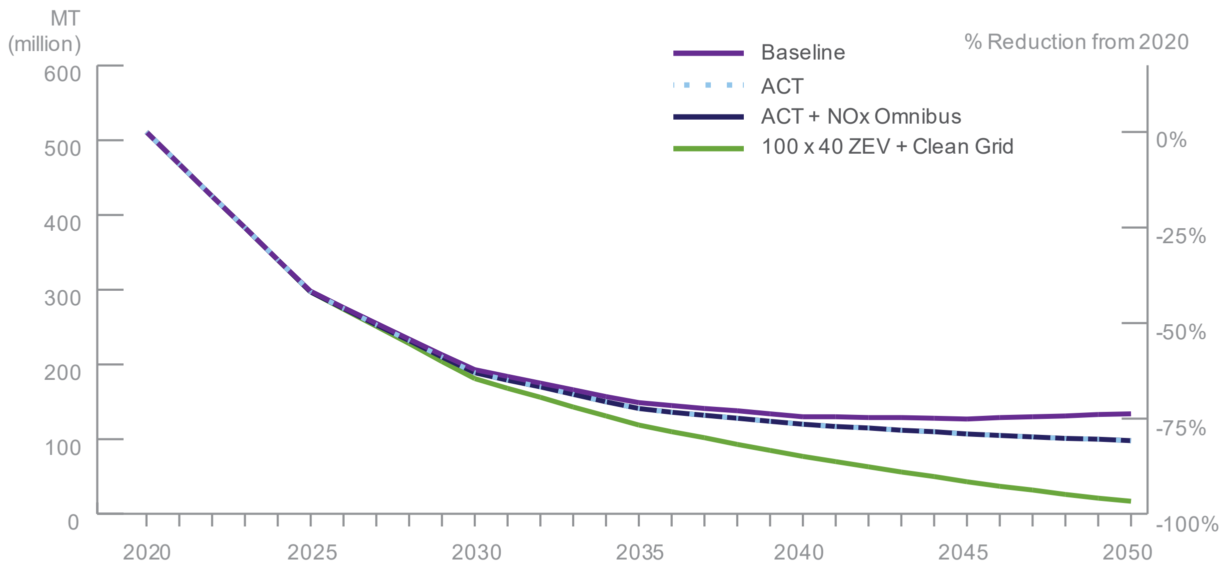


Table B4 Cumulative Public Health Benefits of Clean Truck Policy Scenarios, 2020–2050

Health Metric	ACT Rule	ACT + NOx Omnibus	100 x 40 ZEV + Clean Grid
Avoided Premature Deaths	64	152	190
Avoided Hospital Visits[a]	65	157	196
Avoided Minor Cases[b]	37,821	89,434	111,853
Monetized Value, 2020$ (millions)	$753	$1,776	$2,223

a Includes hospital admissions and emergency room visits.
b Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

Figure B3 Projected M/HD Fleet GHG Emissions

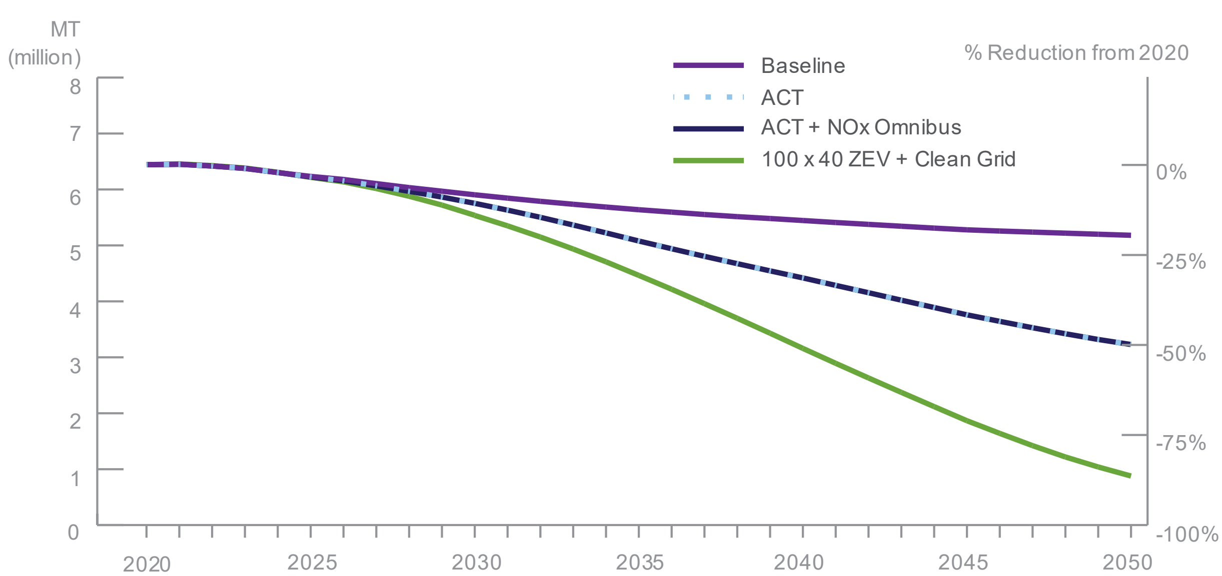


Table B5 Projected Cumulative M/HD Fleet Emissions Reductions (2020-2050)

	NOx (MT)	PM (MT)	GHG (mill MT)
ACT	45,880	324	22.0
ACT + NOx Omnibus	129,100	324	22.0
100x40 + Clean Grid	141,100	1,280	48.8

Figure B4 Projected Lifetime Incremental Costs for Massachusetts ZEVs Compared with Combustion Vehicles

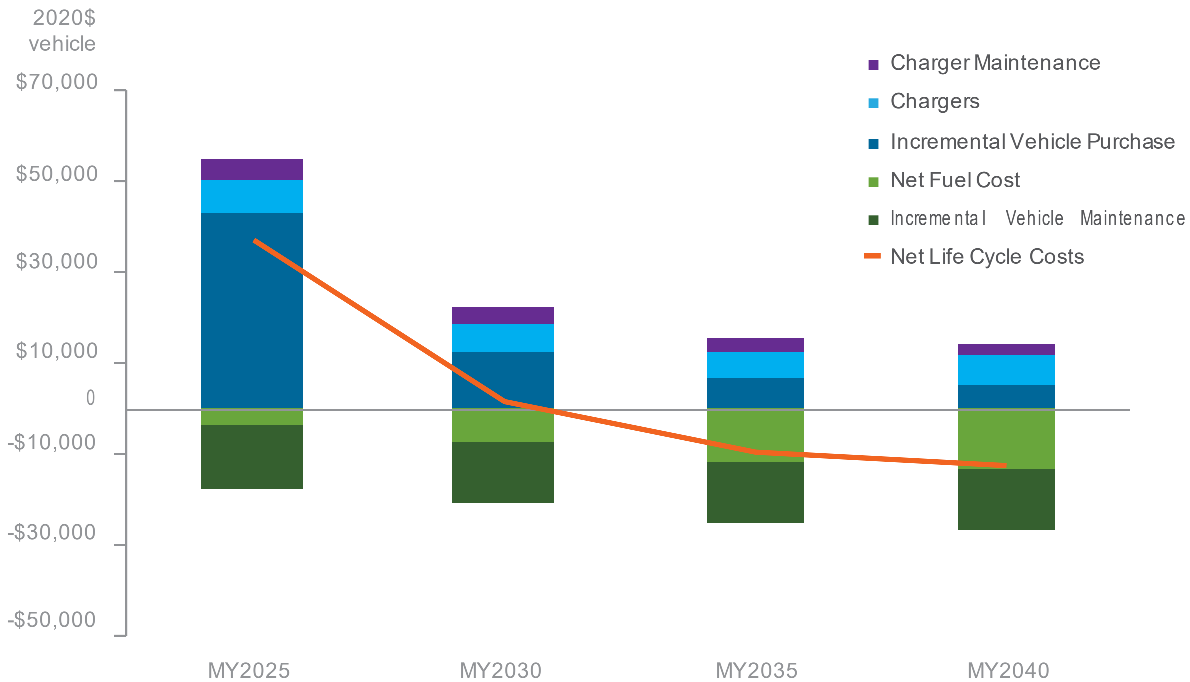


Figure B5 Projected Annual Utility Net Revenue from M/HD EV Charging

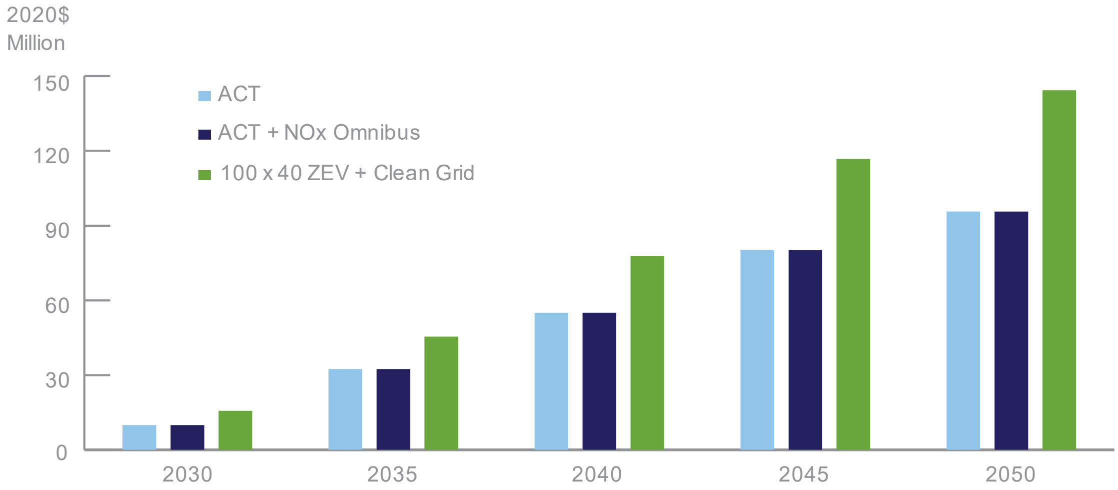


Table B6 Projected Changes in Electricity Usage and Demand from Massachusetts Clean Truck Policy Scenarios

	2030 Additional Electricity Sales (million MWh)	2050 Additional Electricity Sales (million MWh)	2030 Incremental Monthly Peak Charging Demand (MW)	2050 Incremental Monthly Peak Charging Demand (MW)
ACT and ACT + NOx Omnibus	0.4	4.1	104	1,348
100x40	0.6	6.2	160	2,006

Table B7 Macroeconomic Effects of Massachusetts Clean Truck Policy Scenarios

Metric		ACT + NOx Omnibus		100 x 40 ZEV + Clean Grid	
		2035	2045	2035	2045
Net Change in Jobs		581	-145	716	-601
Net Change in GDP 2020$ (million)		$160	$205	$221	$273
Average Annual Compensation	Added Jobs	$101,317	$101,322	$102,251	$100,888
	Replaced Jobs	$45,175	$47,045	$45,627	$47,549

Table B8 Projected Charging Infrastructure Required for Clean Truck Policy Scenarios

Metric		ACT Rule			100 x 40 ZEV		
		2035	2045	2050	2035	2045	2050
Cumulative Charge Ports	Depot	49,255	145,842	180,910	74,893	236,055	290,893
	Public 150 kW	653	1,917	2,398	969	2,995	3,734
	Public 500 kW	309	817	1,026	456	1,648	2,238
Cumulative Investment, 2020$ (million)	Depot	$253	$711	$946	$383	$1,158	$1,566
	Public	$147	$386	$511	$216	$704	$973

Figure B6 Projected Annual Net Societal Benefits from ACT Rule Policy Scenario

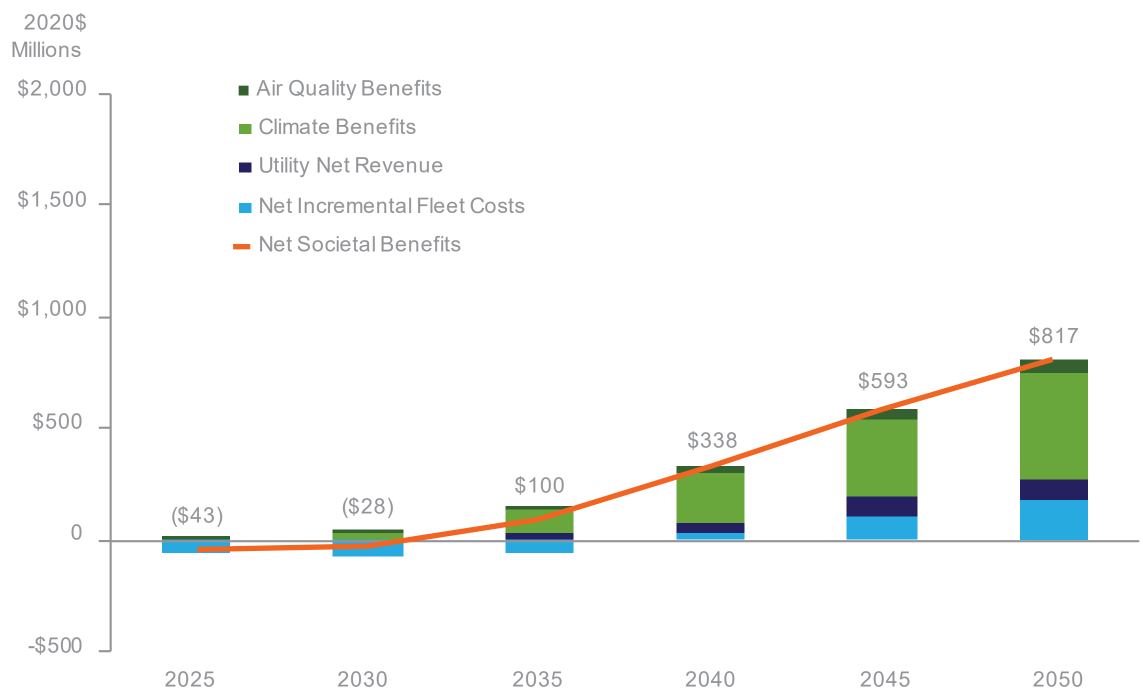


Figure B7 Projected Annual Net Societal Benefits from ACT + NOx Omnibus Policy Scenario

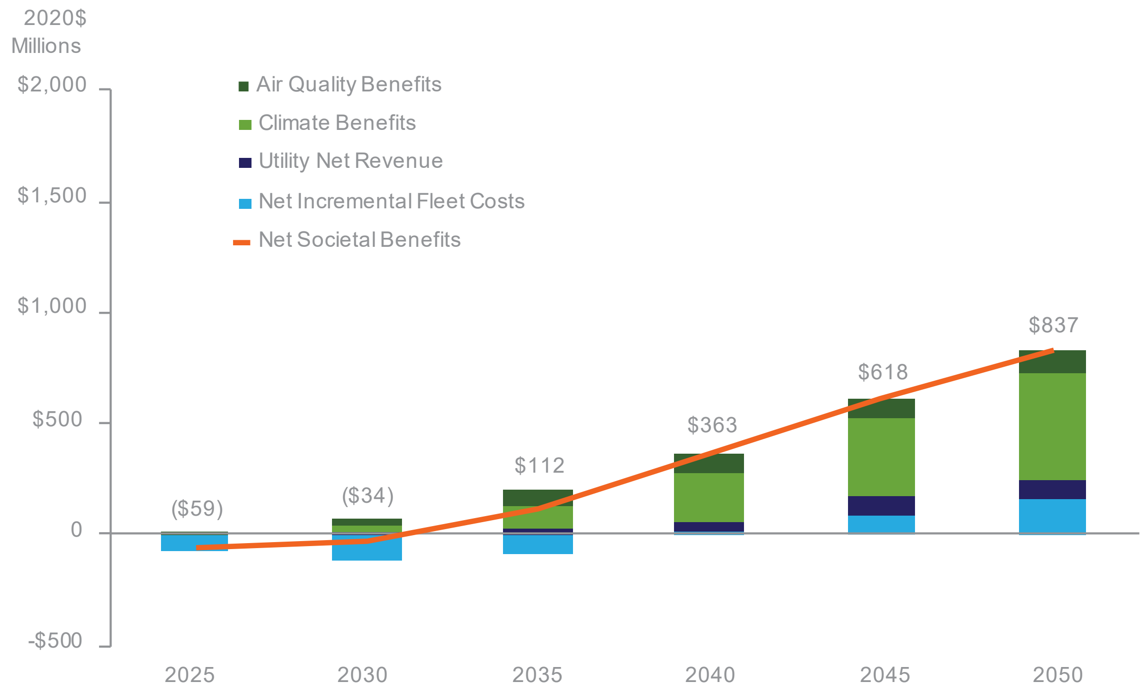


Figure B8 Projected Annual Net Societal Benefits from 100 x 40 ZEV + Clean Grid Policy Scenario

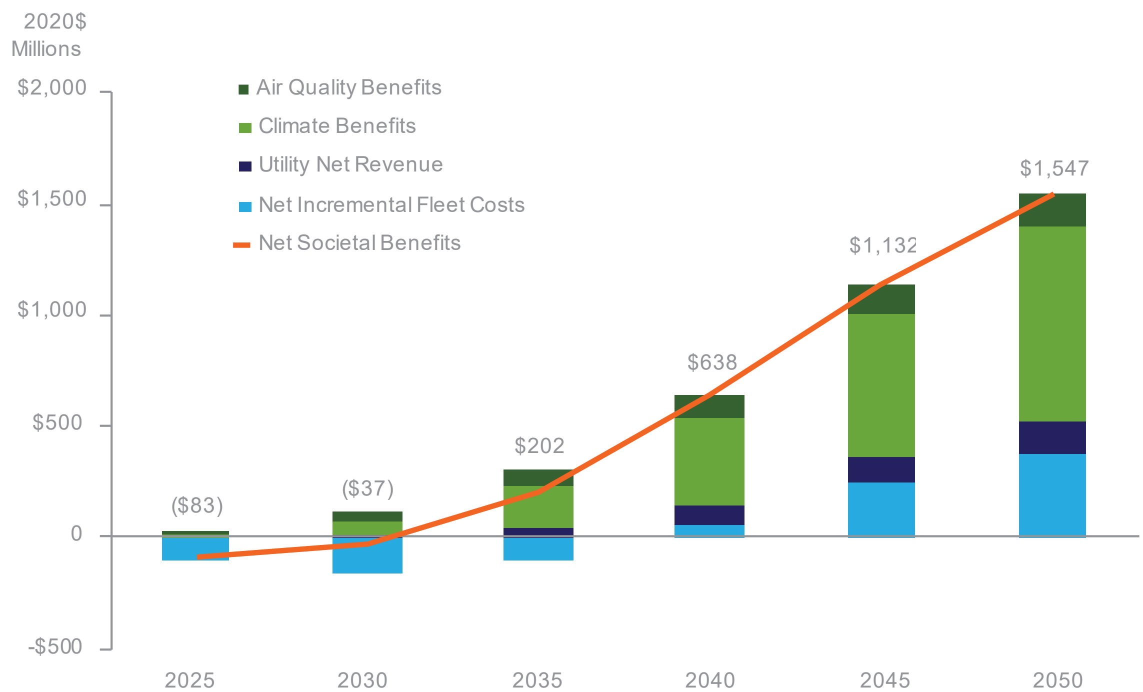


Table B9 Massachusetts Business as Usual Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	14.1%	15.1%	53.6%	57.3%	70.7%	75.9%	86.0%
Natural Gas	78.8%	77.6%	37.5%	33.3%	18.6%	13.0%	6.5%
Coal	7.1%	7.2%	8.9%	9.4%	10.6%	11.1%	7.6%

These business-as-usual grid mix assumptions were applied to the baseline, ACT Rule, and ACT + NOx Omnibus policy scenarios.

Table B10 Massachusetts Decarbonized Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	14.0%	15.4%	66.5%	93.8%	95.8%	97.5%	100.0%
Natural Gas	78.9%	77.4%	26.6%	1.9%	0.7%	0.1%	0.0%
Coal	7.0%	7.2%	6.9%	4.3%	3.5%	2.4%	0.0%

These Decarbonized grid mix assumptions were applied to the 100 x 40 ZEV + Clean Grid policy scenario.

For simplicity, results from EPA's Integrated Planning Model for coal, oil, and biomass were combined under "coal," as noted in the accompanying methodology report. The zero-emitting category includes nuclear and renewable resources such as wind, solar, and hydropower. Analysis of new, state-specific electricity policies, such as from more stringent Renewable Portfolio Standards, was beyond the scope of this study but would be expected to increase the usage of these renewable resources.

Table B11 M/HD In-Use ZEVs Population

M/HD In-Use ZEVs	2025	2030	2035	2040	2045	2050
Baseline	680	1,242	1,829	2,617	3,338	4,015
ACT	2,598	29,406	100,378	194,751	288,226	359,366
ACT + NOx OMN	2,598	29,406	100,378	194,751	288,226	359,366
100x40 ZEV + Clean Grid	3,460	44,069	148,817	301,926	460,979	575,490
Total M/HDV Fleet (ZEV + ICE)	549,894	561,956	574,323	587,006	600,014	613,360

Table B12 Net Incremental Fleet Benefits

2020$ (millions)	2025	2030	2035	2040	2045	2050
ACT	($46)	($74)	($57)	$33	$116	$179
ACT + NOx OMN	($72)	($111)	($85)	$9	$94	$157
100x40 ZEV + Clean Grid	($105)	($155)	($101)	$62	$246	$381

Table B13 Average Massachusetts Household and Commercial Customer Electric Bill Savings in 2050

2020$	Household	Commercial Customer
ACT	$27	$116
ACT + NOx OMN	$27	$116
100x40 ZEV + Clean Grid	$40	$176

Based on average annual electricity use of 7,010 kWh per household and 30,640 kWh per commercial customer in Massachusetts.

APPENDIX C: Results from Connecticut Analysis

Table C1 Current Connecticut M/HD Fleet

Vehicle Type	No. of Vehicles	Annual VMT (billion miles)	Annual Fuel (million gallons)
Heavy-Duty Pickup and Van **Class 2b** 	17,113	0.19	10.3
Bus **Class 3–8** 	9,159	0.17	20.8
Single-Unit Work and Freight Truck **Class 3–8** 	100,721	1.24	152.2
Combination Truck **Class 7–8** 	18,217	1.09	160.0
TOTAL	**145,210**	**2.686**	**343.3**

Table C2 Current Connecticut M/HD Fleet's Share of Total Transportation Emissions

	M/HDV share of total on-road fleet
Greenhouse Gas Emissions	25%
NOx Emissions	53%
PM Emissions	45%
Share of On Road Vehicles	6%

Table C3

Projected M/HD Fleet Petroleum Fuel and Electricity Usage

	2050 M/HDV Petroleum Fuel Use (million Gallon)	Fuel Saved 2020-2050 (million Gallon)	2050 Residential and Commercial Electricity Use (million MWh)
Baseline	290	-	27
ACT and ACT + NOx Omnibus	140	1,800	30 (+11%)
100 x 40 + Clean Grid	25	3,000	32 (+16%)

Figure C1

Projected M/HD Fleet NOx Emissions

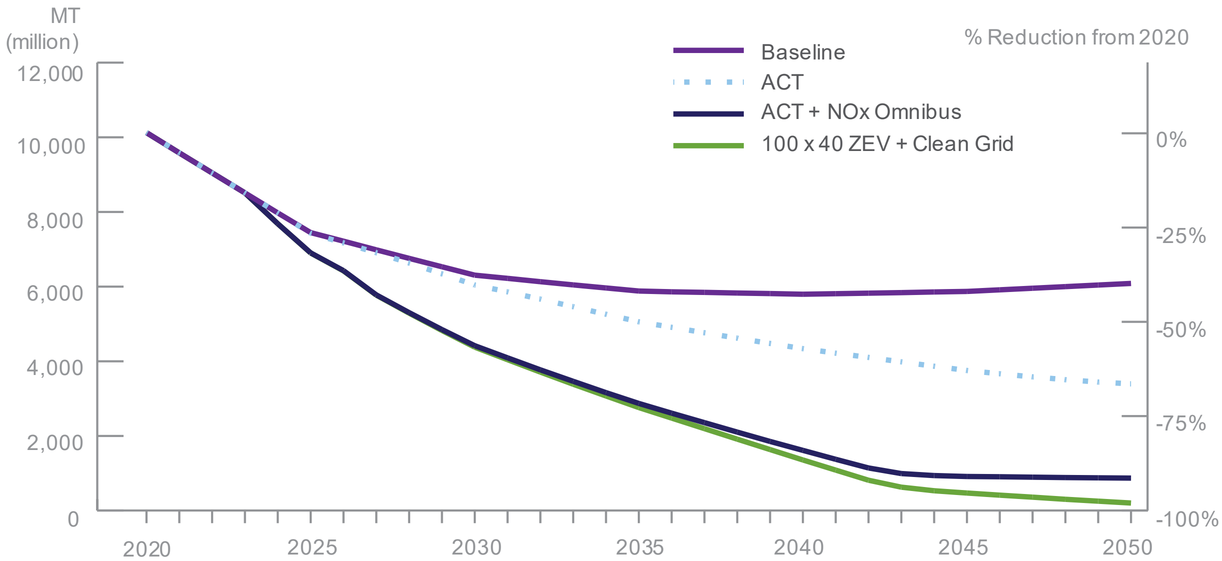


Figure C2 Projected M/HD Fleet PM Emissions

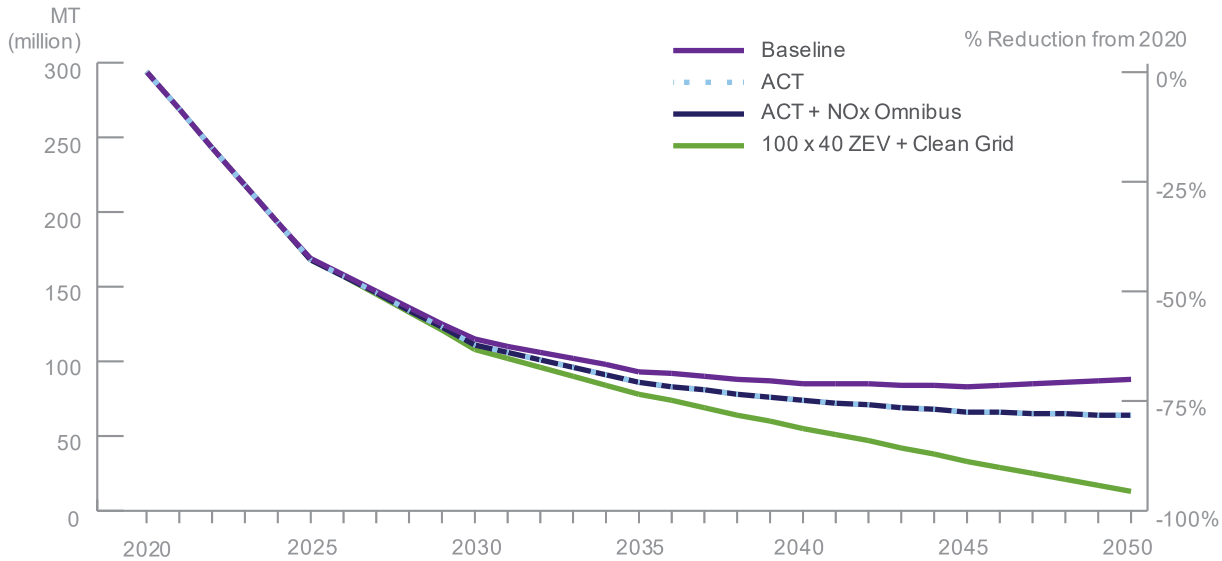


Table C4 Cumulative Public Health Benefits of Clean Truck Policy Scenarios, 2020–2050

Health Metric	ACT Rule	ACT + NOx Omnibus	100 x 40 ZEV + Clean Grid
Avoided Premature Deaths	43	104	125
Avoided Hospital Visits[a]	42	102	123
Avoided Minor Cases[b]	24,027	57,438	69,171
Monetized Value, 2020$ (millions)	$507	$1,218	$1,465

a Includes hospital admissions and emergency room visits.
b Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

Figure C3 Projected M/HD Fleet GHG Emissions

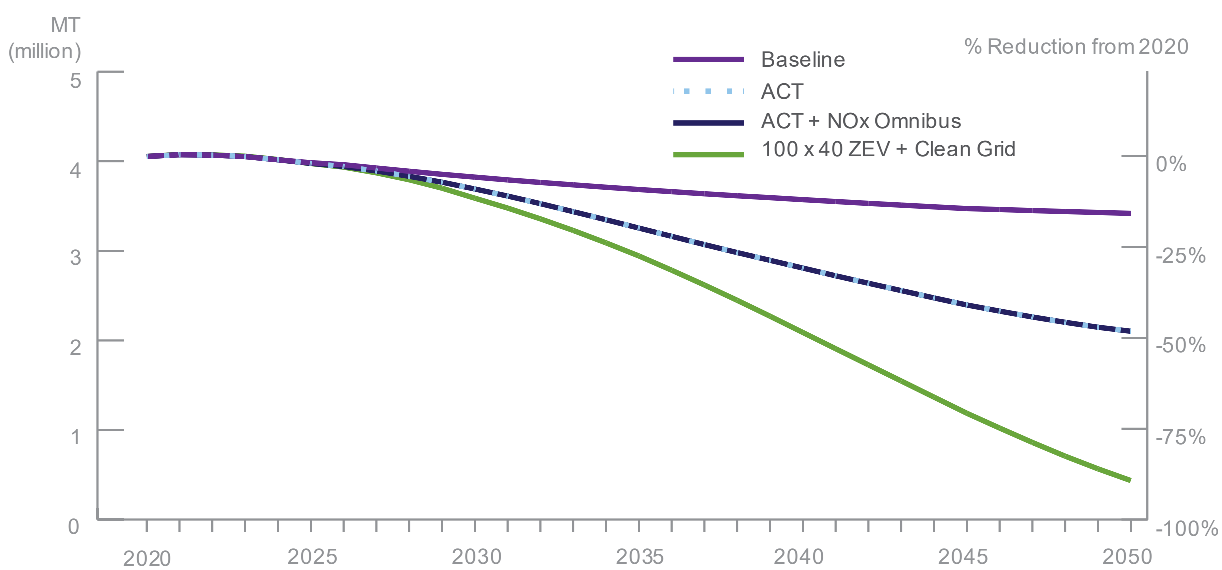


Table C5 Projected Cumulative M/HD Fleet Emissions Reductions (2020-2050)

	NOx (MT)	PM (MT)	GHG (mill MT)
ACT	31,360	270	15.9
ACT + NOx Omnibus	88,740	270	15.9
100x40 + Clean Grid	94,990	740	32.4

Figure C4 Projected Lifetime Incremental Costs for Connecticut ZEVs Compared with Combustion Vehicles

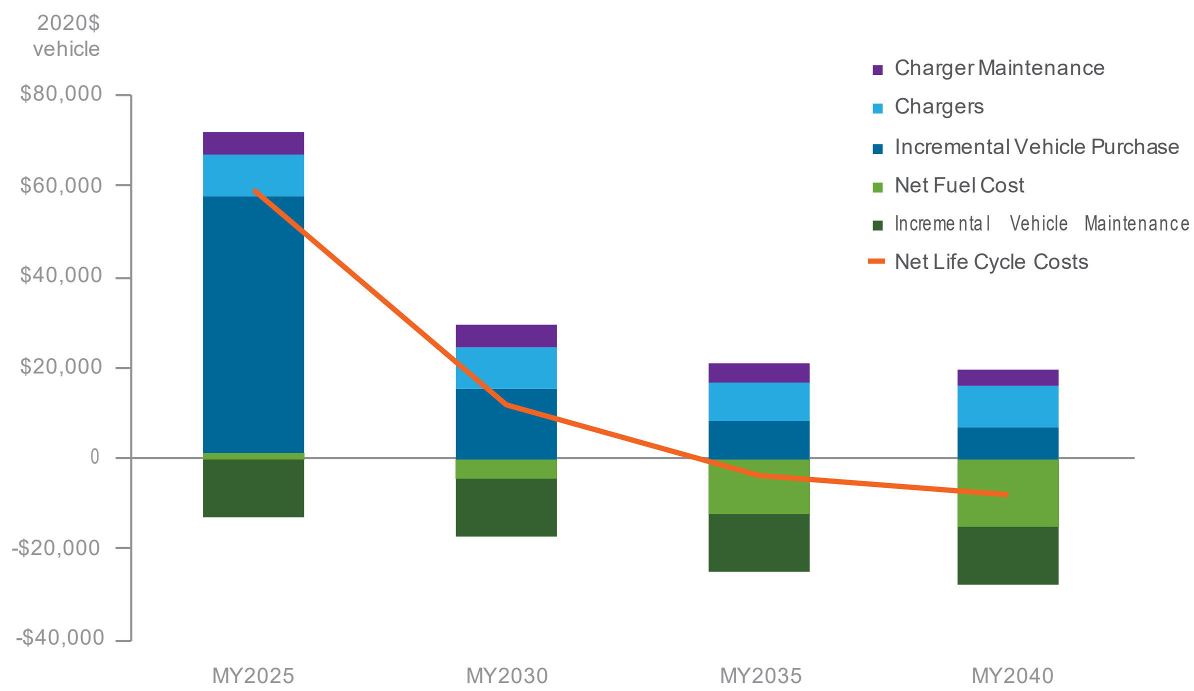


Figure C5

Projected Annual Utility Net Revenue from M/HD EV Charging

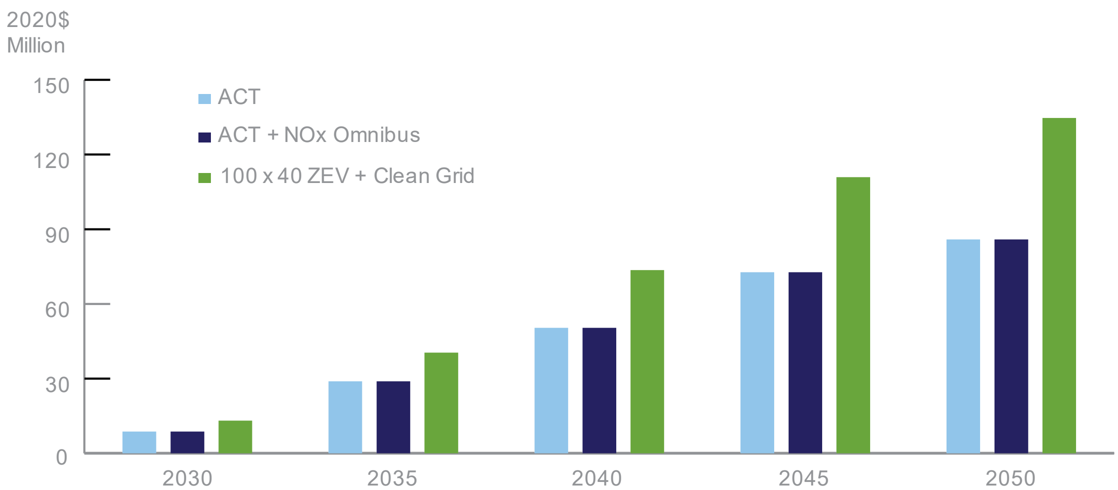


Table C6

Projected Changes in Electricity Usage and Demand from Connecticut Clean Truck Policy Scenarios

	2030 Additional Electricity Sales (million MWh)	2050 Additional Electricity Sales (million MWh)	2030 Incremental Monthly Peak Charging Demand (MW)	2050 Incremental Monthly Peak Charging Demand (MW)
ACT and ACT + NOx Omnibus	0.3	2.9	53	687
100x40	0.4	4.3	80	987

Table C7

Macroeconomic Effects of Connecticut Clean Truck Policy Scenarios

Metric		ACT + NOx Omnibus		100 x 40 ZEV + Clean Grid	
		2035	2045	2035	2045
Net Change in Jobs		509	472.78	690	635
Net Change in GDP 2020$ (million)		$114	$185	$161	$271
Average Annual Compensation	Added Jobs	$100,931	$101,826	$101,679	$101,139
	Replaced Jobs	$43,377	$44,990	$43,795	$45,259

Table C8 Projected Charging Infrastructure Required for Clean Truck Policy Scenarios

Metric		ACT Rule			100 x 40 ZEV		
		2035	2045	2050	2035	2045	2050
Cumulative Charge Ports	Depot	20,757	60,443	76,252	30,670	93,828	118,879
	Public 150 kW	317	923	1,168	460	1,391	1,768
	Public 500 kW	264	695	874	387	1,403	1,908
Cumulative Investment, 2020$ (million)	Depot	$132	$367	$488	$197	$596	$807
	Public	$105	$271	$358	$153	$506	$703

Figure C6 Projected Annual Net Societal Benefits from ACT Rule Policy Scenario

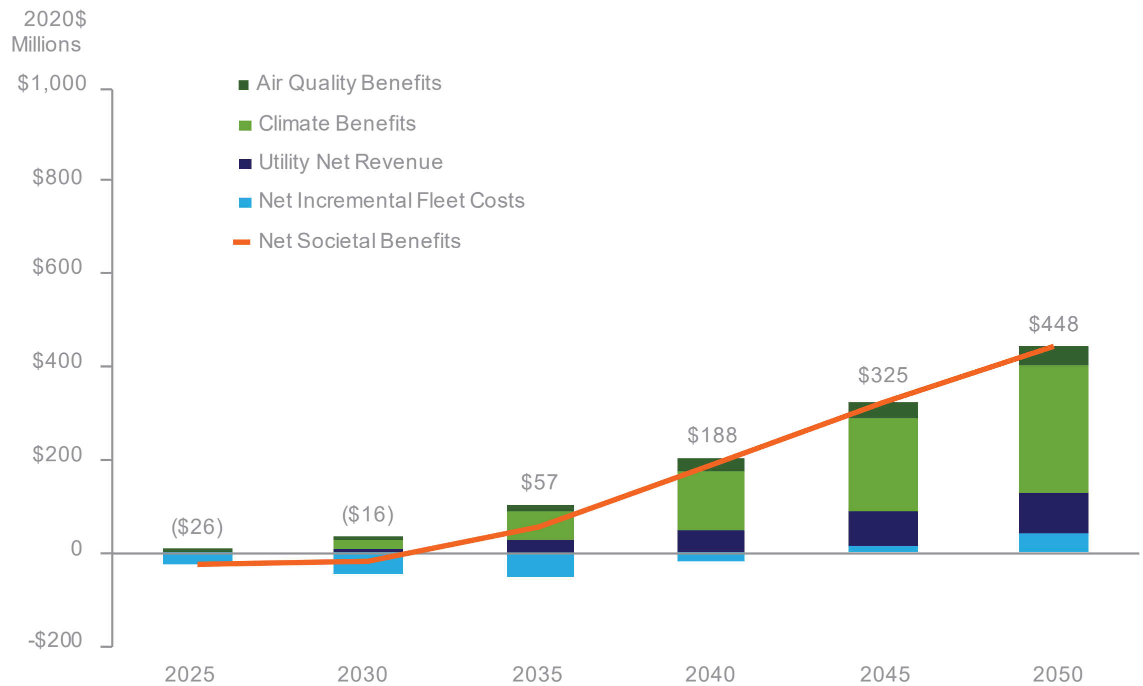


Figure C7

Projected Annual Net Societal Benefits from ACT + NOx Omnibus Policy Scenario

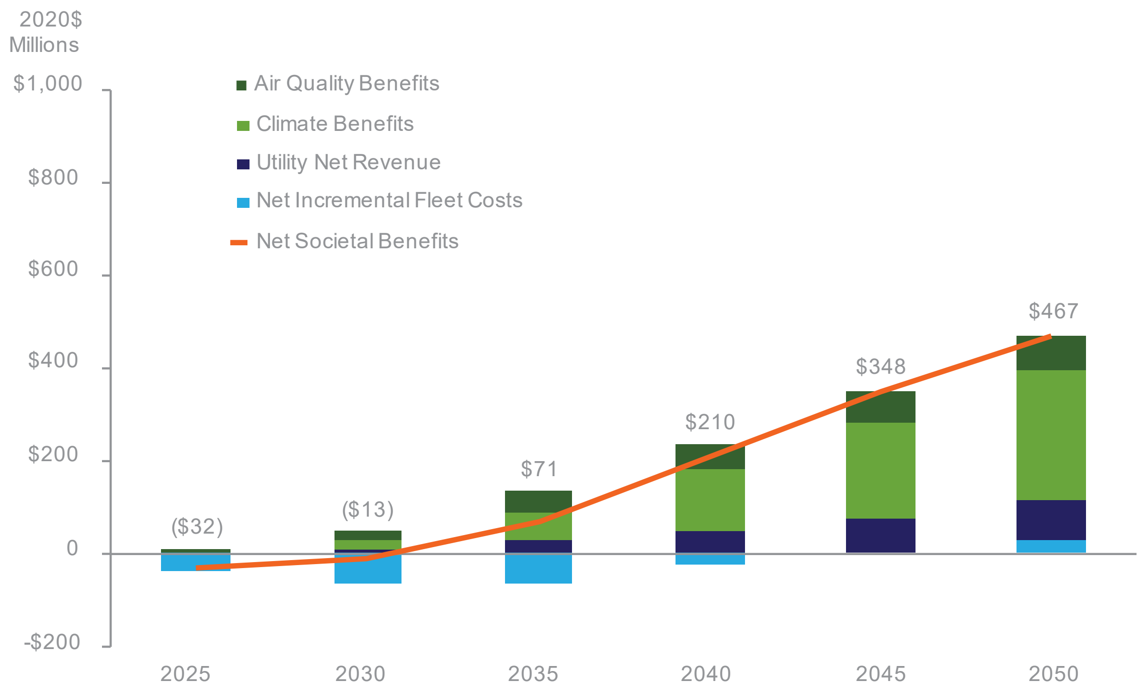


Figure C8

Projected Annual Net Societal Benefits from 100 x 40 ZEV + Clean Grid Policy Scenario

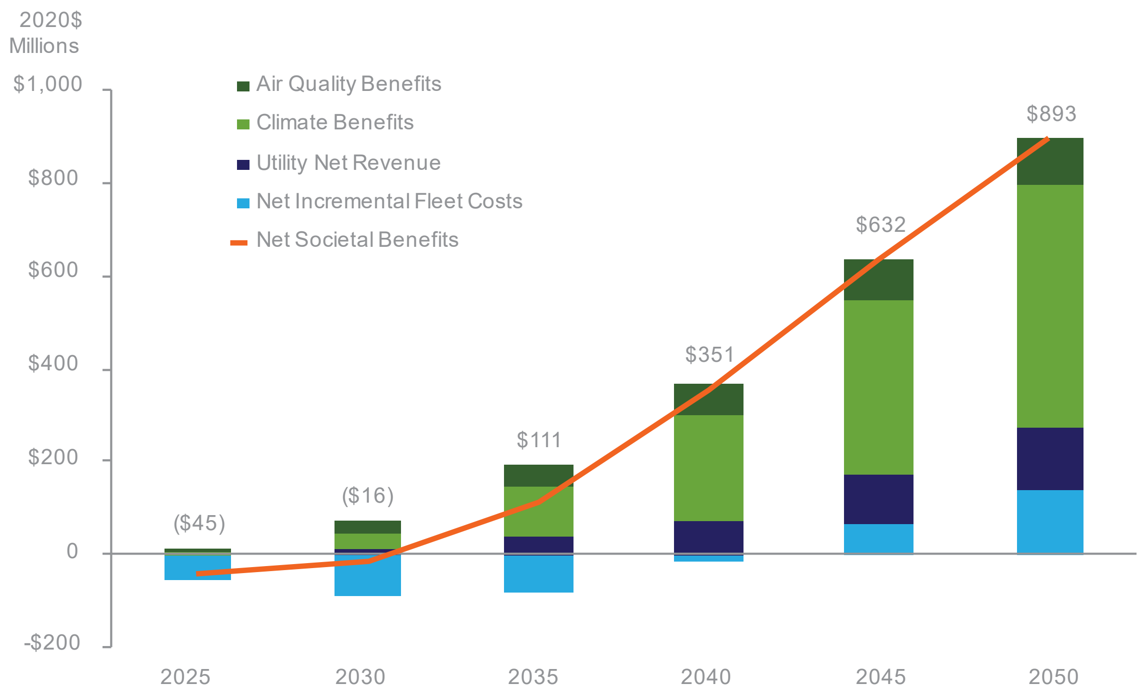


Table C9 Connecticut Business as Usual Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	48.6%	47.8%	55.9%	69.5%	71.2%	73.4%	79.8%
Natural Gas	46.9%	47.7%	39.8%	26.4%	24.3%	22.3%	15.7%
Coal	4.6%	4.5%	4.3%	4.1%	4.5%	4.3%	4.4%

These business-as-usual grid mix assumptions were applied to the baseline, ACT Rule, and ACT + NOx Omnibus policy scenarios.

Table C10 Connecticut Decarbonized Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	47.4%	40.1%	50.8%	88.8%	89.1%	92.6%	100.0%
Natural Gas	48.2%	56.2%	45.1%	6.9%	6.5%	4.6%	0.0%
Coal	4.4%	3.8%	4.2%	4.4%	4.4%	2.8%	0.0%

These Decarbonized grid mix assumptions were applied to the 100 x 40 ZEV + Clean Grid policy scenario.

For simplicity, results from EPA's Integrated Planning Model for coal, oil, and biomass were combined under "coal," as noted in the accompanying methodology report. The zero-emitting category includes nuclear and renewable resources such as wind, solar, and hydropower. Analysis of new, state-specific electricity policies, such as from more stringent Renewable Portfolio Standards, was beyond the scope of this study but would be expected to increase the usage of these renewable resources.

Table C11 M/HD In-Use ZEVs Population

M/HD In-Use ZEVs	2025	2030	2035	2040	2045	2050
Baseline	232	428	633	908	1,159	1,397
ACT	727	8,027	27,346	52,583	77,986	98,288
ACT + NOx OMN	727	8,027	27,346	52,583	77,986	98,288
100x40 ZEV + Clean Grid	959	11,893	39,969	80,233	122,719	156,414
Total M/HDV Fleet (ZEV + ICE)	149,711	153,289	156,967	160,751	164,644	168,651

Table C12 Net Incremental Fleet Benefits

2020$ (millions)	2025	2030	2035	2040	2045	2050
ACT	($28)	($46)	($48)	($15)	$16	$44
ACT + NOx OMN	($41)	($65)	($62)	($26)	$4	$32
100x40 ZEV + Clean Grid	($59)	($90)	($80)	($16)	$64	$138

Table C13 Average Connecticut Household and Commercial Customer Electric Bill Savings in 2050

2020$	Household	Commercial Customer
ACT	$50	$215
ACT + NOx OMN	$50	$215
100x40 ZEV + Clean Grid	$78	$337

Based on average annual electricity use of 8,090 kWh per household and 34,840 kWh per commercial customer in Connecticut.

APPENDIX D: Results from Rhode Island Analysis

Table D1 Current Rhode Island M/HD Fleet

Vehicle Type		No. of Vehicles	Annual VMT (billion miles)	Annual Fuel (million gallons)
Heavy-Duty Pickup and Van **Class 2b**		15,406	0.17	9.3
Bus **Class 3–8**		3,205	0.06	7.3
Single-Unit Work and Freight Truck **Class 3–8**		28,014	0.34	42.3
Combination Truck **Class 7–8**		2,388	0.14	21.0
TOTAL		**49,013**	**0.718**	**79.8**

Table D2 Current Rhode Island M/HD Fleet's Share of Total Transportation Emissions

	M/HDV share of total on-road fleet
Greenhouse Gas Emissions	24%
NOx Emissions	50%
PM Emissions	44%
Share of On Road Vehicles	6%

Table D3 Projected M/HD Fleet Petroleum Fuel and Electricity Usage

	2050 M/HDV Petroleum Fuel Use (million Gallon)	Fuel Saved 2020-2050 (million Gallon)	2050 Residential and Commercial Electricity Use (million MWh)
Baseline	60	-	7.5
ACT and ACT + NOx Omnibus	29	400	8.1 (+8%)
100 x 40 + Clean Grid	5	700	8.4 (+12%)

Figure D1 Projected M/HD Fleet NOx Emissions

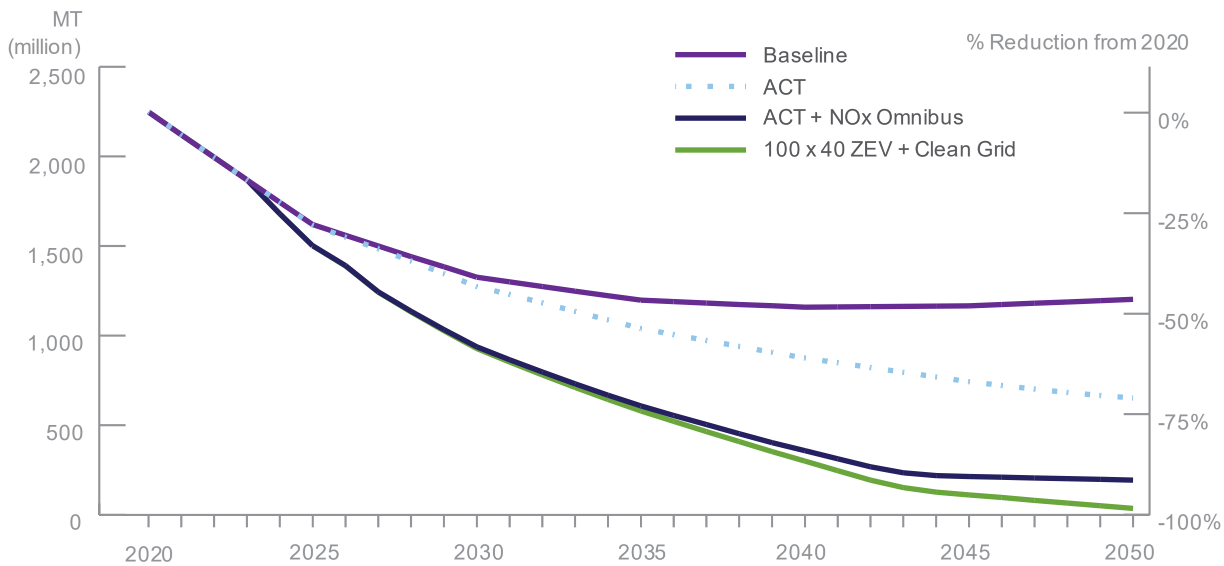


Figure D2 Projected M/HD Fleet PM Emissions

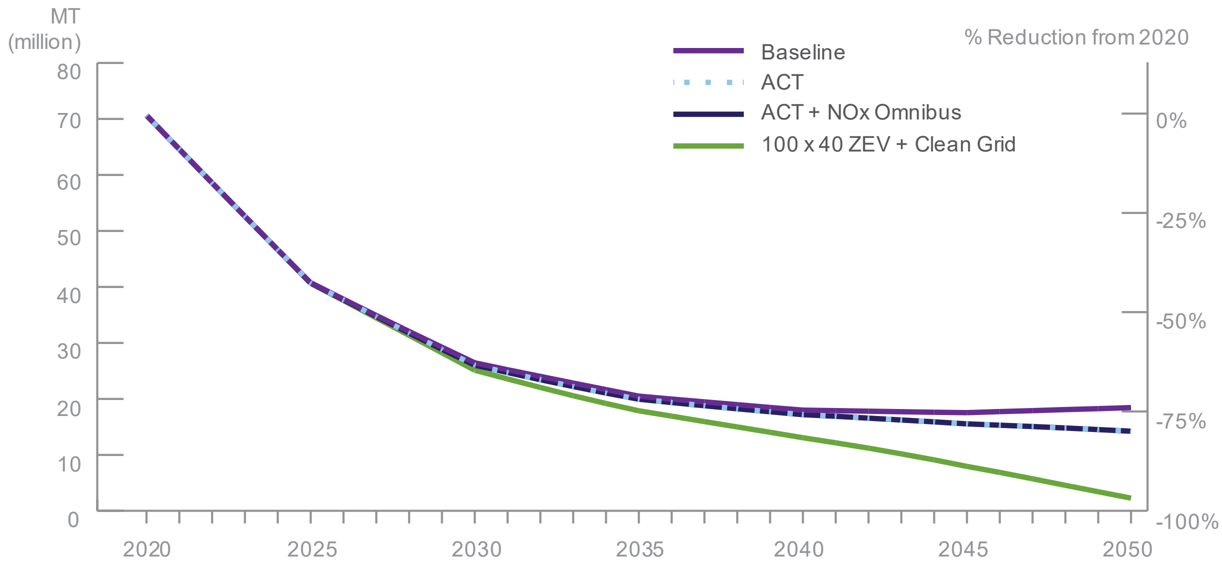


Table D4 Cumulative Public Health Benefits of Clean Truck Policy Scenarios, 2020–2050

Health Metric	ACT Rule	ACT + NOx Omnibus	100 x 40 ZEV + Clean Grid
Avoided Premature Deaths	6	13	17
Avoided Hospital Visits[a]	5	12	16
Avoided Minor Cases[b]	2,974	6,551	8,939
Monetized Value, 2020$ (millions)	$66	$148	$200

a Includes hospital admissions and emergency room visits.
b Includes reduced cases of acute bronchitis, exacerbated asthma, and other respiratory symptoms, and reduced restricted activity days and lost workdays.

Figure D3 Projected M/HD Fleet GHG Emissions

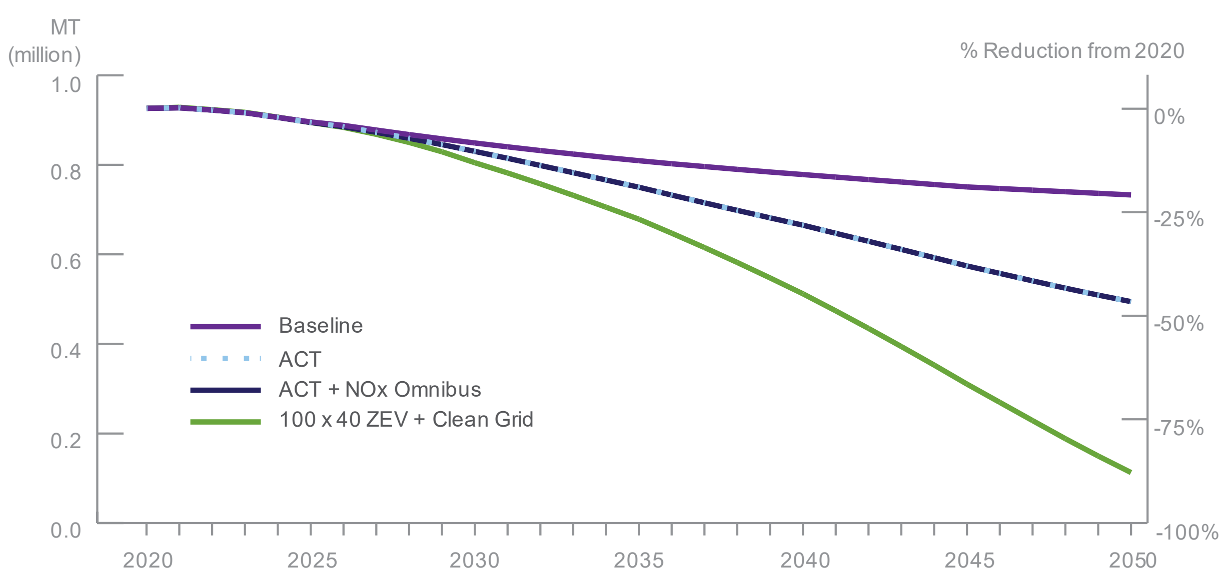


Table D5 Projected Cumulative M/HD Fleet Emissions Reductions (2020-2050)

	NOx (MT)	PM (MT)	GHG (mill MT)
ACT	6,232	32	2.5
ACT + NOx Omnibus	17,316	32	2.5
100x40 + Clean Grid	18,794	143	6.2

Figure D4 Projected Lifetime Incremental Costs for Rhode Island ZEVs Compared with Combustion Vehicles

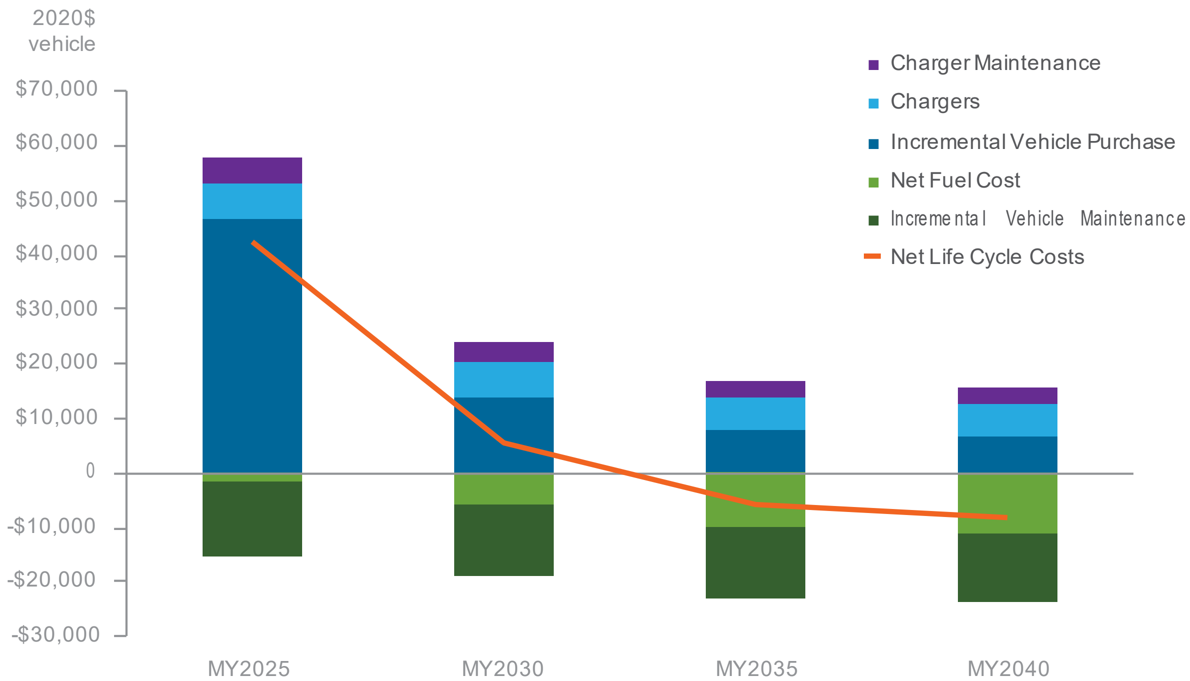


Figure D5	Projected Annual Utility Net Revenue from M/HD EV Charging

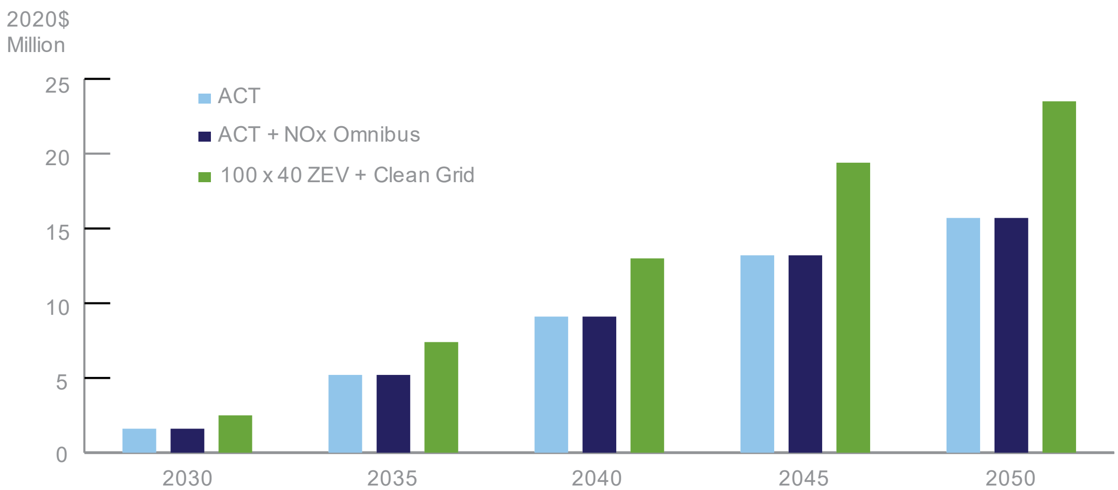


Table D6	Projected Changes in Electricity Usage and Demand from Rhode Island Clean Truck Policy Scenarios

	2030 Additional Electricity Sales (million MWh)	2050 Additional Electricity Sales (million MWh)	2030 Incremental Monthly Peak Charging Demand (MW)	2050 Incremental Monthly Peak Charging Demand (MW)
ACT and ACT + NOx Omnibus	0.06	0.6	16	208
100x40	0.09	0.9	25	305

Table D7	Macroeconomic Effects of Rhode Island Clean Truck Policy Scenarios

Metric		ACT + NOx Omnibus		100 x 40 ZEV + Clean Grid	
		2035	2045	2035	2045
Net Change in Jobs		114	7	131	-39
Net Change in GDP 2020$ (million)		$27	$35	$36	$48
Average Annual Compensation	Added Jobs	$100,345	$102,356	$102,343	$101,758
	Replaced Jobs	$45,388	$46,479	$45,240	$46,965

Table D8 Projected Charging Infrastructure Required for Clean Truck Policy Scenarios

Metric		ACT Rule			100 x 40 ZEV		
		2035	2045	2050	2035	2045	2050
Cumulative Charge Ports	Depot	7,274	21,440	26,752	10,974	34,136	42,402
	Public 150 kW	103	301	378	152	464	583
	Public 500 kW	35	93	117	52	187	254
Cumulative Investment, 2020$ (million)	Depot	$38	$108	$143	$58	$173	$233
	Public	$19	$50	$66	$28	$89	$123

Figure D6 Projected Annual Net Societal Benefits from ACT Rule Policy Scenario

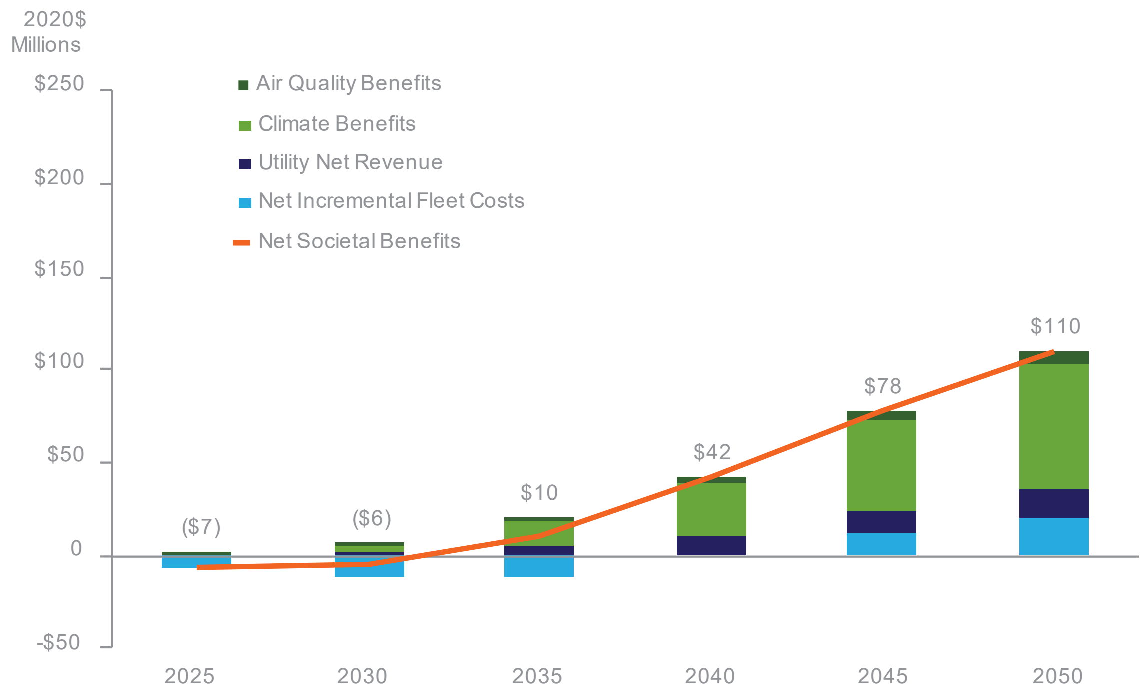


Figure D7

Projected Annual Net Societal Benefits from ACT + NOx Omnibus Policy Scenario

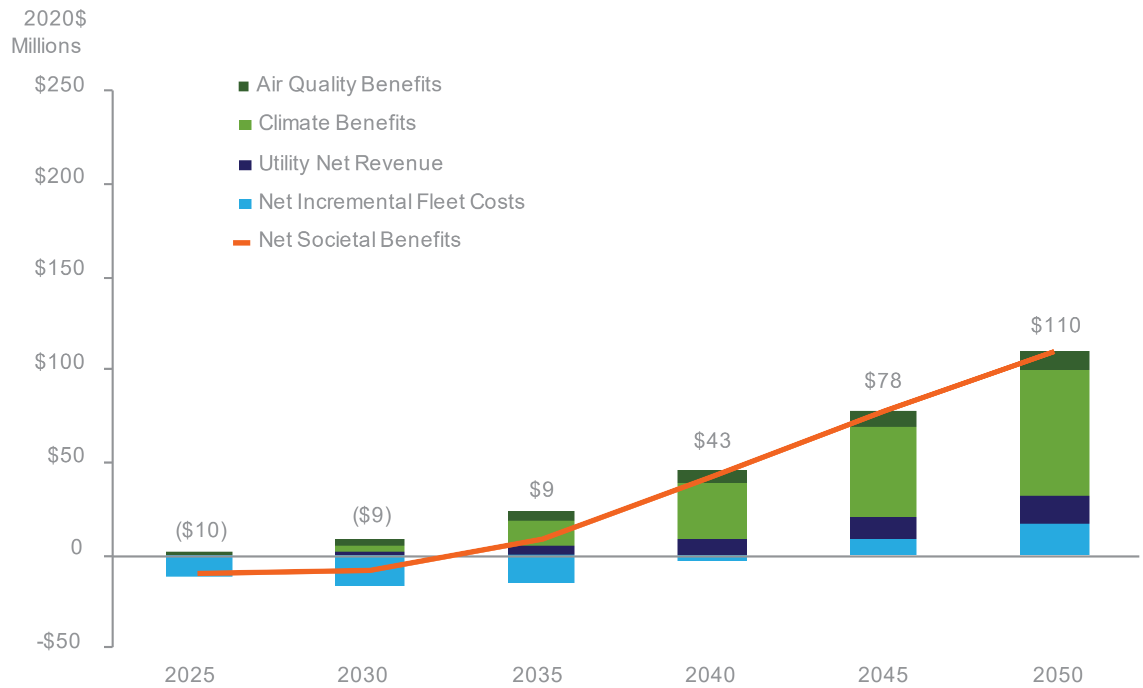


Figure D8

Projected Annual Net Societal Benefits from 100 x 40 ZEV + Clean Grid Policy Scenario

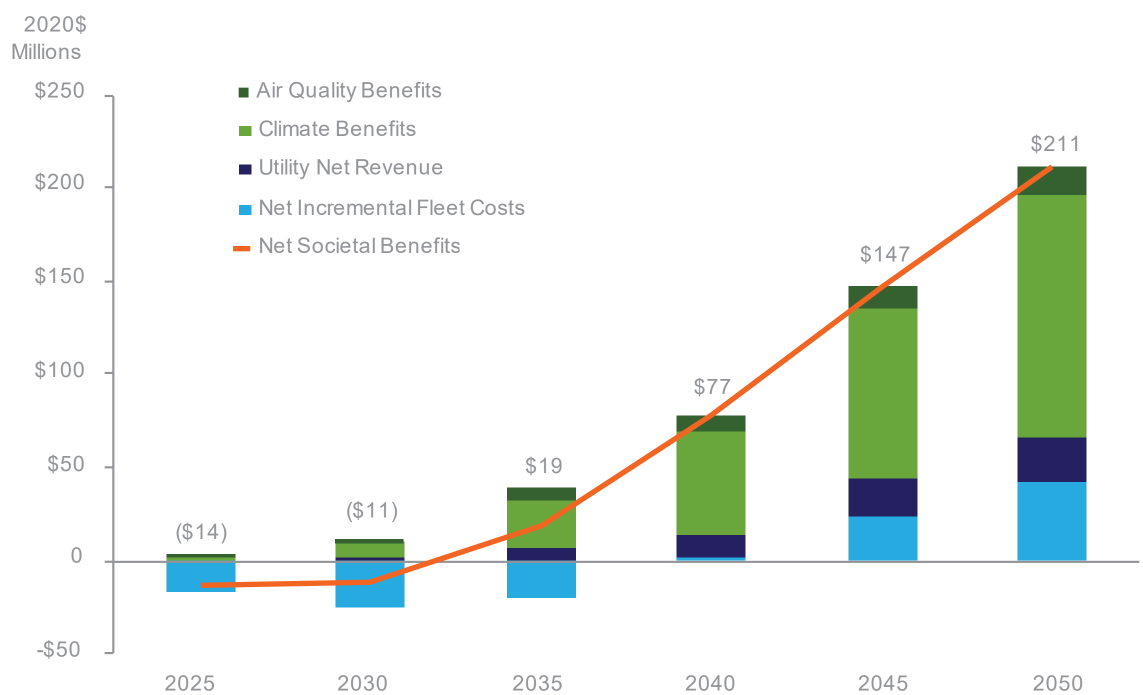


Table D9 Rhode Island Business as Usual Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	7.3%	7.4%	30.2%	31.0%	31.3%	38.8%	60.3%
Natural Gas	92.2%	92.0%	69.6%	68.9%	68.4%	60.8%	39.2%
Coal	0.6%	0.6%	0.1%	0.1%	0.3%	0.5%	0.5%

These business-as-usual grid mix assumptions were applied to the baseline, ACT Rule, and ACT + NOx Omnibus policy scenarios.

Table D10 Rhode Island Decarbonized Grid Mix Assumptions

Percent of Generation	2020	2022	2025	2030	2035	2040	2050
Zero-emitting	7.1%	7.2%	30.0%	64.1%	62.5%	73.1%	100.0%
Natural Gas	92.3%	92.3%	69.7%	35.8%	37.4%	26.8%	0.0%
Coal	0.6%	0.6%	0.3%	0.1%	0.1%	0.0%	0.0%

These Decarbonized grid mix assumptions were applied to the 100 x 40 ZEV + Clean Grid policy scenario.

For simplicity, results from EPA's Integrated Planning Model for coal, oil, and biomass were combined under "coal," as noted in the accompanying methodology report. The zero-emitting category includes nuclear and renewable resources such as wind, solar, and hydropower. Analysis of new, state-specific electricity policies, such as from more stringent Renewable Portfolio Standards, was beyond the scope of this study but would be expected to increase the usage of these renewable resources.

Table D11 M/HD In-Use ZEVs Population

M/HD In-Use ZEVs	2025	2030	2035	2040	2045	2050
Baseline	65	118	174	248	316	380
ACT	242	2,713	9,265	18,007	26,664	33,266
ACT + NOx OMN	242	2,713	9,265	18,007	26,664	33,266
100x40 ZEV + Clean Grid	323	4,082	13,753	27,792	42,306	52,710
Total M/HDV Fleet (ZEV + ICE)	50,582	51,644	52,732	53,845	54,982	56,149

Table D12 Net Incremental Fleet Benefits

2020$ (millions)	2025	2030	2035	2040	2045	2050
ACT	($7)	($12)	($11)	$0	$11	$20
ACT + NOx OMN	($11)	($18)	($15)	($3)	$8	$16
100x40 ZEV + Clean Grid	($16)	($25)	($19)	$1	$25	$42

Table D13 Average Rhode Island Household and Commercial Customer Electric Bill Savings in 2050

2020$	Household	Commercial Customer
ACT	$28	$107
ACT + NOx OMN	$28	$107
100x40 ZEV + Clean Grid	$41	$160

Based on average annual electricity use of 6,760 kWh per household and 26,170 kWh per commercial customer in Rhode Island.