


Pennsylvania Advanced Clean Cars II Program

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Acknowledgements

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EXECUTIVE SUMMARY

Nationally, light-duty vehicles (LDVs) currently make up almost 90 percent of all on-road vehicle miles traveled, and emit an estimated 67 percent of total greenhouse gas (GHG) emissions annually from the on-road vehicle fleet.[1] LDVs are also responsible for 33 percent of the nitrogen oxide (NOx) and 30 percent of the particulate matter (PM)[2] emitted by on-road vehicles, both of which contribute to poor air quality and negative health impacts in many urban areas, including in low-income and communities of color that are often disproportionately affected by emissions due to their proximity to transportation infrastructure.

For the study of Pennsylvania, ERM investigated the state adopting the Advanced Clean Cars II (ACC II) regulation under two different manufacturer compliance scenarios:

- Manufacturers, as expected, use many of their compliance flexibilities to comply with the regulation.
- Manufacturers do not use these flexibilities to meet compliance.

These two compliance strategies provide, respectively, a reasonable midpoint estimate and an upper limit of zero-emission vehicles (ZEV) placements under ACC II policy.[3] ERM also investigated the impact of Pennsylvania reaching 100 percent clean electricity by 2040 under both ACC II compliance scenarios.

Depending on the scenario chosen, the ACC II regulation will have significant cumulative net societal benefits through 2050. Shown in the table below are the cumulative benefits for each of the scenarios (in constant 2022 dollars).

Table 1: Cumulative Net Societal Benefits of ACC II Scenarios, 2027–2050

Scenario	Cumulative Net Societal Benefits ($ billions)
ACC II Flex	$136
ACC II Flex + Clean Grid	$150
ACC II Full + Clean Grid	$157

The cumulative net societal benefits illustrated above include the monetized value of climate and public health benefits resulting from reduced GHG, NOx, and PM emissions in the state, including up to 288 to 432 fewer premature deaths and 269 to 404 fewer hospital visits from breathing polluted air. Net societal benefits also include net cost savings to LDV owners from operating ZEVs 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. Between the different scenarios, by 2050 annual vehicle cost savings for Pennsylvania vehicle owners are estimated to be $7.5 billion.[4]

Implementing ACC II will require a continued shift in the automotive industry, as development and manufacturing of light-duty internal combustion engine vehicles transitions to producing new electric and plug-in hybrid vehicles. This change in vehicle technology will also affect the production and sale of petroleum fuels, which are replaced by increased generation and sale of electricity. This analysis indicates that this transition will have positive macroeconomic effects, including increased net jobs and

[1] The remainder of emissions are from commercial medium- and heavy-duty trucks.

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

[3] Under the ACC II rule, battery electric, fuel cell electric and plug-in hybrid electric vehicles meeting a minimum all-electric range of 50 miles are eligible ZEVs; however, for the purposes of this analysis, only battery electric and plug-in hybrids are considered.

[4] The modeling tools used for this analysis could not apportion these estimated benefits to individual communities within Pennsylvania.

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, all three ACC II scenarios result in positive net national job gains of approximately 3,500 by 2050. This will be accompanied by a $1.5 billion increase in 2050 GDP, across the scenarios. Average wages for the new jobs created under the ZEV transition are expected to be, on average, about 50% higher than average wages for the jobs that will be replaced.

INTRODUCTION

ERM was commissioned by the Natural Resources Defense Council to evaluate the costs and benefits of Pennsylvania adopting the ACC II regulation. This rule, recently adopted by California, would require vehicle manufacturers to increase sales of light-duty ZEV within the state, reaching 100 percent sales by 2035. The ramp up of these vehicles to reach that 2035 goal is affected by manufacturer's use of compliance flexibilities in the first 5 years of the program. The analysis examines on-road vehicles registered in Pennsylvania less than 8,500 pounds gross vehicle weight, encompassing passenger cars, crossovers, SUVs, and pickup trucks—collectively called light-duty vehicles (LDVs).[5]

The Pennsylvania LDV fleet includes nearly 8 million vehicles that annually travel more than 90 billion miles and consume more than 4 billion gallons of petroleum-based fuels.

Internal combustion engine (ICE) vehicles included in the LDV fleet emit criteria pollutant and greenhouse gas (GHG) emissions from their tailpipes that contribute to air pollution and climate change. Since the LDV fleet is projected to grow by 13 percent by 2050, this problem will only grow larger.

Advanced Clean Cars I and II

In 2012, California's Air Resource Board (CARB) adopted a regulation package to address criteria and GHG emissions from new LDVs. This package included the low emission vehicle (LEV) regulation for GHG and criteria emissions, and a manufacturer requirement to increase sales of ZEVs. Both regulations were applicable for model years (MY) 2015–2025.[6]

In 2022, CARB adopted the second phase of ACC, called ACC II, which increases the stringency of both the LEV and ZEV standards starting with MY 2026. The main goal of the ACC II program is to have all new passenger cars, light trucks, and SUVs sold in California be ZEV by 2035. To accomplish this, CARB developed a compliance trajectory that starts in MY 2026 and ramps up through 2035.

The ACC II regulation provides manufacturers with several types of flexibilities that can ease their transition to the required ZEV sales levels. The regulation measures compliance in terms of "vehicle values," which are obtained by manufacturing ZEVs, or through other provisions under which manufacturers can earn vehicle values, which then can be used to offset specified portions of the regulatory requirement for MY 2026 through 2031.[7,8]

CARB also increased the stringency of the LEV criteria pollutant standards for new ICE vehicles purchased in MY 2026 and beyond. As part of the new regulation, they eliminated several higher-emitting emission bins, introduced new lower-emission categories, and increased the durability requirements for vehicle's emission controls. On top of the per-vehicle emission certifications, they also changed the manufacturer's compliance requirements for fleet average oxides of nitrogen (NOx) and non-methane organic gas emissions, by phasing out ZEVs from being included in the average.

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[5] ACC II also includes requirements for some medium-duty vehicles up to 14,000 pounds gross vehicle weight. Because this weight range overlaps with California's Advanced Clean Truck rule, ERM assumed manufacturers would certify these vehicles under that rule rather than ACC II.

[6] California Air Resources Board. "States that have Adopted California's Vehicle Standards under Section 177 of the Federal Clean Air Act". May 13, 2022. https://ww2.arb.ca.gov/sites/default/files/2022-05/%C2%A7177_states_05132022_NADA_sales_r2_ac.pdf.

[7] Manufacturers can use vehicle values from early compliance, converted vehicle values, proportional fuel cell allowances, and state-to-state shifting, called "pooling". For further details on these compliance flexibilities, see Advanced Clean Cars II Program: An Analysis of the Impacts of Zero-Emission Light-Duty Vehicles on the Environment, Public Health, Industry, and the Economy — Methodologies and Assumptions, February 2023.

[8] Regardless of which year a state adopts the ACC II regulation, its first year of compliance must be aligned with California's model year compliance percentage in that year. For Pennsylvania, its first year of compliance would be MY 2027.

POLICY SCENARIOS

This report summarizes the projected environmental and economic effects of Pennsylvania adopting ACC II. To better understand the range of possible outcomes from adopting such a policy, three scenarios were modeled which varied the manufacturer compliance mechanisms as well as the electric grid. Three specific ACC II scenarios were evaluated:

- ACC II Flex: Pennsylvania adopts California's ACC II regulation starting in MY2027 and manufacturers use many of the compliance flexibilities discussed above.[9] Due to these flexibilities, manufacturers would be able to sell fewer ZEVs needed for compliance in Pennsylvania by about 14 percent of total sales in MY 2027 (i.e., about 29 percent of sales as opposed to the 43 percent of sales nominally required in that model year). A similar reduction of about 11 to 13 percent from the nominal requirement is assumed in each year for MYs 2028 through 2030, with full compliance needed in MY 2031 through the program's end in MY 2035. Under this scenario, new ICE vehicles that are purchased between MY 2027 and MY 2034 are certified to CARB's LEV standards.
- ACC II Flex + Clean Grid: Manufacturers follow the sales trajectories in the ACC II Flex scenario, and additionally Pennsylvania decarbonizes their electric grid faster than currently required and Pennsylvania reaches 100 percent clean generation by 2040.
- ACC II Full + Clean Grid: Pennsylvania adopts California's ACC II regulation and manufacturers do not use any of the compliance flexibilities discussed above. Under this scenario, manufacturers follow the "ACC II Full" compliance schedule shown on Figure 1. Like the ACC II Flex + Clean Grid scenario, this scenario assumes that Pennsylvania decarbonizes their electric grid faster than currently required and reaches 100 percent clean generation by 2040.

Additional details of the assumptions are provided in the corresponding technical document.[10] Figure 2 represents the resulting LDV in-use ZEV population starting in 2027 through 2050.

The Pennsylvania ACC II policy scenarios are compared with a baseline "business-as-usual" (BAU) scenario in which all new LDVs sold in the state continue to meet existing United States Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration vehicle standards,[11] and ZEV sales increase but never reach more than a third of new vehicle sales each year.[12]

[9] The ACC II regulation is structured such that manufacturers cannot simultaneously use the maximum amount of all available compliance flexibilities in all states. This scenario, based on projections provided by Shulock Consulting, provides a reasonable midpoint estimate of ZEV placements.

[10] *Advanced Clean Cars II Program: An Analysis of the Impacts of Zero-Emission Light-Duty Vehicles on the Environment, Public Health, Industry, and the Economy —Methodologies and Assumptions, February 202*3.

[11] For the BAU scenario, emission and vehicle standards are assumed to remain constant after 2025 and assume no introduction of more stringent emission regulations.

[12] The baseline ZEV sales assumptions used in this analysis were provided by Shulock Consulting based on estimates provided by NRDC.

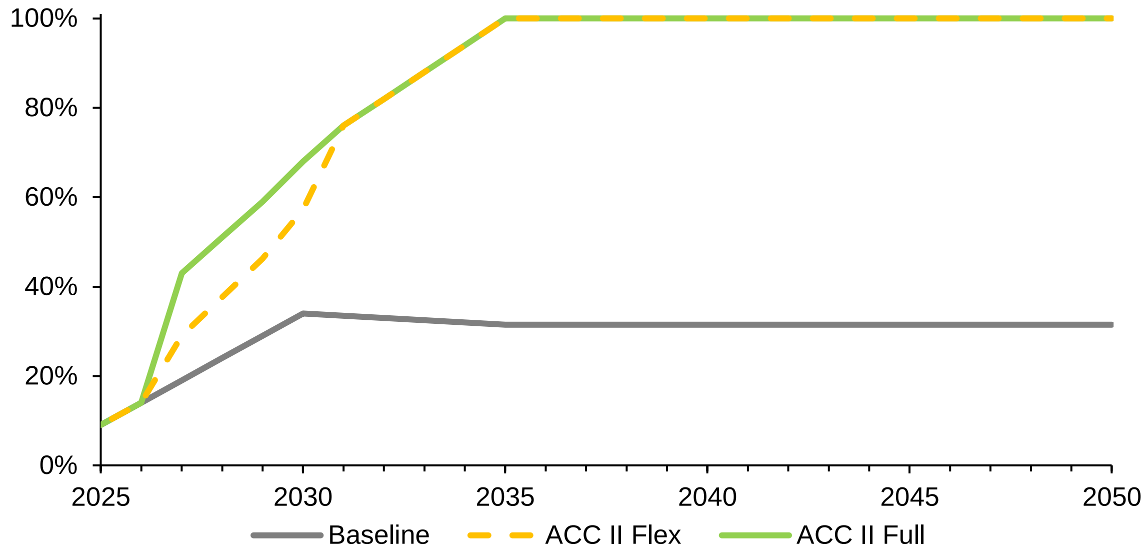

Figure 1: Annual Zero-Emission Vehicle Sales in ACC II Scenarios

The analysis assumes that light-duty annual vehicle miles traveled (VMT) in Pennsylvania will continue to grow by approximately 0.4 percent annually through 2050, as projected by the Energy Information Administration, as the economy and population continue to grow.

The analysis was conducted using ERM's Transportation Policy toolkit as well as baseline ZEV sales estimates from Shulock Consulting. The climate and air quality impacts of each scenario were estimated on the basis of changes in LDV fleet fuel use and include both tailpipe emissions and "upstream" emissions from production of the transportation fuels used in each scenario.[13] These include petroleum fuels used by conventional ICE vehicles (gasoline, diesel, natural gas) and electricity used by ZEVs, which are assumed to include both battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV).[14]

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 NO_x and PM emissions, and the 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 LDV 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 ICE vehicles, but they have lower fuel and maintenance costs. In addition, recent cost projections have shown that ZEVs are rapidly approaching cost parity with ICE vehicles, adding to the fuel and maintenance savings received by vehicle owners.[15]

[13] While tailpipe emissions are assumed to be captive within Pennsylvania, upstream emissions are not necessarily constrained to the state due to where petroleum fuel production and power generation take place. Regardless, reductions in upstream emissions will benefit society as a whole.

[14] Per ACC II stipulations, no more than 20 percent of a state's ZEV sales can be met with PHEV sales, which has been reflected in the analysis.

[15] Slowik, Peter et al. International Council on Clean Transportation (ICCT). "Assessment of Light-Duty Electric Vehicle Costs and Consumer Benefits in the United States in the 2022-2035 Time Frame". October 2022. https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf.

The analysis also estimated the impact of each scenario on Pennsylvania's electric utilities, including the total state change in power demand (kW) and energy consumption (kWh) for light-duty electric vehicle (LD EV) charging, as well as the additional costs that would be placed on the state's electric utilities for providing this power. Based on projected utility net costs, the analysis estimates the potential effect on state 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 LD EVs under each scenario—both residential chargers and shared public chargers—compared with the existing charging network in the state.

For a full description of the modeling approach and sources of assumptions used for this analysis, see Advanced Clean Cars II Program: An Analysis of the Impacts of Zero-Emission Light-Duty Vehicles on the Environment, Public Health, Industry, and the Economy —Methodologies and Assumptions, February 2023.

The Pennsylvania electric grid mix and energy cost assumptions used can also be found in Appendix A.

PENNSYLVANIA RESULTS

The sections below detail the results of the Pennsylvania ACC II analysis, beginning with a description of the current Pennsylvania LDV fleet and the projected vehicle fleet under each ACC II scenario. This is followed by a summary of the environmental and public health benefits of each scenario and the economic impacts of the modeled ZEV transition.

Pennsylvania LDV Fleet

This analysis uses current LDV fleet registrations in Pennsylvania as the starting point, then assumes future vehicle sales under each of the scenarios. In 2022, Pennsylvania had an estimated 10 million on-road LDVs registered, with the vast majority currently burning fossil fuels. 87.4 percent used gasoline, 6.9 percent used E85, 2 percent used gasoline hybrid, and 1.9 percent used diesel.[16] The remaining 1.8 percent was made up of Biodiesel (0.7 percent), BEVs (0.5 percent), PHEVs (0.2 percent) and unknown fuel (0.4%).[17]

The modeled scenarios envision an LDV fleet that transitions to ZEVs and sees significant reductions in fossil fuel combustion vehicles. Figure 2 summarizes the modeled turnover of the Pennsylvania in-use fleet to ZEV under the ACC II scenarios as well as the BAU. Fleet turnover to new LDVs is based on historical survival rates and projected fleet growth rates. Approximately 6 percent of existing LDVs are retired each year and replaced with new vehicles.[18]

The BAU scenario experiences substantial increases in ZEV adoption relative to current low levels with 9 percent of the LDV in-use fleet being ZEVs by 2030, 25 percent by 2040, and 30 percent by 2050. As shown, the compliance flexibilities reduce ZEV adoption in 2026 to 2030, after which both scenarios assume the same level of ZEV sales. Under both ACC II Flex vehicle sales scenarios (ACC II Flex and ACC II Flex + Clean Grid) 13 percent of the in-use LDV fleet will turn over to ZEV by 2030, 64 percent by 2040, and 92 percent by 2050. Under the ACC II Full scenario, the in-use ZEV percentage grows faster earlier, reaching 16 percent by 2030 and 66 percent by 2040. By 2050, all ACC II scenarios have 92 percent in-use ZEVs.

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16 Alternative Fuels Data Center (AFDC). "2022 Light-Duty Vehicle Registration Counts by State and Fuel Type." https://afdc.energy.gov/vehicle-registration.

17 AFDC. "2022 Light-Duty Vehicle Registration Counts by State and Fuel Type."

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

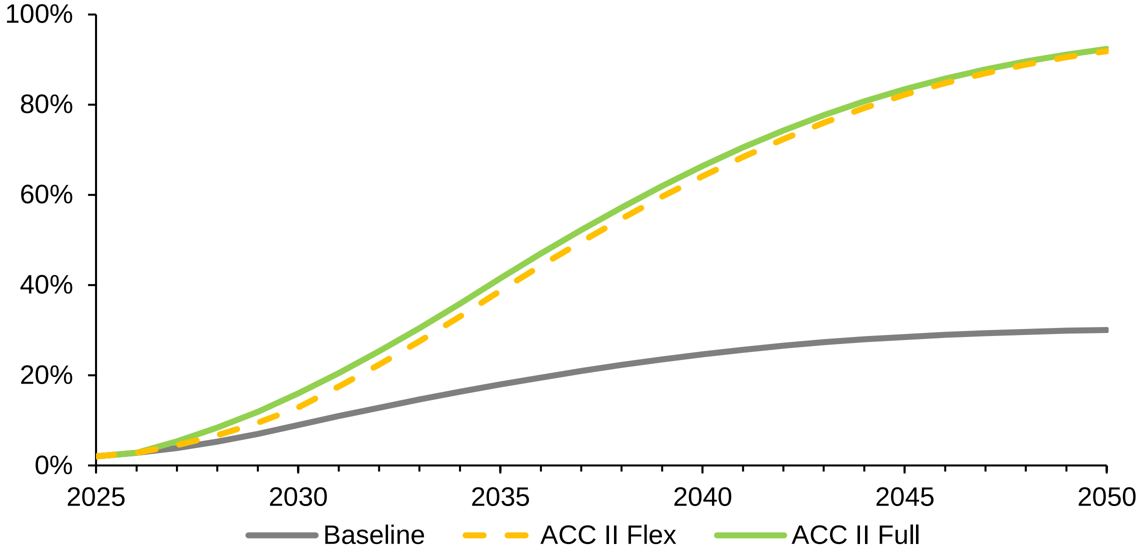


Figure 2: Fleet Turnover to Zero-Emission Vehicles in ACC II Scenarios

Changes in LDV Fuel Use

Under all modeled ACC II scenarios, ZEV sales result in a significant portion of the Pennsylvania LDV population turning over to BEVs and PHEVs. As more and more ZEVs enter operation, petroleum fuel use is replaced with electricity.

Under the baseline scenario, total petroleum fuel use by the Pennsylvania LDV fleet in 2050 is projected to be 2.3 billion gallons, and cumulative LDV fuel use is estimated to be 81 billion gallons between 2022 and 2050. Under the ACC II scenarios, petroleum fuel use in 2050 ranges from an estimated 144 to 154 million gallons (approximately a 93 percent decrease compared to estimated baseline scenario fuel use in 2050). Under the ACC II scenarios, cumulative fuel use by the LDV fleet is estimated to range between 52 to 53 billion gallons between 2022 and 2050. Therefore, compared to the baseline scenario, under the ACC II scenarios cumulative reductions in fuel use by the LDV fleet vary from 28 to 29 billion gallons between 2022 and 2050. This petroleum fuel is replaced by 284 to 299 million megawatt-hours (MWh) of electricity between 2022 and 2050. Electricity use for LD EV charging in 2050 is estimated to be about 21 million MWh, a 20 percent increase from the estimated baseline electricity use by Pennsylvania residential and commercial customers that year, according to AEO 2023 (106 million MWh)[19].

Public Health and the Environment

The modeled ACC II scenarios produce significant reductions in NOx, PM, and GHG emissions from the LDV fleet, even after accounting for the emissions from producing the electricity 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 LDV fleet NOx and PM emissions, respectively, under the baseline scenario and the modeled ACC II scenarios. Under the baseline scenario, annual LDV fleet NOx emissions are projected to fall by 59 percent and annual fleet PM emissions are projected to fall

[19] Energy Information Administration, Annual Energy Outlook 2023. March 2023.

32 percent through 2047, as the current fleet turns over to new gasoline and diesel vehicles with cleaner engines that meet more stringent EPA new engine emissions standards. After 2047 baseline annual NOx and PM emissions are then projected to start rising again as annual fleet VMT continues to grow.

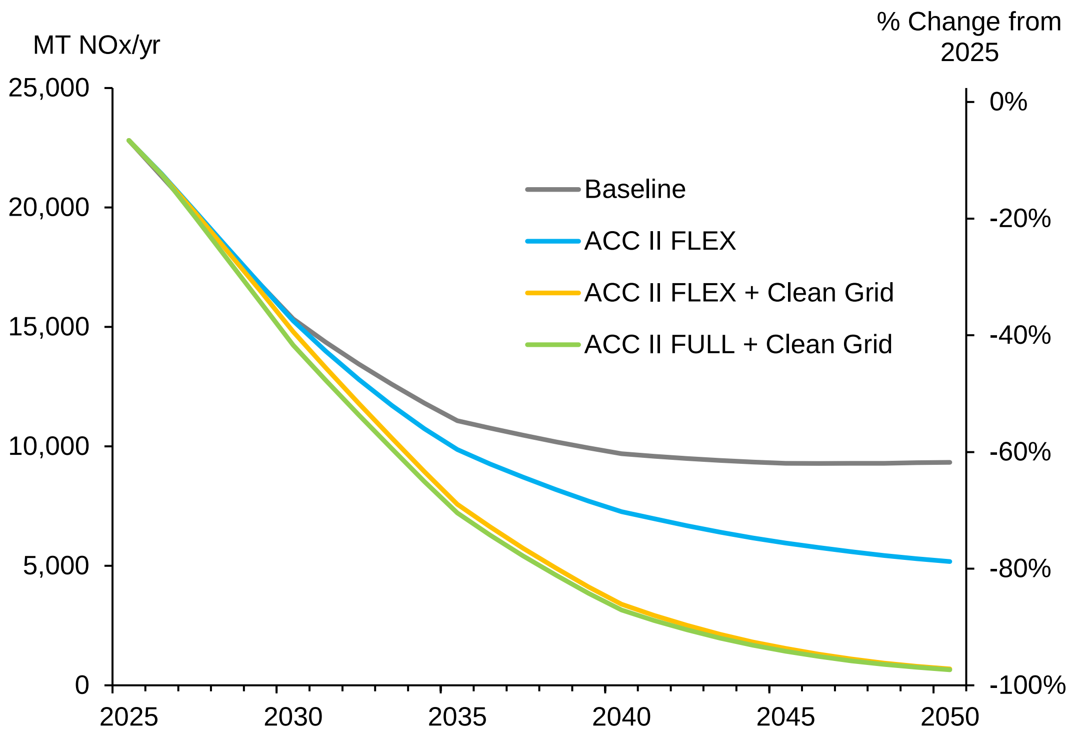


Figure 3: Projected LDV Fleet NOx Emissions

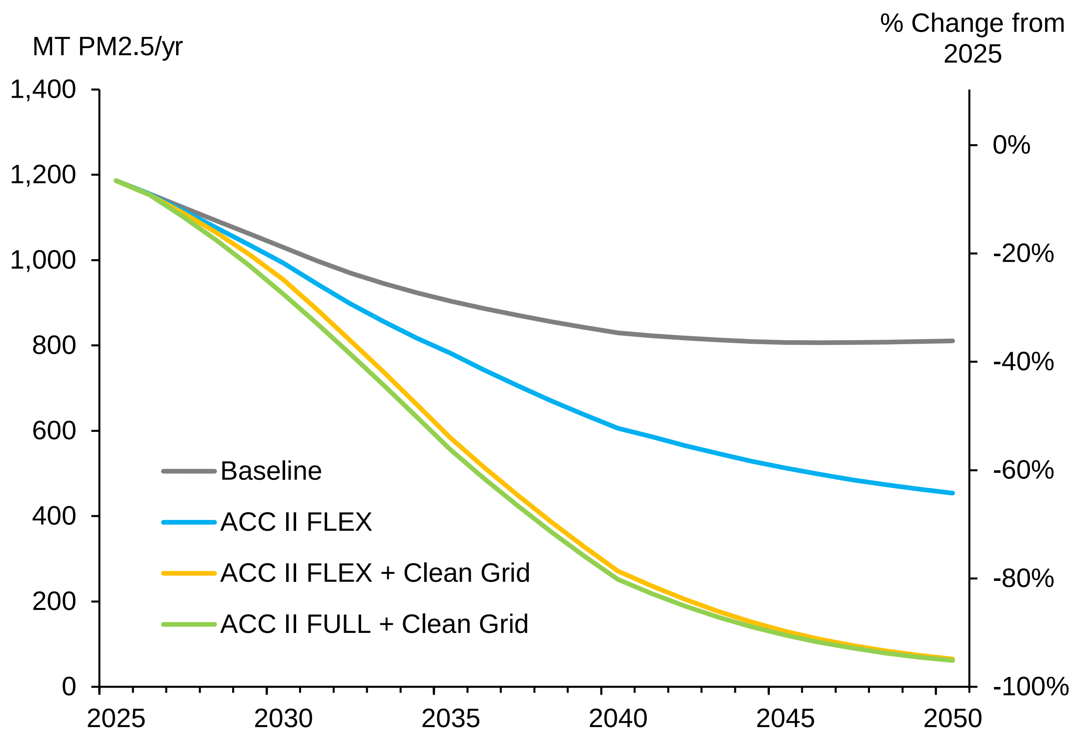


Figure 4: Projected LDV Fleet PM Emissions

Compared with the baseline, by 2050 the ACC II Flex scenario with a baseline grid is projected to reduce annual LDV fleet NOx and PM emissions by 77 percent and 62 percent, respectively. Both ACC II scenarios, Flex and Full with a clean grid are estimated to reduce annual LDV fleet NOx and PM emissions by 97 percent and 95 percent, respectively, as ICE vehicles are phased out and replaced with electric vehicles. As shown on Figures 3 and 4, emission levels during the ACC II compliance period, as well as several years after, vary between scenarios due to the compliance trajectories assumed, as well as the grid emission intensity.

Cumulative NOx and PM emission reductions from the ACC II scenarios (compared with the baseline scenario) range from 48,100 to 122,700 metric tons (MT) and 4,400 to 10,800 MT, respectively.

Public Health Benefits

The reduced annual NOx and PM emissions under the ACC II scenarios will decrease ambient particulate levels in the air, which will reduce negative health effects on Pennsylvania residents breathing in these airborne particles.[20] 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 Pennsylvania under the modeled ACC II scenarios are shown in Table 2; these benefits were estimated using the EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool.

[20] 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.

Table 2: Cumulative Public Health Benefits of ACC II Scenarios, 2027–2050

Health Metric	ACC II Flex	ACC II Flex + Clean Grid	ACC II Full + Clean Grid
Avoided Premature Deaths	288	410	432
Avoided Hospital Visits[a]	269	383	404
Avoided Minor Cases[b]	160,752	214,196	226,197
Monetized Value, 2022 dollars (billions)	$3.8	$5.4	$5.7

[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.*

As shown, the monetized value of cumulative public health benefits from the ACC II Flex scenario totals about $3.8 billion. If Pennsylvania also implements strategies to reduce grid emissions such that electricity is 100 percent clean by 2040 (ACC II Flex + Clean Grid scenario) this would marginally increase the monetized value of cumulative net public health benefits to $5.4 billion. The monetized value of cumulative public health benefits under the ACC II Full + Clean Grid scenario also totals $5.7 billion through 2050.

Climate Benefits

Figure 5 illustrates estimated annual LDV fleet GHG emissions under the baseline scenario and the modeled ACC II scenarios. As shown, under the baseline scenario annual LDV fleet GHG emissions are projected to fall by 29 percent through 2050 as roughly one-third of the fleet electrifies, and the remaining ICE vehicles turn over to new, more efficient vehicles that meet more stringent EPA GHG emission and National Highway Traffic Safety Administration fuel economy standards.

Compared with the baseline, by 2050 all three ACC II scenarios are estimated to further reduce annual fleet GHG emissions due to increased sales of ZEVs. ACC II Full + Clean Grid reduces GHG emissions by 10 percent relative to the baseline in 2030—compared to only about a 4 percent reduction under ACC II Flex—due to the increase in ZEV adoption as well as the cleaner grid. The ACC II Flex Scenario scenarios realizes approximately a 60 percent reduction in GHGs by 2050 compared to the baseline, while both the ACC II Clean Grid Scenarios realize a 94 percent reduction.

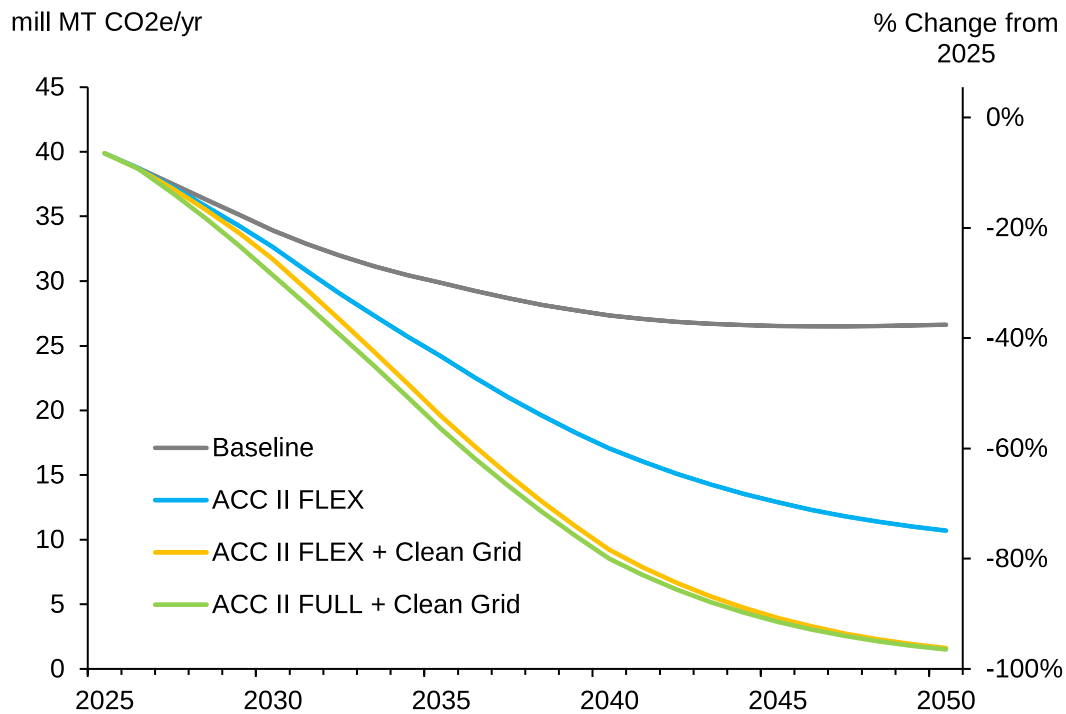


Figure 5: Projected LDV Fleet GHG Emissions

From 2027 through 2050, cumulative GHG emission reductions under the ACC II Flex scenario (compared with the baseline scenario) total 202 million MT, while cumulative GHG emission reductions from the ACC II Flex + Clean Grid scenario are projected to total 340 million MT, and the ACC II Full + Clean Grid scenario are projected to total 367 million MT. These estimates of GHG reductions from each scenario account for reductions in petroleum fuel use (gasoline, diesel fuel) by the LDV fleet, the decreased upstream emissions from gasoline and diesel production, as well as increased emissions from electricity production to fuel the EVs that will replace gasoline and diesel vehicles.

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 $17.7 billion for the ACC II Flex scenario, $29.8 billion for the ACC II Flex + Clean Grid scenario, and $31.8 billion for the ACC II Full + Clean Grid policy scenario.[21] The social value of GHG reductions represents potential societal cost savings from avoiding the negative effects of climate change, if GHG emissions are reduced enough to keep long-term warming below 2 degrees Celsius from preindustrial levels.[22]

The assumed grid mix for electricity production each year is shown in the Appendix for Pennsylvania. For the baseline and ACC II Flex scenario, this analysis uses a BAU grid mix, while the ACC II Flex + Clean Grid and ACC II Full + Clean Grid scenarios assume a grid mix that decarbonizes more quickly. In 2022, the BAU grid mix is 17.2 percent coal-fired generation, 48.8 percent natural gas-fired generation, and 34 percent "zero-emitting" generation sources. By 2030, the zero-emitting portion of the BAU grid mix

[21] For the social cost values used, see ERM's *Advanced Clean Cars II Program: An Analysis of the Impacts of Zero-Emission Light-Duty Vehicles on the Environment, Public Health, Industry, and the Economy—Methodologies and Assumptions.* February 2023.

[22] The Interagency Working Group developed GHG social cost estimates using a range of discount rates. These values are based on the average 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.

decreases to 32.9 percent while the coal portion decreases to 1.5 percent and gas decreases to 65.6 percent. By 2040, the BAU grid reaches about 35 percent zero-emitting, 63.2 percent gas and 2 percent coal. Lastly, by 2050, the BAU grid reaches 42.4 percent zero-emitting, 1.8 percent coal and 55.8 percent natural gas.

Under the ACC II Flex + Clean Grid and ACC II Full + Clean Grid scenarios, zero-emitting generation shifts to 70.5 percent in 2030 and reaches 100 percent in 2040.

Economic Impacts

This section summarizes projected economic impacts of the modeled ACC II scenarios, including changes in annual operating costs for Pennsylvania vehicle owners, impacts to Pennsylvania electric utilities and their customers, net societal benefits, and macroeconomic effects on jobs, wages, and GDP from the transition to zero-emission LDVs. This section also estimates the required public and private investment in electric vehicle charging infrastructure to support the electric LDV fleet under each scenario.

ZEV Owner Costs and Benefits

Average Incremental Costs for ZEV Owners

For all the modeled ACC II scenarios, this analysis estimated annual incremental costs associated with purchase and use of LD ZEVs compared with baseline conventional vehicles with combustion engines that operate on petroleum fuels. The analysis includes the incremental purchase cost of the new ZEV (instead of a new combustion vehicle), the cost of charging infrastructure, and the lifetime net fuel and maintenance costs.

Net fuel costs include reductions in purchases of petroleum fuels (due to fewer combustion vehicles), offset by the increased purchase of electricity 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 infrastructure.

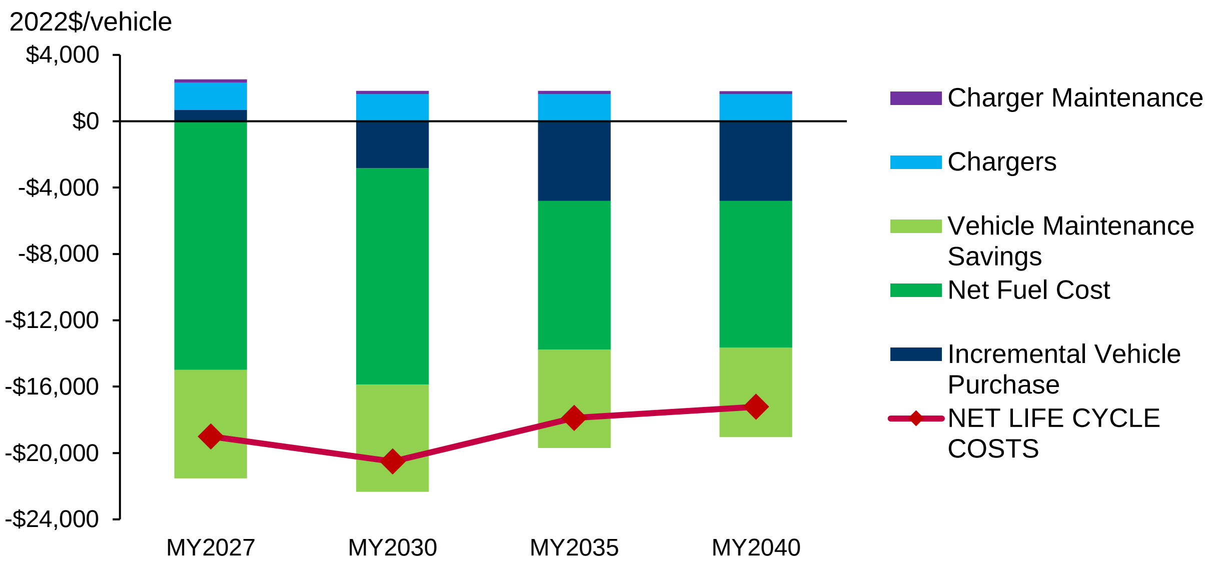


Figure 6: Average Incremental Cost for Pennsylvania ZEVs Compared with Combustion Vehicles

Figure 6 shows projected average lifetime incremental costs for new ZEVs purchased in Pennsylvania compared with lifetime costs for combustion vehicles purchased in the same MY; the bars show fleet average values for all LD ZEVs purchased each year under the ACC II Full + Clean Grid scenario. Incremental fuel and maintenance costs are discounted lifetime costs, assuming 16-year vehicle life, and 7 percent annual discount rate.

As shown, the average LD ZEV in Pennsylvania is projected to produce between $14,000 and $22,000 in discounted fuel and maintenance cost savings over its lifetime. The average LD ZEV and charger purchased in MY 2027 will cost $2,320 more than an ICE vehicle, but the fuel and maintenance savings outweigh the projected incremental cost of vehicle as well as the charger costs, resulting in nearly $19,000 in lifetime savings. For MY 2030 and beyond, the average ZEV purchase price is projected to be lower than the average ICE vehicle, such that the ZEV owners will realize savings up to $20,500 over the lifetime of the vehicle. Net fuel costs shown in Figure 6 do not account for utility customer savings (discussed further below) and their potential to reduce utility rates – if these adjustments were included, net fuel savings and the resulting lifetime savings would be higher.

It is important to reiterate that the values on Figure 6 are average values, which masks variability across different vehicle types (e.g., passenger cars vs pickup trucks) or for different charging behaviors (e.g., home charging vs public direct current fast chargers [DCFC]).

LD ZEVs with smaller battery packs and reduced range will likely achieve lifetime cost parity with combustion vehicles earlier than 2026, while vehicles equipped with bigger batteries or all-wheel drive may lag current estimates predicted. Note that this analysis and the values shown on Figure 6 do not account for government incentives for vehicle purchase or development of fueling infrastructure. A recent study by ICCT and Energy Innovation estimate that the LDV tax credits provided under the Inflation Reduction Act could offer between $3,400 to $6,150 in incentives to vehicle owners.[23] If these tax credits,

[23] Slowik, Peter et al. International Council on Clean Transportation (ICCT) and Energy Innovation Policy & Technology LLC. "Analyzing the Impact Of The Inflation Reduction Act On Electric Vehicle Uptake In The United States". January 2023. https://theicct.org/wp-content/uploads/2023/01/ira-impact-evs-us-jan23-2.pdf.

as well as other potential incentives such as improved electricity rates for EV charging are considered, then actual net costs to vehicle owners will be lower, resulting in purchase price parity sooner and increased savings for ZEV owners.

Incremental Cost for Rural ZEV Owners

As discussed in the previous section, the average ZEV owner in Pennsylvania could save between $17,000 and $21,000, depending on the year of vehicle purchase and assuming 'typical' annual VMT. For rural drivers, who must travel further distances for work, school, or shopping, annual mileage can be much higher than the typical vehicle owner. Due to this higher mileage and potentially less access to charging infrastructure, ZEV owners may choose to purchase a vehicle with a longer range, such as a PHEV with 70 miles all-electric range or a BEV with 400 miles of all-electric range. These vehicles, due to their larger battery packs, will have a higher upfront purchase cost than other ZEVs, but the added battery capacity of these vehicles will help alleviate range concerns and could reduce (or eliminate) the need for ad-hoc charging on longer trips.

To better understand the cost impact of ZEV ownership for rural drivers in the state, the same cost calculation as described in the previous section was performed but with the assumption that ZEV owners purchase a longer-range offering and operate their vehicle 16,500 miles per year (approximately 62 percent more than the national average).[24] While the initial cost of the vehicle is higher, rural ZEV owners also experience increased fuel and maintenance savings due to the longer distances driven per year.

[24] US DOT Federal Highway Administration. Highway Statistics 2020. Table VM-1, 2020 Average miles traveled per vehicle – All Light Duty Vehicles (10,165 miles per vehicle). https://www.fhwa.dot.gov/policyinformation/statistics/2020/vm1.cfm.

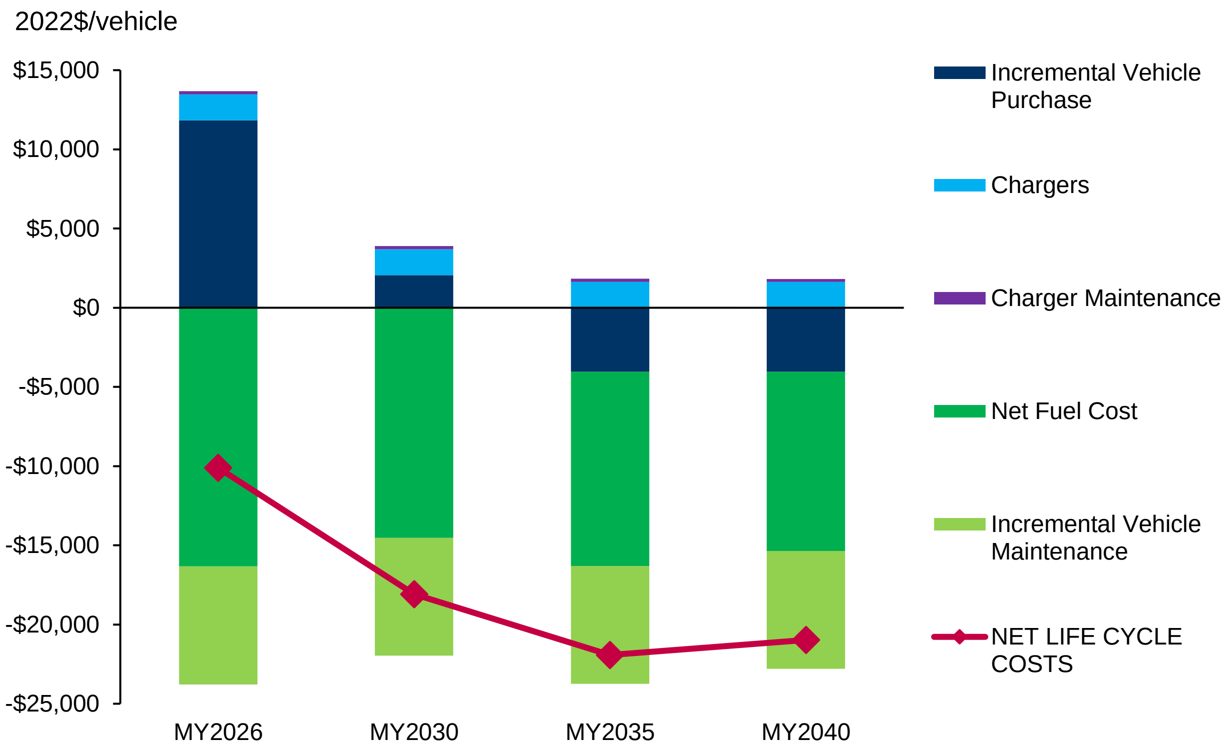


Figure 7: Average Incremental Cost for Pennsylvania Rural ZEVs Compared with Combustion Vehicles

As shown on Figure 7, for MY 2027, rural ZEV owners save around $10,100 over the lifetime of the vehicle. This is lower than the lifetime savings for average ZEV owners and caused by the higher cost of a rural longer-range ZEV over the average ZEV. By MY 2030, there is greater annual savings of approximately $18,100 resulting from reduced maintenance costs and falling incremental purchase cost of a rural ZEV over a comparable ICE vehicle. This trend continues after MY 2030, with savings increasing to about $22,000. Net fuel costs shown in Figure 7 do not account for utility customer savings (discussed further below) and their potential to reduce utility rates – if these adjustments were included, net fuel savings and the resulting lifetime savings would be higher.

Also note that rural drivers could alternatively choose to purchase a shorter-range ZEV to minimize the upfront cost. In turn, they will need to rely on publicly available charging infrastructure to refuel their vehicles on longer trips. Public charging stations, especially direct current fast chargers (DCFCs), can incur higher costs compared with charging at home, which can increase the charger and fuel costs for a vehicle.[25]

Used Light-duty Vehicle Market

Historically, used car prices have steadily increased from 1997 to 2019, and have exponentially increased in the past three years (2020 to 2023), as shown on Figure 8.[26] Cox Automotive tracks monthly pricing

[25] Gorzelany, Jim. "What it Costs to Charge an Electric Vehicle". https://www.myev.com/research/ev-101/what-it-costs-to-charge-an-electric-vehicle.

[26] "Manaheim Used Vehicle Value Index". https://publish.manheim.com/content/dam/consulting/ManheimUsedVehicleValueIndex-LineGraph.png.

trends in the U.S. used vehicle market using their 'Manheim Used Vehicle Value Index (MUVVI)'. The MUVVI applies statistical analysis to its database of more than 5 million used vehicle transactions annually.[27] Manheim's MUVVI measures used vehicle prices, independent of underlying shifts in the characteristics of vehicles being sold. The monthly MUVVI has been increasingly recognized by both financial and economic analysts as the premier indicator of pricing trends in the used vehicle market. The MUVVI differs slightly from the Consumer Price Index (CPI) in that its index accounts for seasonal adjustments based on vehicle mixes and mileage, whereas the CPI does not.

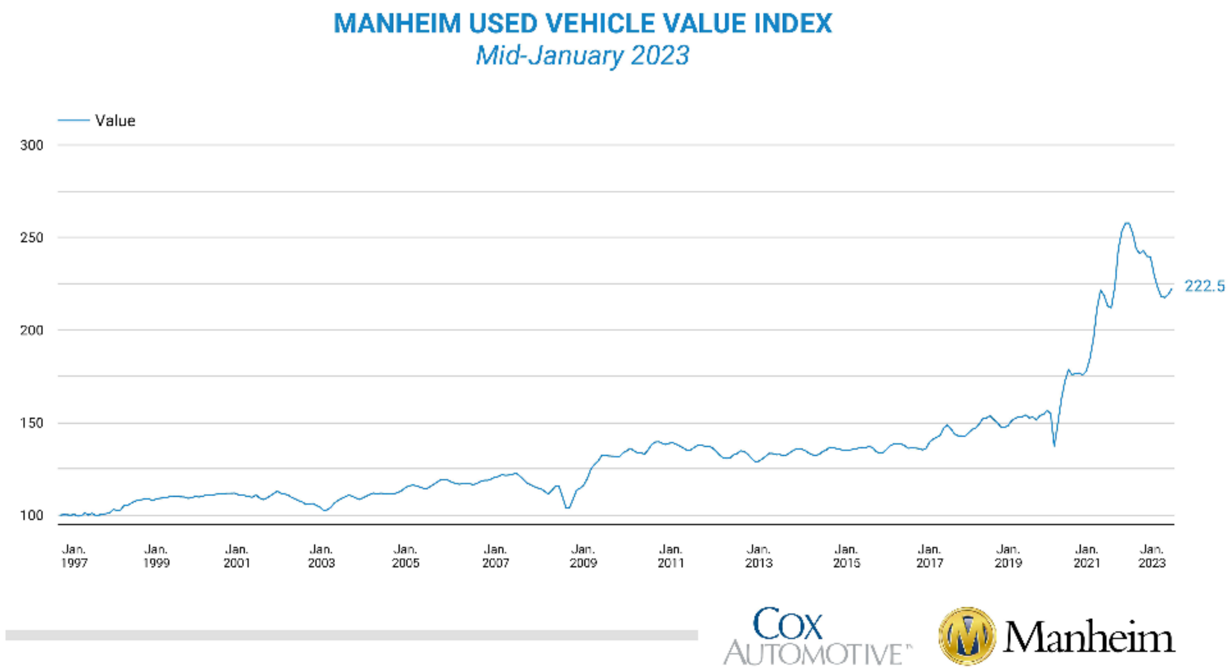


Figure 8: Manheim Used Vehicle Value Index (Mid-January 2023)

In 2021 and 2022, used vehicle prices rose due to global supply chain disruptions. These supply chain issues, including ongoing microchip shortages and elevated raw material costs, have been exacerbated due to recent geopolitical events and continue to impact the availability of new vehicles. The shortage of new cars has fueled demand for used cars, causing prices to surge in 2021 and 2022. This creates a compounding issue, as fewer new vehicles on the road also mean there are fewer second-hand vehicles to trade in, straining used car inventories. Many reports indicate that used car prices likely peaked at the end of 2022.[28] However, with uncertainty prevailing with the impacts of COVID-19 and geopolitical events on the supply chain and inventory, it may take more time for new vehicle sales to pick up the pace and the used vehicle market to return to its normal upward price trajectory.

In response to rising prices, President Biden signed the Inflation Reduction Act (IRA), which provides incentives for clean energy and transportation technologies, including an EV tax credit for new and used vehicles. Beginning in 2023, the IRA established a used clean vehicle tax credit (electric vehicles or fuel cell vehicles [FCVs]) of 30 percent of the sale price up to a maximum credit of $4,000. To qualify, a used vehicle must meet these requirements:

27 The MUVVI excludes heavy trucks and motorcycles.

28 Brinkman, Ryan. J.P. Morgan. "Inflation and the Auto Industry: When Will Car Prices Drop?" February 22, 2023. https://www.jpmorgan.com/insights/research/when-will-car-prices-drop.

- Have a sale price of $25,000 or less;
- Have a model year at least two years earlier than the calendar year when you purchase it;
- Have a gross vehicle weight rating of less than 14,000 pounds;
- Be an eligible FCV or plug-in EV with a battery capacity of at least 7 kWh;
- Be for use primarily in the United States.

Although it is unclear how the dynamic between new and used vehicle sales will look in the future, vehicle tax credits will help incentivize consumers to choose cleaner vehicle options, while providing them the flexibility to purchase new or used vehicles that are within their budgets. Additionally, more states adopting the ACC II regulation would rapidly accelerate the prevalence of EVs in the marketplace. This rapid increase in new EV availability is expected to lead to growth in the used EV market, as first-generation EV drivers may choose to sell their vehicles to the used car market. While complementary policies may be required, ACC II is a policy that would make this technology and its benefits more accessible to more individuals, regardless of their income level.

Electric Utility Impacts

Projected annual electricity sales to residential and commercial customers in Pennsylvania total 97 million MWh in 2030 and are projected to grow to 106 million MWh in 2050.[29]

Under the ACC II scenarios, additional annual electricity sales for LD EV charging are estimated to range from 1.6 to 2.8 million MWh in 2030, rising to 21 million MWh in 2050. This incremental load represents 1.6 to 2.8 percent and roughly 20 percent of the total electricity demand in 2030 and 2050, respectively. Incremental monthly peak charging demand under the ACC II scenarios is between 270 to 482 MW in 2030, and 4,671 to 4,708 MW in 2050.

This analysis estimated the revenue that Pennsylvania electric utilities would receive from these incremental electricity sales, the marginal generation and transmission costs of providing this power, and the net costs that utilities would realize (net costs = 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 9 summarizes the estimated annual utility net revenue from LD EV charging under the modeled ACC II scenarios. Under the ACC II Flex and ACC II Flex + Clean Grid scenarios, annual net utility revenue for LD ZEVs is projected to be $66 million in 2030, increasing to $737 million in 2040 and $1,043 million in 2050. Under the ACC II Full + Clean Grid scenario, utility net revenue is projected to be $117 million in 2030, rising to $767 million in 2040 and to $1,046 million in 2050.

[29] This growth assumption is from the EIA Annual Energy Outlook 2023. It does not include sales to large industrial customers.

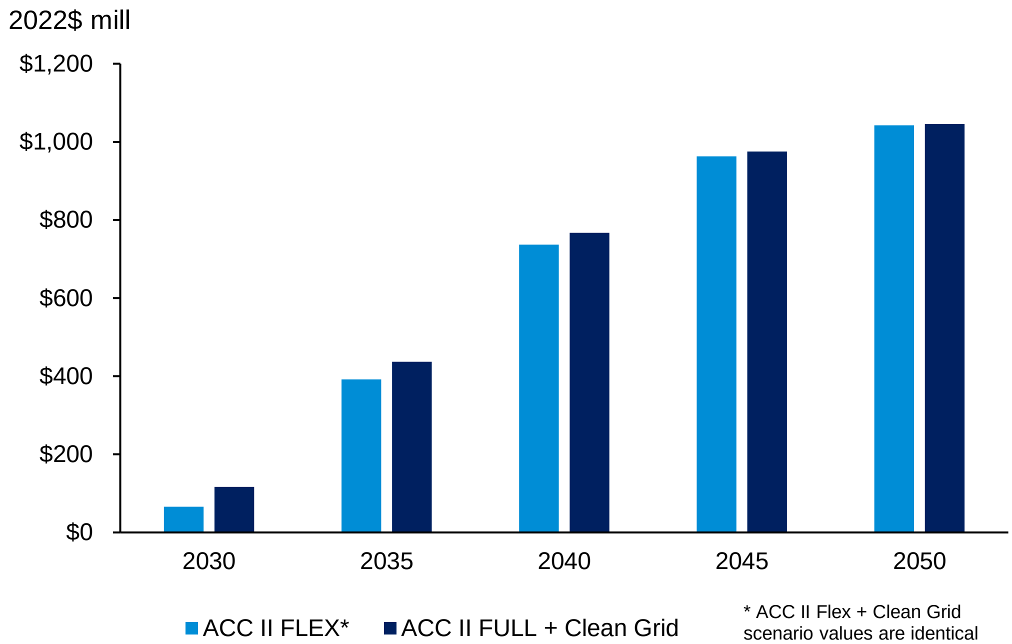


Figure 9: Projected Annual Utility Net Revenue from LD EV Charging

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 Pennsylvania Public Utility Commission via periodic increases in residential and commercial electric rates. However, projected utility net revenue from increased electricity sales for LD EV charging could lower energy distribution rates ($/kWh), since fixed annual distribution system costs would be spread over a larger energy sales base. This analysis indicates that utility net revenue from LD ZEV charging, could potentially reduce average residential and commercial electricity rates in Pennsylvania by as much as 5.4 percent ($0.0176/kWh in 2022 dollars) by 2050. This could save the average Pennsylvania household around $180 per year and the average commercial customer $895 per year on their electricity bills (2022 dollars).[30]

Required Public and Private Investments

Using a detailed charging model that considers typical daily usage patterns, this analysis assumes that most LD ZEVs in Pennsylvania will use overnight charging at single family and multi-family homes, though about 26 percent will need to rely on a publicly accessible network of chargers.[31] Overnight charging is assumed to meet the needs of the vast majority of vehicle owners, however owners without dedicated parking such as apartment buildings and locations where charging infrastructure will be difficult to site will need to rely on publicly available chargers.

The charging model evaluates the effect of ZEV charging on the Pennsylvania grid under a "managed" charging scenario, assuming that ZEV owners participate in a utility managed charging program where

[30] Figures are based on average annual electricity use of 8,157 kWh per housing unit and 34,014 kWh per commercial customer in Pennsylvania.

[31] See the methodology report for a detailed discussion of LD EV charging needs.

owners plug in and charge their vehicles during designated periods of lower energy demand, rather than just charging their vehicles as soon as they arrive at home.

Home chargers are assumed to be either Level 1 (e.g., a standard 120V outlet) or Level 2, which requires a dedicated 208-240V circuit but can reduce charging times and provide flexibility to coincide with utility designated charging periods. Level 1 chargers can only add about 3 to 5 miles of range per hour, while Level 2 chargers can add 12 to 80 miles of range per hour, depending on the rating of the charger. [32] For public charging, two types of chargers were modeled – public Level 2 and DCFC ports, with the latter able to provide 150 to 350 kW of energy and the ability to replenish 3 to 20 miles of range per minute of charging.[33]

As of September 2023, there were 1,521 publicly accessible charging stations in Pennsylvania with a total of 2,896 public Level 2 ports and 893 DCFC ports (>50 kW).[34] There were at least 57 fast-charging Tesla supercharger stations that currently can be used only by Tesla owners.[35] In Pennsylvania, there were only 268 DCFC ports fully available to any vehicle.

Table 3 summarizes the estimated charging infrastructure required to support LD electric vehicles under the ACC II scenarios.

Table 3: Projected Charging Infrastructure Required for ACC II Scenarios

Metric		ACC II Flex*			ACC II Full + Clean Grid		
		2030	2040	2050	2030	2040	2050
In-Use Charge Ports	Home L1	7,055	74,688	122,076	12,599	78,907	123,042
	Home L2	263,906	2,793,993	4,566,767	471,325	2,951,854	4,602,878
	Public L2	1,445	15,294	24,998	2,580	16,158	25,196
	Public DCFC	911	9,645	15,765	1,627	10,190	15,889
Cumulative Investment, 2022 dollars (billions)	Home	$0.39	$4.40	$8.90	$0.70	$4.70	$9.20
	Public	$0.14	$1.50	$3.10	$0.24	$1.60	$3.20

** Represents both the ACC II Flex and ACC II Flex + Clean Grid scenarios due to equal number of ZEVs assumed under both scenarios.*

Under the ACC II Flex and ACC II Flex + Clean Grid scenarios, Pennsylvania's LDV owners will have to invest an average of $357 million per year (2022 dollars) between 2027 and 2050 to purchase and install home-based charging infrastructure. The government and private investors will need to invest an average of $123 million per year over the same time period to build out a publicly accessible charging network across the region to serve the EV LD fleet.

Under the ACC II Full + Clean Grid scenario, fleet investments in home charging infrastructure from 2027 to 2050 increase to an average of $369 million per year (2022 dollars), and public and private investments in the public charging network rise to an average of $128 million per year.

[32] Moloughney, Tom. "What are the Different Levels of Electric Vehicle Charging?", October 4, 2021, https://www.forbes.com/wheels/advice/ev-charging-levels/

[33] Ibid.

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

[35] Tesla state-by-state list of superchargers, https://www.tesla.com/findus/list/superchargers/United%20States.

Jobs, Wages, and GDP

The transition from gasoline and diesel LD 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).[36]

This analysis used the Impact Analysis for Planning (IMPLAN) model to estimate these macroeconomic effects of the modeled Pennsylvania ACC II scenarios based on estimated changes in spending in various industries (relative to the baseline scenario). These estimates of spending change by industry and were developed from the fleet cost analysis. For example, under the modeled ACC II scenarios, more money will be spent to manufacture batteries and electric drive components for ZEVs, but less will be spent to manufacture ICE engines and their transmissions. Similarly, vehicle owners will spend less money to purchase petroleum fuels, but more will be spent to purchase electricity.

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 savings for ZEV owners.

The IMPLAN analysis was run at the national level, but assuming only the industry spending changes (from application of the ACC II regulation) occurring due to LD vehicle purchase and use in Pennsylvania. Table 3 offers a summary of estimated macroeconomic effects of the modeled ACC II scenarios on jobs, GDP, and wages.

[36] For example, in-state charging infrastructure is estimated to increase by 1,734 jobs in 2050 under the most aggressive scenario.

Compared with the baseline scenario, adoption of the ACC II Flex, ACC II Flex + Clean Grid and ACC II Full + Clean Grid scenarios will increase national net jobs through 2050 by around 3,500 jobs. The scenarios also increase annual GDP through 2050 by about $1.5 billion. For all scenarios in all years, the average wages for new jobs added to the economy are higher than average wages for jobs that are replaced by about 50%. 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 4: Macroeconomic Effects of Pennsylvania ACC II Scenarios

Metric		ACC II Flex*			ACC II Full + Clean Grid		
		2030	2040	2050	2030	2040	2050
Net Change in Jobs		13,858	6,437	3,531	19,661	5,856	3,466
Net Change in GDP 2022 dollars (millions)		$2.24	$1.71	$1.53	$3.21	$1.67	$1.53
Average Annual Compensation	Added Jobs	$103,112	$92,741	$90,318	$103,187	$92,620	$90,305
	Replaced Jobs	$66,495	$61,824	$60,995	$66,158	$61,659	$60,983

** Represents both the ACC II Flex and ACC II Flex + Clean Grid scenarios due to equal number of ZEVs assumed under both scenarios.*

With passage of the IRA,[37] where tax incentives are tied to U.S. manufactured ZEVs and their batteries, the government is heavily investing in the domestic EV, EV battery, and EVSE industries. The scale of U.S. macroeconomic effects from the modeled ACC II scenarios will depend on how the emerging LD ZEV industry develops; for this analysis, ERM assumed that all incremental spending on ZEV batteries and electric drivetrain components would be in the United States. As such, the results summarized in Table 3 represent a higher-end estimate of what is possible from the ZEV transition, assuming the IRA domestic incentives are successful in spurring development of U.S.-based ZEV component manufacturing. If vehicle manufacturers rely on imported batteries and electric drivetrain components, the net job and GDP gains will be lower than those summarized here.

This macroeconomic analysis includes direct, indirect, and induced impacts from changes in LD vehicle manufacturing and use, and from consumer re-spending of net utility revenue and ZEV owner savings.

Net Societal Benefits

The net societal benefits from the modeled Pennsylvania ACC II scenarios include the monetized value of public health and climate benefits, net cost savings for vehicle owners, and net utility costs from increased electricity demand for EV charging.

Figure 10 presents estimated cumulative net societal benefits (2027–2050) under the ACC II Flex, ACC II Flex + Clean Grid, and ACC II Full + Clean Grid scenarios, respectively. Under all three ACC II scenarios for all years, cumulative net societal benefits are positive, due to incremental vehicle savings, utility net revenue, as well as public health and climate benefits.

[37] Yarmuth, John. H.R.5376 – Inflation Reduction Act of 2022. August 16, 2022. https://www.congress.gov/bill/117th-congress/house-bill/5376/text.

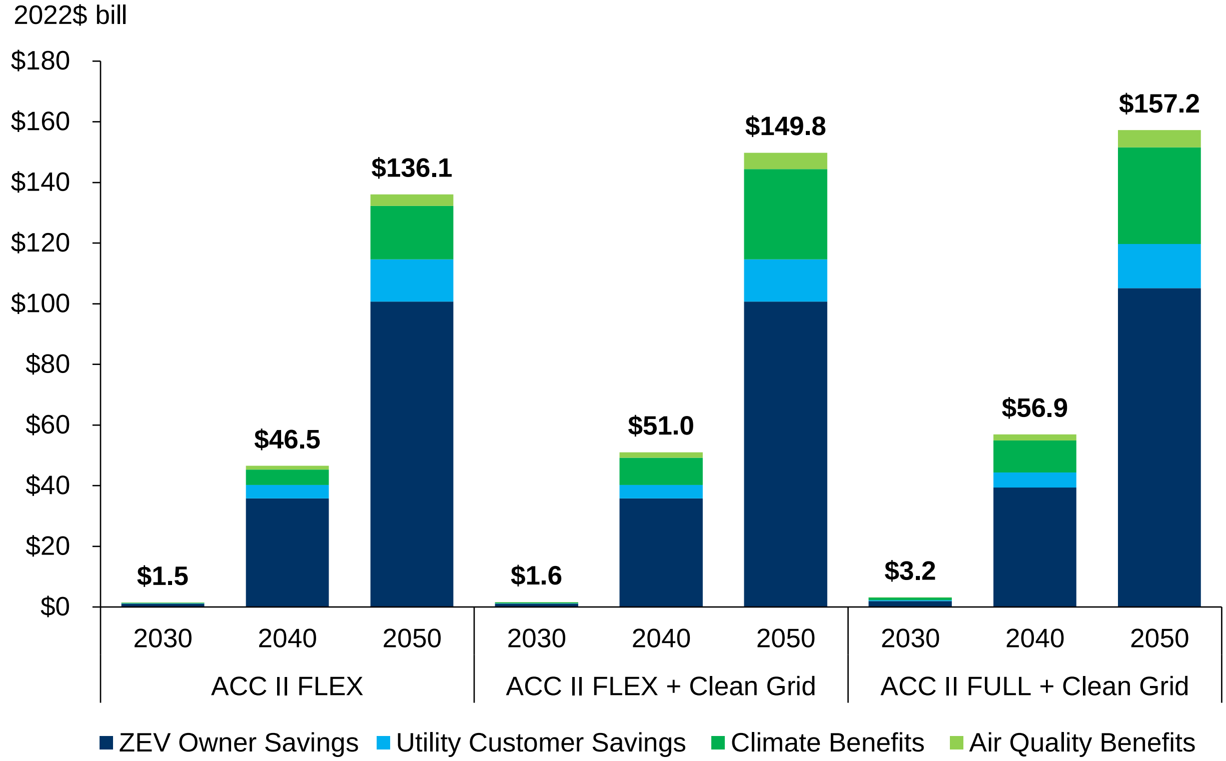
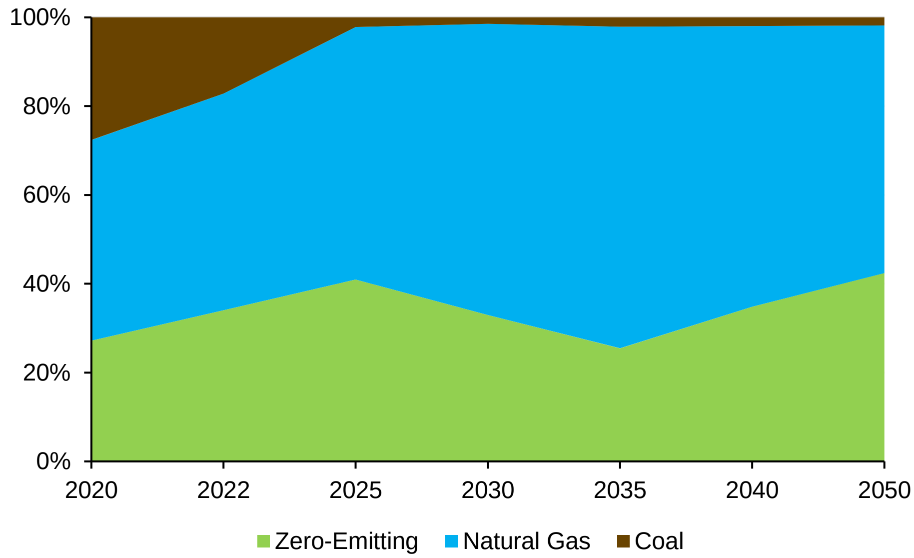


Figure 10: Projected Cumulative Net Societal Benefits from ACC II Scenarios

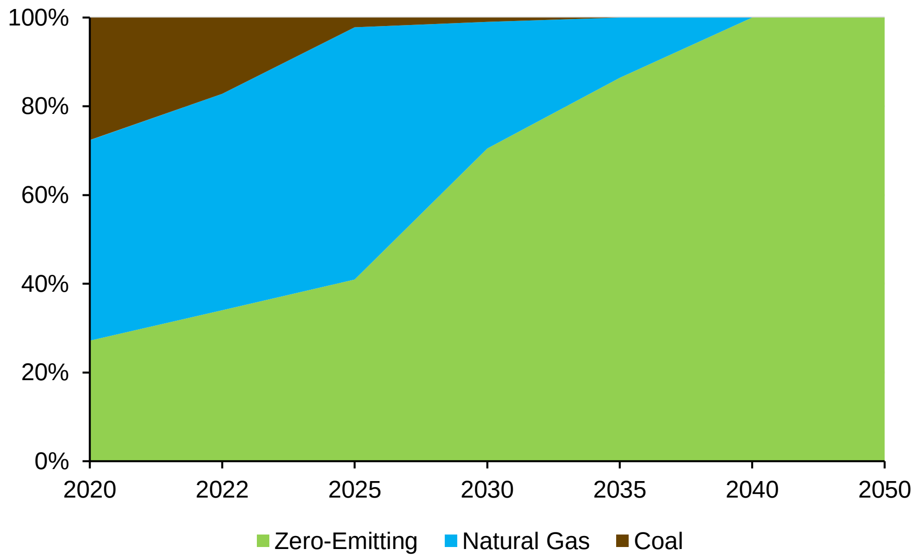
Under the ACC II Flex with BAU grid scenario, the cumulative estimated net societal benefits increase from $1.5 billion by 2030 to $46.5 billion by 2040, and $136.1 billion by 2050. Under the ACC II Flex with Clean Grid scenario, the cumulative estimated net societal benefits increase from $1.6 billion by 2030 to $51.0 billion by 2040, and $149.8 billion by 2050. Under the ACC II Full + Clean Grid scenario, the cumulative estimated net societal benefits increase to total $3.2 billion by 2030, $56.9 billion by 2040, and $157.2 billion by 2050.

APPENDIX A PENNSYLVANIA ENERGY COST ASSUMPTIONS AND SUPPLEMENTAL MATERIAL



These BAU grid mix assumptions were applied to the baseline and the ACC II Flex scenarios.

Figure A1: Pennsylvania Business-as-usual Grid Mix Assumptions



These decarbonized grid mix assumptions were applied to both the ACC II Flex + Clean Grid and ACC II Full+ Clean Grid scenarios.

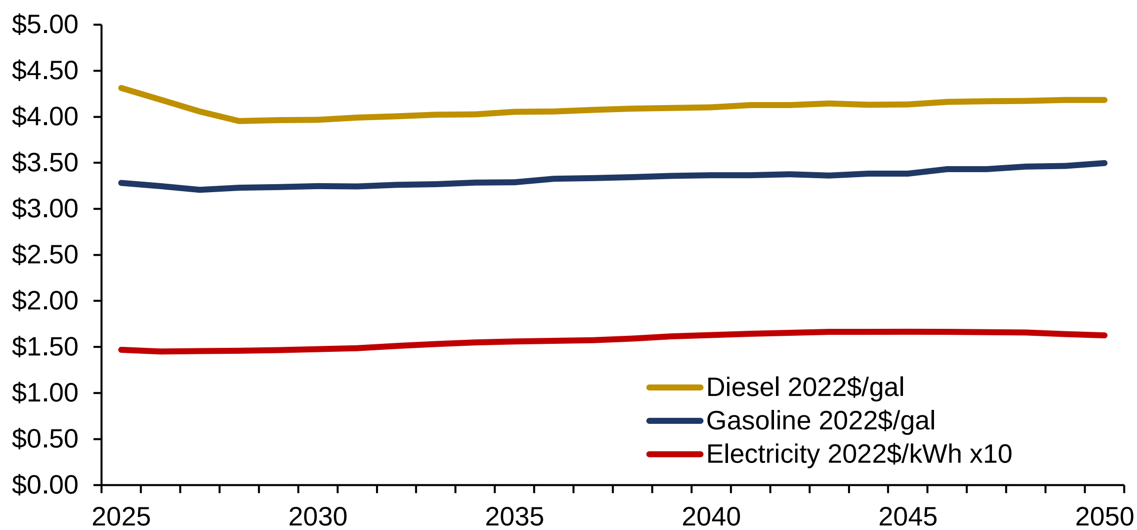
Figure A2: Pennsylvania Decarbonized Grid Mix Assumptions

Table A1: Net Incremental Fleet Benefits

2022 dollars (billions)	2030	2035	2040	2045	2050
ACC II Flex	$0.64	$3.49	$5.18	$6.38	$7.45
ACC II Flex + Clean Grid	$0.64	$3.49	$5.18	$6.38	$7.45
ACC II Full + Clean Grid	$1.09	$3.77	$5.36	$6.46	$7.48

Table A2: Average Pennsylvania Household and Commercial Customer Electric Bill Savings in 2050

2022 dollars	Household	Commercial Customer
ACC II Flex	$179	$894
ACC II Flex + Clean Grid	$179	$894
ACC II Full + Clean Grid	$180	$896



Source: EIA AEO 2023 and ERM analysis

Figure A3: Pennsylvania Average Fuel Costs

Table A3: Annual LDV Climate Reductions in Pennsylvania under ACC II Scenarios

Million Metric Tons CO_2e	2030	2035	2040	2045	2050
ACC II Flex	1.3	5.7	10.3	13.6	15.9
ACC II Flex + Clean Grid	2.2	10.3	18.1	22.6	25.0
ACC II Full + Clean Grid	3.5	11.3	18.8	22.9	25.1

Table A4: Annual LDV NOx Reductions in Pennsylvania under ACC II Scenarios

Metric Tons NOx	2030	2035	2040	2045	2050
ACC II Flex	84	1,209	2,423	3,329	4,149
ACC II Flex + Clean Grid	532	3,502	6,296	7,749	8,644
ACC II Full + Clean Grid	1,093	3,870	6,540	7,861	8,681

Table A5: Annual LDV PM Reductions in Pennsylvania under ACC II Scenarios

Metric Tons PM	2030	2035	2040	2045	2050
ACC II Flex	37	122	223	294	357
ACC II Flex + Clean Grid	76	321	558	677	745
ACC II Full + Clean Grid	110	349	578	686	749