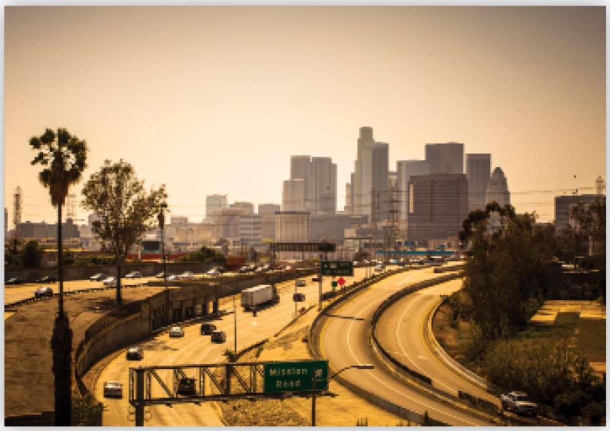
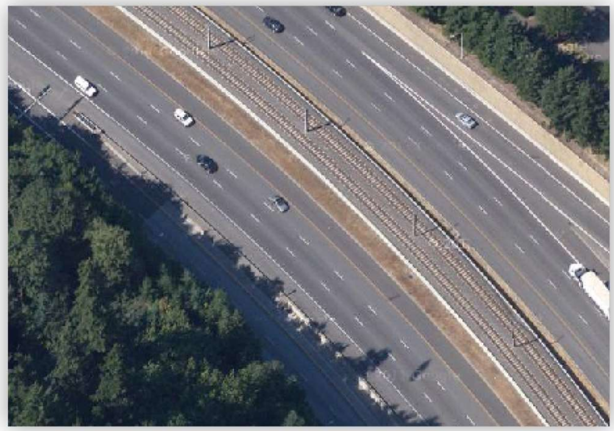
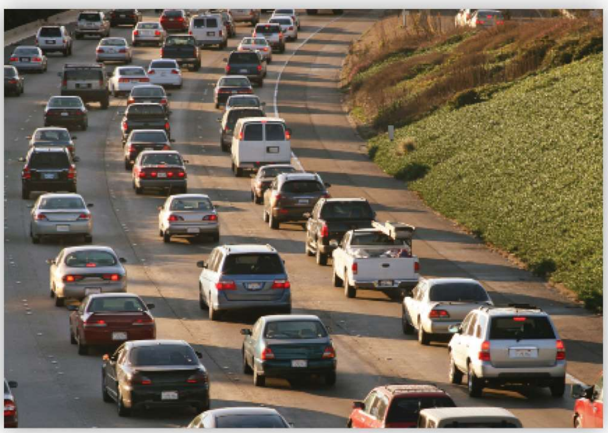
# Benefits of Adopting California's Advanced Clean Cars II Standards in Sixteen U.S. States


Final Report Prepared for

The International Council on Clean Transportation
San Francisco, CA
Northeast States for Coordinated Air Use Management
Boston, MA

April 2023

This document contains blank pages to accommodate two-sided printing.

# Benefits of Adopting California's Advanced Clean Cars II Standards in Sixteen U.S. States


## Prepared by

Jeff Houk
Joey Huang
Eric Sussman

Contact: Jeff Houk, jhouk@sonomatech.com
Sonoma Technology
1450 N. McDowell Blvd., Suite 200
Petaluma, CA 94954
Ph 707.665.9900 | F 707.665.9800
sonomatech.com

## Prepared for

Peter Slowik
The International Council on
Clean Transportation
595 Market Street, Suite 1250
San Francisco, CA 94105
Ph 415.818.0206
theicct.org/

Jeremy Hunt
Northeast States for
Coordinated Air Use Management
89 South Street, Suite 602
Boston, MA 02111
Ph 617-259-2042
nescaum.org



## Final Report

STI-922029-7866

April 26, 2023

# Contents

# Figures



# Tables

# Executive Summary

This report documents the technical steps and findings of our project to help the International Council on Clean Transportation (ICCT) and the Northeast States for Coordinated Air Use Management (NESCAUM) evaluate the benefits of adopting California's Advanced Clean Cars II (ACC II) standards in 16 other states. The California Air Resources Board (CARB) adopted these standards on August 25, 2022.[1] These standards require increasing sales of zero-emission vehicles (ZEVs) in the light-duty vehicle (LDV) fleet, to cover 100% of new sales by 2035. For the remaining new LDV sales prior to that date, CARB is imposing more stringent pollutant emissions standards. These standards also apply to some medium-duty vehicles.

The analysis of program benefits for each of the 16 states was conducted by Sonoma Technology with technical input on data and methods from the ICCT and NESCAUM. The overall analysis approach is summarized below:

1. Baseline emissions modeling using the U.S. Environmental Protection Agency's (EPA) MOtor Vehicle Emission Simulator 3 (MOVES3) model was conducted. MOVES was run at the County scale for the representative counties in each state used in EPA's National Emissions Inventory (NEI). MOVES input data and growth rates relevant to the analysis were provided by each state, and these were used along with NEI input data. Emissions modeling was conducted for 2017 as a base year, 2030, and 2040. Results for the representative counties were scaled to the statewide level using apportionment factors developed for the NEI.

2. The baseline MOVES output was adjusted in post-processing to account for the benefits of ACC II. The adjustment factors for oxides of nitrogen ($NO_x$), fine particulate matter ($PM_{2.5}$), volatile organic compounds (VOCs), and carbon dioxide equivalent ($CO_2e$) were developed using baseline and ACC II rule emissions inventories provided by CARB. Adjustment factors for sulfur dioxide ($SO_2$) and ammonia ($NH_3$) were calculated from the in-use ZEV fractions resulting from the rule.

3. Emissions scenarios were developed with the ACC II program starting in model years 2026 and 2027. Delaying implementation from model year 2026 to model year 2027 typically leads to a net loss of emissions reduction benefit of 7.5% in calendar year 2027 and 3% in calendar year 2040.

4. The in-use ZEV fractions were used to calculate ZEV electricity consumption. Emissions factors from the U.S. Department of Energy's GREET 2021 model and EPA's eGRID database were used to calculate grid emissions associated with ZEVs and reductions in emissions in the petroleum sector. In turn, the changes in LDV energy consumption and GREET $CO_2e$

[1] Proposed ACC II Regulations: https://ww2.arb.ca.gov/rulemaking/2022/advanced-clean-cars-ii.

emissions were used to calculate net well-to-wheel (WTW) emissions for $NO_x$, $PM_{2.5}$, VOC, $SO_2$, and $CO_2e$.

5. Projections of light-duty ZEV population over time were generated using each state's current in-use ZEV population, and CARB estimates of in-use ZEV increases due to the rule.

6. EPA's CO–Benefits Risk Assessment (COBRA) model was used to estimate the health benefits associated with implementation of the ACC II program in each state for calendar year 2040.

Emission reductions for adoption of the California ACC II program vary by calendar year, program start date (model year 2026 or model year 2027), and state. By calendar year 2040, the LDV emissions reductions ranged from 40% to 54% for $NO_x$, 16%-22% for $PM_{2.5}$, and 57%-76% for $CO_2e$. WTW emissions reductions ranged from 9% to 120% for $NO_x$, 2%-57% for $PM_{2.5}$, and 54%-100% for $CO_2e$. Delaying program implementation by one model year leads to a net loss of benefit of 7.5% in calendar year 2027, declining to 3% in calendar year 2040. All states showed a net health benefit in the COBRA modeling.

# 1. Introduction

In April 2022, the Northeast States for Coordinated Air Use Management (NESCAUM), through the International Council on Clean Transportation (ICCT), contracted Sonoma Technology on behalf of 16 states to analyze the environmental and public health impacts of the adoption of the California Air Resources Board's (CARB) Advanced Clean Cars II (ACC II) regulations.[2] These states have adopted California's low-emission vehicle (LEV) and/or zero-emission vehicle (ZEV) standards under Section 177 of the federal Clean Air Act, and are hereafter referred to as "Section 177 states". California adopted ACC II in August 2022, and Section 177 of the Clean Air Act allows other states to adopt California's emission standards for new light-duty vehicles (LDVs). The regulatory processes in each of the 16 states either require or would benefit from an extensive analysis of a proposed regulation's effects. In this case, the ACC II regulation effects would be environmental and public health impacts of adopting increasingly stringent ZEV sales requirements over time.

Sonoma Technology provided MOtor Vehicle Emission Simulator 3 (MOVES3) emissions modeling and air quality analyses to characterize the air quality benefits associated with ACC II adoption and implementation. The objective of this work was to provide these states with an analysis that may be used for their own regulatory purposes should these states choose to adopt ACC II. The 16 states analyzed were Colorado, Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New Mexico, New York, Nevada, Oregon, Rhode Island, Vermont, Virginia, and Washington.

NESCAUM requested the following emissions and vehicle fleet analyses:

1. Annual change in tailpipe exhaust emissions of oxides of nitrogen ($NO_x$), particulate matter ($PM_{2.5}$), volatile organic compounds (VOCs), sulfur dioxide ($SO_2$), and ammonia ($NH_3$) from 2020-2040;
2. Annual change in energy consumption and greenhouse gas (GHG) emissions in terms of carbon dioxide equivalent ($CO_2e$) from 2020-2040;
3. Annual change in vehicle population for internal combustion engine vehicles and ZEVs from 2020-2040; and
4. Annual change in new vehicle sales for internal combustion engine vehicles and ZEVs from 2020-2040.

Sonoma Technology's overall approach for this analysis was similar to that used to analyze California's heavy-duty emissions control programs in 2021 and 2022.[3] We (1) ran MOVES3 to develop baseline emissions and vehicle activity data for the 16 states over calendar years 2020-2040; (2) developed emissions reduction factors to reflect a Business as Usual (BAU) scenario reflecting ZEV

[2] Proposed Advanced Clean Cars II (ACC II) Regulations: https://ww2.arb.ca.gov/rulemaking/2022/advanced-clean-cars-ii.

[3] "Benefits of Adopting California Medium- and Heavy-Duty Vehicle Regulations," September 2022. https://theicct.org/benefits-ca-multi-state-reg-data/.

fleet penetration absent the ACC II program; (3) developed emissions reduction factors to capture the incremental benefit of the ACC II program over BAU; and (4) post-processed the MOVES3 results using these adjustment factors to develop the emissions and activity projections for each state, year, and scenario. Sonoma Technology was also asked to project the annual change in well-to-tank emissions for both internal combustion engine and electric vehicles using emissions factors from the Department of Energy's GREET[4] model for upstream power generation and petroleum refining emissions. These steps are described in more detail below.

Sonoma Technology provided emissions analysis results in spreadsheet form, with output tables including:

1. Tank-to-wheel (vehicle) $NO_x$ and $PM_{2.5}$ Emissions by Scenario (tons per year), 2025-2040;
2. Well-to-wheel $CO_2e$ Emissions by Scenario (metric tons per year), 2025-2040;
3. Cumulative emissions reductions for $NO_x$, $PM_{2.5}$, and $CO_2e$ for 2025-2030, 2025-2035, and 2025-2040;
4. Annual LDV miles traveled (VMT) and vehicle population, 2025-2040;
5. Annual ZEV VMT and vehicle population, 2025-2040; and
6. ZEV sales and in-use ZEV fraction of the overall vehicle fleet, 2025-2040.

Once the emissions analysis was complete, Sonoma Technology used EPA's CO–Benefits Risk Assessment (COBRA) screening model to estimate net monetized health benefits resulting from adopting the ACC II program for calendar year 2040. State-level emission changes resulting from implementation of ACC II were used as inputs for COBRA, including vehicle emissions, electrical-generation emissions, and petroleum-sector emissions. Sonoma Technology calculated the net health benefit estimates for all states resulting from the emissions changes in each individual target state. Analyses assumed an implementation date of model year 2026, although we also completed similar modeling with an assumed implementation data of model year 2027. Finally, we produced state-specific spreadsheets and fact sheets documenting the results of these analyses. The final spreadsheets and fact sheets for each state are available on the ICCT website.[5]

[4] Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model, https://greet.es.anl.gov/.
[5] https://theicct.org/benefits-ca-advanced-clean-cars-ii-reg-data/

# 2. MOVES3 Modeling

Sonoma Technology used the latest available version of the MOVES3 model to generate baseline emissions estimates in the absence of ACC II. MOVES3 was run at the County scale to produce emissions for 2017, 2030, and 2040 for the representative counties modeled as part of EPA's triennial National Emissions Inventory (NEI) process. NESCAUM contacted each of the 16 states and requested MOVES input data, including input databases for the 2017 NEI (or the 2020 NEI, if available), LEV input databases, VMT, and vehicle population growth rates. NESCAUM also requested that the states provide current (calendar year 2021 or newer) ZEV population counts and the fraction of state electricity supply coming from zero-emissions sources through 2040. These data were not used in MOVES3, but were needed for later analysis steps. Sonoma Technology generated MOVES3 input databases using the state-provided data where available and MOVES3 defaults and/or NEI data where individual data items were missing. The VMT and vehicle population data for each representative county from the 2017 NEI are the sum of VMT and population for all counties in the group containing the representative county, not the values for only that county. When the VMT, population, and emissions data for the representative counties are summed, they reflect statewide totals.

Once the County scale runs were complete, Sonoma Technology generated interpolated emissions estimates for (1) 2020, and (2) 2025 through 2040. We ran MOVES3 at the Default scale for each of the states and multiple analysis years (2017, 2020, 2025, 2030, 2035, and 2040) for the purpose of generating interpolation factors to adjust the County-scale results. The trend in default emissions was used to develop interpolated emissions estimates for some analysis years not modeled at the County scale (2020, 2025, and 2035). Finally, annual emissions estimates for 2025 through 2040 were produced through linear interpolation. Vehicle population and VMT estimates were also interpolated using the same approach.

Three MOVES3 regulatory classes were modeled: (1) LDVs (passenger cars - regulatory class 20); (2) light-duty trucks (regulatory class 30); and (3) Class 2b and 3 trucks (regulatory class 41).[6] Under ACC II, these three vehicle classes are subject to tighter pollutant emissions standards. Regulatory classes 20 and 30 are also subject to ZEV sales targets. Sonoma Technology output MOVES VMT and population by regulatory class for detailed model quality assurance checks, and $NO_x$, methane ($CH_4$), nitrous oxide ($N_2O$), $PM_{2.5}$, VOCs, $SO_2$, $NH_3$, and energy by regulatory class for statewide emissions estimates. Representative county and statewide emissions of all target pollutants were summarized using an R script. $NO_x$ emissions for all representative counties and the corresponding state were compared to NEI 2017 data and multiple-year emissions modeling platform data[7] (2016, 2023, and

[6] Note that the term "light-duty vehicles" is commonly used to describe the overall light-vehicle fleet, including both passenger cars and light trucks. Most references to "LDVs" in this report reflect that meaning.

[7] EPA-developed emissions modeling platform with 2016 as the base year. The year 2023 and year 2028 inventories were projected by EPA from the 2016 inventory in support of the Revised Cross State Air Pollution Rule Update for the 2008 Ozone National Ambient Air Quality Standards. https://www.epa.gov/sites/production/files/2020-11/documents/2016v1_emismod_tsd_508.pdf.

2028) as a reasonableness check, and statewide emissions were compared to Default-scale MOVES3 runs for the corresponding state and calendar year. The end result was a table of unadjusted MOVES3 emissions estimates for 2017, 2020, and 2025-2040 in annual increments.

# 3. ACC II Scenario Analysis

As noted above, once MOVES3 runs were completed, Sonoma Technology applied post-processing adjustments to 1) develop a BAU scenario reflecting the future LDV fleet without ACC II, and to 2) account for the effects of the ACC II program. These adjustments are described in detail in the subsections below.

## 3.1 Business as Usual Scenario

EPA's MOVES3 model assumes that there are no ZEVs in the vehicle fleet. However, each of the 16 states analyzed do have ZEVs in their in-use fleets, so the MOVES3 output needed to be adjusted to account for the presence of these vehicles. Also, on December 30, 2021, approximately one year after MOVES3 was released in November 2020, EPA adopted a new LDV GHG rule that is projected to result in additional ZEV sales (reaching 17.2% of sales in model year 2026).[8] Additional adjustments to MOVES3 outputs were necessary to account for the effects of this regulation.

Sonoma Technology's initial step in defining a BAU scenario involved calculating the fraction of the in-use fleet represented by ZEVs. We ran MOVES3 at the Default scale to obtain vehicle population output by model year, and then calculated the fraction of population in each calendar year comprised of the newest model year in that calendar year. This fraction enabled Sonoma Technology to estimate new vehicle sales in each calendar year.[9] NESCAUM provided a table of current (2021) ZEV sales fractions in each state, which ranged from 3.17% (Minnesota) to 8.44% (Washington).[10] The 2021 sales fractions were grown for future years and were capped at CARB's BAU estimate of 12% ZEV sales absent the ACC II regulation. Current ZEV population estimates for each state were provided by the states and were projected by applying estimated future ZEV sales fractions to estimated future vehicle sales. Finally, using the ZEV and total population for each calendar year, Sonoma Technology estimated in-use ZEV fractions for the entire vehicle fleet, including both new and existing vehicles. The in-use fractions are calculated as population fractions, but since the daily mileage accumulation of LDVs (30.5 miles per day for passenger cars and 33.6 miles per day for light trucks in MOVE3) is well below the typical driving range of currently-available ZEVs, they are used as VMT fractions in our projections.

In some cases, the state-provided MOVES3 input files did include ZEVs in the fleet, and the resulting MOVES3 emissions output reflected the presence of these vehicles. To avoid double-counting their benefits, the in-use fraction calculated above was reduced by the in-use fraction modeled in

---

[8] *Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards*, 86 FR 74434, December 30, 2021.

[9] MOVES3 assumes that all new model year vehicles are sold in the same calendar year; e.g., all model year 2020 vehicles were sold in calendar year 2020, and so on. MOVES3 does not account for fact that new model year sales typically begin in the previous calendar year (e.g., model year 2020 vehicle sales actually began in the fall of 2019).

[10] NESCAUM obtained these data from IHS Markit/Polk via Atlas Public Policy's EV Hub: **https://www.atlasevhub.com/**.

MOVES3. In each case, the in-use fraction modeled in MOVES3 was well below the in-use fraction calculated from actual current ZEV population data.

EPA provided detailed emissions reductions estimates for its December 2021 LDV GHG rule.[11] These emissions reductions were used to estimate emissions in the BAU scenario for most pollutants. EPA did not provide estimates emissions reductions for $NH_3$, so the BAU in-use ZEV fractions for each year were used as a surrogate for emissions reductions for that pollutant. Unlike MOVES3, EPA's No Action scenario for the rule did assume the presence of some ZEVs in the fleet (ranging from ~5% in 2025 to ~7% in 2028 and future years). EPA's estimated emissions reductions were adjusted to account for these ZEVs, along with any ZEVs present in the state MOVES3 inputs, to generate revised reduction factors that could be applied directly to MOVES3 output.

In addition to passenger cars and light-duty trucks (LDTs), EPA's LDV GHG rule also applies to medium-duty passenger vehicles, which are a subset of regulatory class 41. The emissions-reductions estimates provided by EPA are a composite estimate for all three classes of vehicles combined. Detailed estimates for the three individual vehicle classes were not provided. Therefore, an apportionment factor was calculated so the reduction estimates could be applied to the MOVES3 regulatory class 41 output without applying to all regulatory class 41 vehicles. EPA did not provide emissions reductions estimates for $NH_3$, so Sonoma Technology continued to use the in-use ZEV fractions calculated above to represent reductions for that pollutant. An intermediate calculation accounts for the fraction of time that plug-in hybrid electric vehicles (PHEVs) operate with internal combustion engines rather than electricity.

## 3.2 Advanced Clean Cars II Program Scenarios

CARB proposed the ACC II standards on April 12, 2022, and finalized them on August 25, 2022. Beginning in the 2026 model year, these standards require LDV manufacturers to sell increasing percentages of ZEVs. By 2035, ACC II requires that all new LDV sales be ZEVs. For the remaining new combustion LDV sales prior to that date, CARB imposed more stringent LEV standards. (These latter standards also apply to some medium-duty vehicles.) For this analysis, Sonoma Technology analyzed two scenarios: (1) ACC II implementation beginning in model year 2026 (consistent with California), and (2) ACC II implementation beginning in model year 2027. Most states were not able to adopt ACC II quickly enough for it to become effective in the 2026 model year.

To estimate emissions reductions, Sonoma Technology relied on emissions reductions and vehicle fleet projections provided by CARB after publication of the final rule.[12] The emissions projections took the form of "baseline" and "proposal" emissions inventories by year, pollutant, and vehicle type. Sonoma Technology calculated percent reductions using these data; emissions estimates by vehicle

[11] Spreadsheet entitled "annual_societal_effects_summary_report_FRM_PrimaryRuns.xlsx," provided via email by Todd Sherwood, EPA Office of Transportation and Air Quality, May 26, 2022.

[12] Spreadsheet summaries provided via email by Cody Livingston, CARB, April 20, 2022, and September 14, 2022.

type were summed to produce emissions reduction factors that could be applied to all vehicle types in the analysis (regulatory classes 20, 30, and 41). CARB did not provide emissions estimates for $SO_2$ or $NH_3$, so we used CARB's estimates of in-use ZEV fraction increases as a surrogate for pollutant emissions decreases for these pollutants.

CARB's emissions inventories for the baseline and proposal scenarios reflect implementation of the program as a whole. CARB did not provide data that reflect reductions resulting from individual components of the program (i.e., the ZEV requirement versus the emissions standards for conventional vehicles), or the impact of the various compliance flexibilities offered as part of the rule. The ACC II implementation scenarios analyzed as part of this project reflect implementation of the entire program, and because they are based on CARB emissions reductions estimates, they implicitly reflect CARB's assumptions about the impact of the vehicle manufacturers' use of compliance flexibilities.

However, for ZEV in-use population projections, Sonoma Technology did develop a "lower-bound" scenario assuming a 20% reduction in ZEV sales relative to the ACC II annual ZEV requirements in model years 2026-2030 to account for use of the various compliance options. The 20% reduction assumes a combination of the available flexibility mechanisms, based on the differing needs of auto manufacturers and varying market conditions across the Section 177 states. (The flexibility mechanisms are early compliance vehicle values, environmental justice vehicle values, converted ZEV and PHEV values, pooled ZEV and PHEV values, proportional fuel cell electric vehicle values, trading, and banking.) The 20% reduction affects calculations of upstream electrical grid and petroleum sector emissions, which are based on the ZEV population, but not the calculations of vehicle emissions, which are based on the CARB inventories.

CARB's estimated emissions inventories reflect reductions from the CARB baseline (the previous Advanced Clean Cars I program), which differs from both the EPA baseline (with 6.7% ZEV sales in model year 2026 and beyond) and the MOVES3 model (0% ZEVs). Interim adjustments were needed so that the emissions reductions calculated from CARB's inventories could be applied to a BAU scenario reflecting implementation of EPA's December 2021 rule rather than CARB's rule. These adjustment factors were calculated using the ratio of the ZEV VMT fraction in CARB's baseline to the ZEV VMT fraction resulting from EPA's rule, with additional adjustments to reflect the fractions of PHEV VMT powered by conventional fuels rather than electricity. CARB-provided vehicle fleet data were used in these calculations. While CARB did provide emissions inventories for individual vehicle classes, Sonoma Technology combined these to calculate a composite emissions reduction across all three affected vehicle classes (LDVs, light-duty trucks, and light heavy-duty vehicles) to be consistent with the approach necessary to calculate BAU emissions.

CARB's inventories also reflect implementation of ACC II beginning in model year 2026. To develop a second scenario reflecting implementation in model year 2027, Sonoma Technology ran MOVES3 to estimate VMT for model year 2026 vehicles for calendar years 2026 through 2040, and calculated the fraction of VMT in those years attributable to model year 2026 vehicles. This served as an adjustment factor to account for the loss of benefit due to delaying program implementation by one model year.

Delaying implementation by one model year leads to a net loss of emissions benefit of 7.5% in 2027, declining to 3% in 2040.

Consistent with normal state emissions inventory methodology, Sonoma Technology did not make any adjustments to account for VMT from out-of-state vehicles (i.e., vehicles that travel into a state for work or vacations, but are domiciled in another state, and vehicles making through trips on major highways where the vehicle trip has neither an origin nor destination in the state). Sonoma Technology has no available data to determine what fraction of the LDV VMT in an individual state is represented by these types of vehicle trips, or whether this share of VMT is different than it is in California. Therefore, Sonoma Technology's emissions estimates are best viewed as an estimate of the emissions of a state's LDV fleet, not the total emissions of LDVs within the geographic boundaries of that state.

## 3.3 Upstream Emissions Calculations

As part of the analysis, Sonoma Technology was asked to estimate the changes in electrical grid and petroleum refining emissions due to the increased ZEV population under the ACC II rule. To accomplish this, Sonoma Technology extracted grid electricity emissions factors (in units of tons of grams of emissions per million BTUs of electricity) from the U.S. Department of Energy's GREET 2021 model.[13] These rates are provided for different regions of the country (**Figure 1**).

[13] GREET2021 Excel-based model, https://greet.es.anl.gov/.

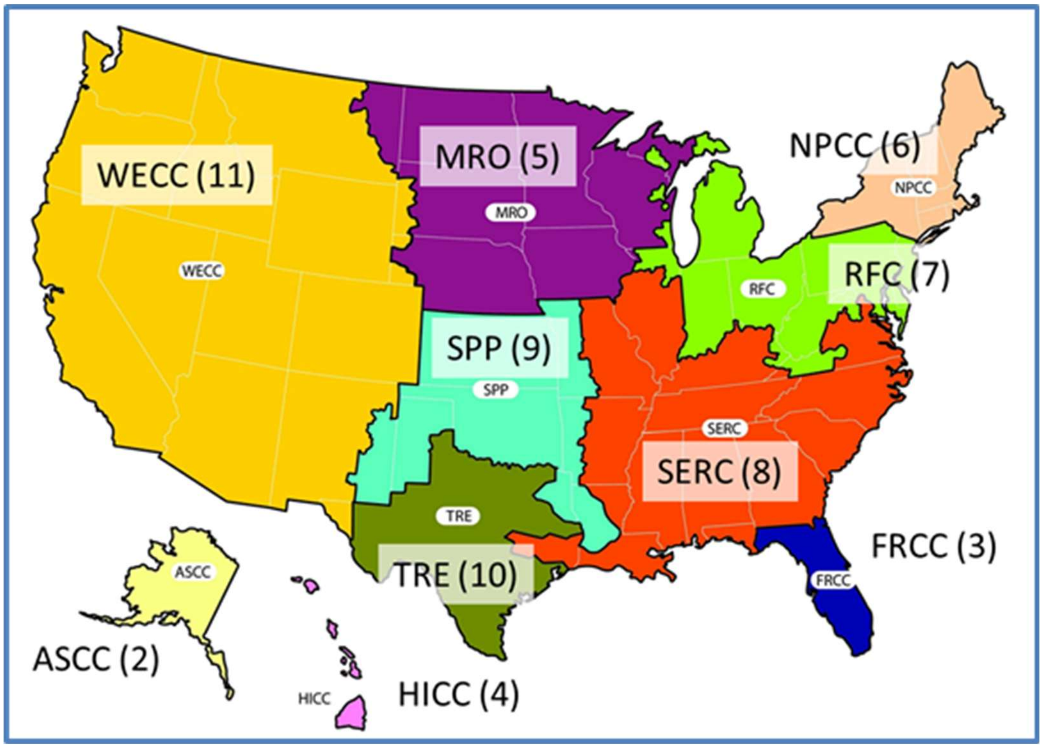



**Figure 1.** GREET electrical generation regions.

EPA's eGRID[14] database also contains electrical grid emissions factors, and in state-specific form rather than by region. However, eGRID does not include emissions factors for all of the pollutants being analyzed as part of this project. Sonoma Technology used state-specific eGRID emissions rates for the available pollutants in that database ($NO_x$, $CH_4$, $N_2O$, $CO_2$, and $SO_2$), and GREET factors for the applicable region of the country for the remaining pollutants ($PM_{2.5}$ and VOCs). Neither database includes emissions factors for $NH_3$, so upstream emissions were not calculated for that pollutant.

The GREET and eGRID emissions rates reflect the electrical generation sources and the associated emissions factors in each state as of 2021. However, all 16 states have plans for increased renewable energy production in the future. Sonoma Technology used state-specific projections of renewable energy deployment to calculate the relative fractions of grid electricity that would be zero-emission in each calendar year, and then applied these fractions to the baseline GREET or eGRID factors to develop emissions rates for future years. GREET or eGRID information on the baseline mix of power sources in each state was used with the overall emissions rates above to calculate emissions rates for the power generated by fossil fuels only, and then these were factored by the state renewable power percentages by year to arrive at weighted rates for each year. The emissions factors by generation type are assumed to be constant for all calendar years, but the relative fractions of renewable and non-renewable generation change by year.

[14] eGRID database, https://www.epa.gov/egrid.

As part of the MOVES3 modeling, Sonoma Technology generated estimates of total energy consumption by vehicle class, in units of million BTUs. Sonoma Technology then used the in-use ZEV fractions calculated for the BAU scenario and the ACC II program to determine the portion of total energy consumption attributable to ZEVs. However, as ZEVs are more energy efficient on a tank-to-wheels basis than conventional vehicles, a ZEV efficiency factor was applied to estimate ZEV electricity consumption more accurately. The ZEV efficiency factors were generated by CARB[15] and used in their rulemaking analyses. Once the adjusted energy consumption estimates were developed, the emissions factors described above were used to estimate the resulting grid emissions.

Sonoma Technology also estimated changes in petroleum sector emissions. Since ZEVs do not consume gasoline or diesel fuel, there are upstream emissions reductions in the petroleum refining, storage, and transportation sectors attributable to these vehicles. We used GREET 2021 factors for $CO_2$, $NO_x$, $PM_{2.5}$, VOCs, and $SO_2$ to estimate these emissions benefits. These factors are applied to the reduction in petroleum energy consumption resulting from ZEVs.

## 3.4 Post-Processing Spreadsheet

Once all necessary post-processing factors were developed, Sonoma Technology incorporated them into a template spreadsheet, which includes summary worksheets and individual results worksheets for each scenario, the original MOVES3 output, and the post-processing adjustments. MOVES3 County-scale (2017, 2030, and 2040) and Default-scale outputs (for all years estimated) are imported into the spreadsheet. The spreadsheet uses the MOVES3 Default-scale output to calculate interpolation trends.[16] Interpolated County-scale estimates for 2020, 2025, and 2035 are also generated. These final MOVES3 emissions tables are used in the various scenario worksheets with the adjustment factors for BAU and the ACC II scenarios to calculate emissions by scenario for the light-duty fleet, and changes in emissions for the utility and petroleum sectors. In the summary worksheets, the emissions totals by year and scenario are imported, and ACC II scenario benefits are calculated. On additional worksheets, ZEV population and sales estimates are calculated, and a separate worksheet includes overall summary tables of emissions, population, and VMT for the light-duty fleet. **Table 1** describes the contents of each of the worksheets in the post-processing spreadsheet. The spreadsheets for all states are available on the ICCT website.[17]

[15] CARB ZEV Cost Modeling Workbook, ww2.arb.ca.gov/sites/default/files/2021-07/ZEV_Cost_Modeling_Workbook_MayWorkshop_Accessible_0.xlsx.

[16] The Default results are used to interpolate emissions for 2020 and 2025, when emissions rates are changing rapidly. For emissions in 2035 and 2045, when most federal control programs have been essentially fully implemented, straight-line interpolation is used. Straight-line interpolation is also used for VMT, the pollutants that are only dependent on VMT (brakewear and tirewear), and population.

[17] https://theicct.org/benefits-ca-advanced-clean-cars-ii-reg-data/

**Table 1.** Contents of the ACC II post-processing spreadsheet.

| Worksheet | Description of Contents |
|---|---|
| Key | Overview of scenarios, programs evaluated, and information on vehicle types |
| Tables | Tables of emissions, VMT, and population by year reflecting EVs sold under the ACC II program |
| COBRA Summary | Detailed COBRA modeling results (Vehicles = LDV vehicles, EGU = electric generation, REF = petroleum refining, STR = petroleum storage, TRN = petroleum transport) |
| Emissions Summary | Emissions summary for all scenarios |
| BAU Scenario | Business as Usual Scenario |
| ACC II - MY2026 | ACC II program starting in model year 2026 |
| ACC II - MY2027 | ACC II program starting in model year 2027 |
| Federal GHG Rule | Emissions reductions and fleet technology penetration from EPA's 12/30/21 LDV GHG rule, used to define BAU |
| ACC Emissions Benefits | CARB estimates of emissions benefits for the ACC II program |
| Fleet ZEV Fractions | Calculated fractions of ZEVs under the different scenarios |
| CARB ZEV Counts | CARB projections of convention/ZEV population |
| ZEV Efficiency | Calculation of relative energy efficiency of ZEVs |
| ZEV Population | Interim table for calculation of ZEV fractions |
| ZEV Sales | Estimates of ZEV sales, based on MOVES3 new vehicle sales rates |
| Combined MOVES Output | County-scale MOVES3 output for 2017, 2030, and 2040; interpolated MOVES3 output for 2020, 2025, 2035 (source data for scenario worksheets) |
| County Scale Output 2017-2040 | Imported MOVES County-scale output |
| Default Output 2017-2040 | Imported MOVES Default-scale output |
| Output Interpolation | Factors derived for using MOVES Default output to interpolate County values for 2020, 2025, 2035 |
| GREET Factors | GREET electricity and petroleum production emissions rates used in the scenarios |
| State Grid Data | State-specific renewable energy projections used to calculate state GREET factors |
| Regional GREET Factors | GREET electricity factors for all areas analyzed as part of this project |

## 3.5 COBRA Analysis

Once the emissions analysis for a state was complete, Sonoma Technology used EPA's COBRA Health Impacts Screening Tool to estimate net monetized health benefits resulting from adopting the ACC II program for calendar year 2040. State-level emission changes resulting from implementation of ACC II, including vehicle and electrical generation emissions, were used as input for COBRA. Sonoma Technology calculated the net health benefit estimates for all states resulting from the emissions changes in each individual target state.

State-level emission changes from implementation of the ACC II program relative to BAU were used as input for COBRA. The emissions inputs for each state reflect the anticipated year of program implementation (model year 2026 or 2027; see **Table 2** in Section 4). Initially, emissions changes from the on-road vehicle and utility sectors were used. Later analyses added emissions changes in the petroleum fuel production, storage, and transport sectors. Emissions changes from petroleum fuel production were only applied in states that host petroleum refineries.

COBRA provides default baseline data only for 2016, 2023, and 2028. To estimate the net monetized health benefits for years other than these default years, data including the human population and health incidence rate needed to be projected to the target year (2040). The human population was projected to the target year based on the U.S. Census Bureau's population projection. The health incidence rate was kept at the level for 2028.

Emissions calculated for all modeled sectors were substituted into the base emissions file to create a BAU base and ACC II adoption sensitivity files. One industry – e.g., LDVs, electricity generation, or petroleum refining – was altered for each COBRA run to monetize individual impact. Calculated emission values for each pollutant were distributed across counties and in the case of some industries, sub-sectors (e.g., fuel types in LDVs) according to state-wide emission fractions determined using the 2028 COBRA Default emissions file. In the case of secondary organic aerosols (SOAs), industry and sub-sector specific fractions from the 2028 COBRA Default emission file were used to calculate SOA values from our VOC emissions estimates.

Outputs from COBRA included the absolute change in number of cases of adverse health outcomes, as well as the monetary value of these changes for each county, based on the emissions differences between the base and sensitivity scenarios. Output information was then aggregated for each state. Monetary values of the health impacts due to changes regarding in-state and out-of-state vehicle and petroleum-sector emissions (always positive, due to reduced conventional fuel usage) and in-state and out-of-state changes in utility emissions (always negative, except in cases of zero-emissions grids) were summed to calculate a net benefit or burden produced by implementing the program. For each state, COBRA also output estimates of the magnitude of impacts on downwind states, and Sonoma Technology reported the five states most impacted by on-road vehicle emissions reductions and upstream electrical generation emission increases in the fact sheets produced for each state. The COBRA results for each state are included in the spreadsheets discussed above.

# 4. Results

## 4.1 Emissions

Table 2 shows the emissions reductions from implementation of ACC II, presented as reductions relative to the BAU scenario. "Vehicle Only" reductions are for vehicle emissions only (tank-to-wheel), and the "Well-to-Wheel" results include both vehicle emissions and changes in upstream emissions. Emission reductions for adoption of the California ACC II program vary by calendar year, program scenario (model year 2026 or 2027), and state. By calendar year 2040, the LDV emissions reductions ranged from 40%-54% for $NO_x$, 16%-22% for $PM_{2.5}$, and 57%-76% for $CO_2e$. WTW emissions reductions ranged from 9%-120% for $NO_x$, 2%-57% for $PM_{2.5}$, and 54%-100% for $CO_2e$.

**Table 2.** ACC II percentage reductions from BAU, calendar year 2040.

| State | Starting Model Year* | Vehicle Only | | | Well-to-Wheel | | |
|---|---|---|---|---|---|---|---|
| | | $NO_x$ | $PM_{2.5}$ | $CO_2e$ | $NO_x$ | $PM_{2.5}$ | $CO_2e$ |
| CO | 2027 | 54% | 22% | 76% | 71% | 34% | 100% |
| CT | 2027 | 42% | 17% | 59% | 93% | 45% | 84% |
| DE | 2027 | 43% | 17% | 60% | 78% | 18% | 66% |
| MA | 2026 | 44% | 17% | 61% | 98% | 41% | 84% |
| MD | 2027 | 43% | 17% | 62% | 81% | 14% | 69% |
| ME | 2027 | 42% | 17% | 59% | 54% | 47% | 81% |
| MN | 2027 | 49% | 20% | 70% | 40% | 16% | 80% |
| NJ | 2027 | 41% | 16% | 58% | 89% | 44% | 77% |
| NM | 2027 | 42% | 18% | 65% | 50% | 29% | 80% |
| NV | 2027 | 40% | 17% | 60% | 9% | 2% | 54% |
| NY | 2026 | 45% | 18% | 62% | 120% | 49% | 89% |
| OR | 2026 | 41% | 16% | 57% | 84% | 46% | 82% |
| RI | 2027 | 41% | 16% | 58% | 97% | 57% | 83% |
| VA | 2026 | 47% | 19% | 66% | 94% | 41% | 87% |
| VT | 2026 | 42% | 17% | 59% | 104% | 47% | 84% |
| WA | 2026 | 42% | 17% | 58% | 77% | 43% | 84% |

*A starting model year of 2026 indicates that the state adopted the ACC II program in 2022, and implementation will begin with the 2026 model year.

There are several reasons for differences in emissions trends among these states. First, use of NEI data as a starting point means that the individual states have different vehicle age distributions (which influence the rate of fleet turnover), and different mixes of vehicle population by vehicle class (some states may have more or fewer light trucks than others). State-specific estimates of VMT and population growth also drive overall emissions levels and reductions from Business as Usual.

Emissions reductions for $PM_{2.5}$ are relatively lower than the reductions in $NO_x$ and $CO_2e$ because electrification does not reduce brakewear or tirewear emissions. Brakewear and tirewear emissions are a large source of $PM_{2.5}$, and ZEVs still have these emissions even when tailpipe $PM_{2.5}$ emissions are eliminated. By 2040, brakewear and tirewear emissions combined exceed tailpipe emissions in most states. Road dust emissions are not included in this analysis because the ACC II program emissions reductions were calculated based on CARB's emissions inventories, which did not include road dust.

While reductions in vehicle-only emissions are reasonably consistent across the states, the WTW emissions reductions vary considerably. The WTW emissions reductions are a combination of the LDV emissions reductions, the electrical grid emissions increases, and the emissions reductions associated with reduced petroleum fuel production. Note that this analysis does not represent a full lifecycle analysis, and these projections focus on the emissions reductions from the rule. The analysis does not include the upstream petroleum emissions associated with the remaining internal combustion engine vehicles in the fleet, or total emissions from the petroleum and electrical generation sectors, but is limited to the increase in grid emissions and the reduction in petroleum emissions from vehicles that would have been conventionally-fueled but would instead be ZEVs due to the rule.

The GREET petroleum factors for all of the states are identical. However, the amount of displaced petroleum varies based on the in-use ZEV fraction, which in turn is a function of underlying vehicle fleet characteristics (the pre-regulation ZEV population, new vehicle sales, vehicle population and VMT growth rates, and the share of regulatory class 41 vehicles, which are not subject to the ZEV requirement).

On the electricity side, the grid emissions rates from EPA's eGRID database and the GREET model vary widely by state: eGRID factors vary between states by factors of 6 for $NO_x$, 42 for $CO_2e$ and, 26 for $SO_2$; GREET factors vary by factors of 3 for $PM_{2.5}$ and 4 for VOCs. The variation in these emissions rates is a function of both the mix of electrical generation sources within a state or region (coal, natural gas, oil, biomass, nuclear, and renewables) as well as the age and emissions control technology associated with the non-zero-emissions facilities. Finally, the calendar year 2040 state renewable energy projections range from 50% (Maryland and Nevada) to 100% (Connecticut, New Jersey, New York, Oregon, Rhode Island and Washington). The large variation in upstream emissions rates and renewable energy goals leads to wide variations in WTW emissions reductions among the states.

Two states (New York and Vermont) have calculated WTW $NO_x$ reductions greater than 100%. These states are projected to have very clean electrical grids in 2040 (97% to 100% renewable), resulting in very low or no grid emissions to power ZEVs. Also, in these two states, the emissions rates for the conventionally fueled LDV fleet in 2040 are lower than the emissions rate for petroleum production, on a gram-per-million-Btu basis. Displacing these very clean vehicles with electric vehicles relying on near-zero or zero-emitting electricity results in negative total well-to-wheel $NO_x$ emissions, and thus a net emissions reduction of over 100% compared to the BAU scenario. Colorado has the largest calculated reduction in $CO_2e$ emissions, at 100%. This state has the highest vehicle miles traveled growth between 2025 and 2040 (24%) and the highest growth in LDT population (79%). Transitioning a large fraction of the fast-growing LDT fleet from conventional to ZEV vehicles results in large reductions in petroleum-related emissions, but only modest increases in grid emissions (Colorado projects an 80% renewable grid in 2040).

At the other extreme, Nevada had the lowest WTW reductions of $NO_x$, $PM_{2.5}$, and $CO_2e$. Nevada has relatively high $NO_x$ and $PM_{2.5}$ grid emissions factors and a low projected percentage of renewable energy in 2040 compared to the other states.

For all pollutants, the increase in emissions from electrical generation needed to charge ZEVs was always smaller than the reduction in tailpipe and petroleum sectors, meaning that the electrification scenarios provided a net benefit to emissions even with electrical generation considered. Note that the petroleum-related reductions only occur in states that host refineries, meaning that these large reductions may not occur in the same state where the ZEVs themselves are registered. The COBRA modeling incorporated changes in petroleum fuel storage and transportation emissions, which occur in all states.

Table 3 shows the cumulative reductions for these same pollutants from LDVs. $NO_x$ and $PM_{2.5}$ reductions are tank-to-wheel (vehicle only), and $CO_2e$ reductions are WTW. The largest states (in terms of human population) are not always the states with the largest reductions in emissions. For example, Colorado and Minnesota have the highest and second highest cumulative reductions in $NO_x$ even though they rank seventh and eighth in human population (as of 2022). These two states have the fastest predicted growth in vehicle population; Colorado predicts 46% overall growth in the LDV fleet, with 79% growth for LDTs; Minnesota predicts 44% overall growth in the LDV fleet with 46% growth in LDTs. Having a large future truck population results in large reductions from electrifying those vehicles, relative to BAU. These states also have large reductions in $PM_{2.5}$ relative to their population; however, Minnesota has only a moderate reduction in WTW $CO_2e$ because its grid is projected to be 63% renewable in 2040 (the states with the largest reductions have 80-100% renewables in 2040).

**Table 3.** Cumulative light-duty vehicle emissions reductions from BAU.

| State | Starting Model Year | 2025-2030 | | | 2025-2040 | | |
|---|---|---|---|---|---|---|---|
| | | $NO_x$ (U.S. tons) | $PM_{2.5}$ (U.S. tons) | $CO_2e$ (MMT)* | $NO_x$ (U.S. tons) | $PM_{2.5}$ (U.S. tons) | $CO_2e$ (MMT)* |
| CO | 2027 | 1,794 | 87 | 8.9 | 18,903 | 1,161 | 113.8 |
| CT | 2027 | 460 | 31 | 3.6 | 4,341 | 324 | 39.5 |
| DE | 2027 | 123 | 8 | 1.2 | 1,169 | 85 | 11.9 |
| MA | 2026 | 855 | 74 | 8.7 | 8,551 | 770 | 94.3 |
| MD | 2027 | 668 | 52 | 7.1 | 5,978 | 585 | 76.7 |
| ME | 2027 | 236 | 16 | 1.8 | 2,274 | 160 | 19.0 |
| MN | 2027 | 1,843 | 82 | 8.0 | 18,114 | 1,075 | 87.0 |
| NJ | 2027 | 881 | 59 | 8.2 | 8,886 | 649 | 94.2 |
| NM | 2027 | 890 | 34 | 3.7 | 6,708 | 359 | 39.2 |
| NV | 2027 | 582 | 33 | 3.3 | 4,382 | 350 | 29.7 |
| NY | 2026 | 1,675 | 132 | 16.9 | 15,231 | 1,373 | 189.5 |
| OR | 2026 | 1,260 | 40 | 4.3 | 9,360 | 408 | 51.0 |
| RI | 2027 | 114 | 7 | 0.9 | 1,134 | 78 | 10.4 |
| VA | 2026 | 2,299 | 102 | 12.7 | 17,511 | 1,111 | 139.2 |
| VT | 2026 | 74 | 7 | 0.9 | 811 | 72 | 9.6 |
| WA | 2026 | 1,407 | 61 | 6.9 | 12,332 | 642 | 77.3 |

*million metric tons

## 4.2 Health Outcomes

The results from the COBRA modeling are provided in Table 4. Health benefits (positive values) and health burdens (negative values) are expressed in units of millions of 2017 U.S. dollars. They represent benefits in calendar year 2040 (not cumulative benefits between 2026 and 2040). The ACC II program produced a net in-state health benefit in all states analyzed. Because the ACC II program has emissions and health benefits in each calendar year of implementation, the cumulative health benefits between 2026 (or 2027) and 2040 would be considerably larger.

Table 4. ACC II-related health benefits (positive values) and burdens (negative values), calendar year 2040. Expressed in units of millions of 2017 US dollars.

| State | In-State Vehicle Benefit | Out-of-State Vehicle Benefit | In-State Upstream Burden/ Benefit | Out-of-State Upstream Burden/ Benefit | Net Benefit |
|---|---|---|---|---|---|
| CO | 361.2 | 38.3 | 10.5 | 10.8 | 420.9 |
| CT | 140.2 | 81.0 | 19.8 | 31.6 | 272.7 |
| DE | 29.9 | 54.3 | 4.0 | 7.5 | 95.7 |
| MA | 360.6 | 87.3 | 98.8 | 32.4 | 579.2 |
| MD | 470.9 | 189.3 | -14.2 | -42.4 | 603.5 |
| ME | 19.3 | 5.8 | 1.9 | 0.6 | 27.6 |
| MN | 264.7 | 59.7 | 9.5 | -8.6 | 325.3 |
| NJ | 662.0 | 483.2 | 86.5 | 103.7 | 1,335.4 |
| NM | 33.2 | 16.3 | 1.1 | 5.0 | 55.7 |
| NV | 43.3 | 21.0 | 1.2 | -5.9 | 59.5 |
| NY | 1,086.7 | 307.9 | 76.7 | 21.7 | 1,493.0 |
| OR | 73.3 | 26.1 | 4.9 | 1.9 | 106.3 |
| RI | 31.1 | 26.5 | 1.4 | 1.7 | 60.7 |
| VA | 460.7 | 283.4 | 43.9 | 26.6 | 814.5 |
| VT | 5.2 | 7.1 | 0.3 | 0.4 | 13.0 |
| WA | 168.9 | 11.7 | 24.6 | 1.1 | 206.3 |

## 4.3 ZEV Population and Sales

Table 5 provides estimates of the total LDV population by year, and the population and annual sales of electric vehicles expected under the BAU scenario and the ACC II program. Population and sales estimates include passenger cars and light trucks, not Class 2b-3 vehicles. Values in the "ACC II ZEVs" column represent total LDV ZEV population under the ACC II scenario, not incremental ZEVs in addition to the BAU scenario. BAU ZEV sales for calendar year 2020 are not included because these data were not available.

**Table 5.** Projected light-duty ZEV population and sales.

| Colorado (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 4,754,856 | 7,475 | N/A | N/A | N/A |
| 2025 | 5,275,436 | 123,425 | N/A | 40,201 | N/A |
| 2030 | 5,796,017 | 385,820 | 717,868 | 53,422 | 168,964 |
| 2035 | 6,784,556 | 678,316 | 2,220,207 | 61,837 | 359,516 |
| 2040 | 7,724,554 | 1,011,638 | 4,158,126 | 69,883 | 406,296 |

| Delaware (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 816,046 | 766 | N/A | N/A | N/A |
| 2025 | 848,335 | 20,408 | N/A | 6,555 | N/A |
| 2030 | 880,623 | 62,557 | 115,723 | 8,522 | 26,954 |
| 2035 | 898,797 | 106,212 | 339,319 | 8,873 | 51,585 |
| 2040 | 917,644 | 151,132 | 600,482 | 9,058 | 52,664 |

| Connecticut (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 2,799,303 | 3,106 | N/A | N/A | N/A |
| 2025 | 2,867,184 | 68,055 | N/A | 22,193 | N/A |
| 2030 | 2,935,066 | 209,755 | 388,160 | 28,519 | 90,200 |
| 2035 | 2,994,530 | 355,601 | 1,135,104 | 29,604 | 172,116 |
| 2040 | 3,056,662 | 505,144 | 2,004,545 | 30,112 | 175,070 |

| Maine (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 1,106,306 | 3,681 | N/A | N/A | N/A |
| 2025 | 1,139,640 | 28,055 | N/A | 8,756 | N/A |
| 2030 | 1,172,974 | 83,776 | 153,869 | 11,191 | 35,394 |
| 2035 | 1,188,203 | 140,707 | 445,377 | 11,520 | 66,975 |
| 2040 | 1,202,136 | 198,761 | 782,902 | 11,672 | 67,859 |

| Maryland (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 4,489,350 | 15,141 | N/A | N/A | N/A |
| 2025 | 4,737,278 | 120,945 | N/A | 36,599 | N/A |
| 2030 | 4,985,206 | 357,811 | 657,057 | 48,066 | 152,024 |
| 2035 | 5,212,545 | 606,957 | 1,933,813 | 51,011 | 296,574 |
| 2040 | 5,439,116 | 868,183 | 3,452,568 | 53,068 | 308,536 |

| Minnesota (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 5,153,813 | 18,868 | N/A | N/A | N/A |
| 2025 | 5,897,588 | 142,377 | N/A | 45,448 | N/A |
| 2030 | 6,641,362 | 448,779 | 839,937 | 63,784 | 201,734 |
| 2035 | 7,603,604 | 798,390 | 2,635,824 | 74,048 | 430,510 |
| 2040 | 8,560,979 | 1,195,968 | 4,947,325 | 83,161 | 483,494 |

| Massachusetts (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 5,038,698 | 25,953 | N/A | N/A | N/A |
| 2025 | 5,146,339 | 147,444 | N/A | 39,737 | N/A |
| 2030 | 5,253,980 | 400,139 | 749,563 | 50,722 | 160,422 |
| 2035 | 5,374,462 | 659,650 | 2,078,668 | 52,692 | 306,348 |
| 2040 | 5,495,168 | 926,184 | 3,628,285 | 53,717 | 312,307 |

| New Jersey (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 6,232,732 | 41,096 | N/A | N/A | N/A |
| 2025 | 6,295,432 | 198,663 | N/A | 48,743 | N/A |
| 2030 | 6,358,132 | 507,483 | 895,500 | 61,841 | 195,592 |
| 2035 | 6,418,979 | 821,781 | 2,504,724 | 63,539 | 369,412 |
| 2040 | 6,486,445 | 1,115,669 | 4,221,415 | 63,976 | 371,951 |

| New Mexico (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 1,689,544 | 2,000 | N/A | N/A | N/A |
| 2025 | 1,811,600 | 40,826 | N/A | 13,931 | N/A |
| 2030 | 1,933,656 | 131,480 | 246,180 | 18,465 | 58,401 |
| 2035 | 2,065,259 | 228,285 | 742,504 | 19,961 | 116,054 |
| 2040 | 2,193,980 | 331,685 | 1,343,667 | 21,159 | 123,018 |

| Nevada (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 1,962,351 | 2,333 | N/A | N/A | N/A |
| 2025 | 2,031,239 | 45,592 | N/A | 15,705 | N/A |
| 2030 | 2,100,126 | 146,397 | 273,496 | 20,361 | 64,397 |
| 2035 | 2,143,604 | 250,735 | 807,915 | 21,212 | 123,324 |
| 2040 | 2,189,226 | 358,136 | 1,432,338 | 21,659 | 125,925 |

| New York (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 10,093,584 | 45,372 | N/A | N/A | N/A |
| 2025 | 10,617,132 | 310,585 | N/A | 81,872 | N/A |
| 2030 | 11,140,679 | 839,137 | 1,571,985 | 107,121 | 338,801 |
| 2035 | 11,557,297 | 1,391,491 | 4,401,890 | 112,715 | 655,319 |
| 2040 | 11,968,216 | 1,966,151 | 7,742,939 | 116,410 | 676,804 |

| Oregon (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 3,220,669 | 36,076 | N/A | N/A | N/A |
| 2025 | 3,267,828 | 124,779 | N/A | 25,175 | N/A |
| 2030 | 3,314,988 | 283,912 | 503,719 | 31,815 | 100,625 |
| 2035 | 3,363,030 | 445,683 | 1,332,010 | 32,713 | 190,193 |
| 2040 | 3,408,518 | 610,308 | 2,289,132 | 33,066 | 192,245 |

| Rhode Island (MY 2027 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 795,286 | 2,954 | N/A | N/A | N/A |
| 2025 | 823,769 | 21,601 | N/A | 6,443 | N/A |
| 2030 | 852,251 | 63,432 | 116,336 | 8,513 | 26,925 |
| 2035 | 879,178 | 107,546 | 342,395 | 9,032 | 52,513 |
| 2040 | 910,449 | 153,572 | 609,992 | 9,321 | 54,190 |

| Virginia (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 7,110,135 | 20,305 | N/A | N/A | N/A |
| 2025 | 7,585,079 | 188,166 | N/A | 58,586 | N/A |
| 2030 | 8,060,022 | 570,004 | 1,100,337 | 77,864 | 246,267 |
| 2035 | 8,591,734 | 978,521 | 3,194,909 | 84,280 | 490,002 |
| 2040 | 9,124,302 | 1,414,723 | 5,730,969 | 89,214 | 518,685 |

| Vermont (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 533,145 | 4,360 | N/A | N/A | N/A |
| 2025 | 541,897 | 18,157 | N/A | 4,170 | N/A |
| 2030 | 550,649 | 44,520 | 80,935 | 5,271 | 16,671 |
| 2035 | 559,240 | 71,333 | 218,223 | 5,424 | 31,533 |
| 2040 | 567,243 | 98,648 | 377,034 | 5,489 | 31,915 |

| Washington (MY 2026 Implementation) | | | | | |
|---|---|---|---|---|---|
| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs | BAU ZEV Sales | ACC II ZEV Sales |
| 2020 | 6,620,277 | 66,192 | N/A | N/A | N/A |
| 2025 | 6,838,355 | 247,268 | N/A | 52,801 | N/A |
| 2030 | 7,056,433 | 585,372 | 1,053,500 | 68,184 | 215,651 |
| 2035 | 7,191,444 | 934,265 | 2,840,414 | 70,862 | 411,988 |
| 2040 | 7,330,465 | 1,292,722 | 4,924,469 | 72,245 | 420,027 |

# Appendix: Supplemental Analyses

## A.1 New Jersey Calendar Year 2050 Emissions Analysis

At the request of New Jersey and NESCAUM, Sonoma Technology extended the New Jersey calendar year 2040 analysis to 2050. The existing MOVES outputs for 2040 were extrapolated to 2050 using emissions trends calculated from our earlier heavy-duty vehicle (HDV) analysis[18] (some LDV emissions were modeled as part that analysis) as well as MOVES Default runs for VOCs, $NH_3$, and $SO_2$, which were not modeled under the HDV analysis. We also had 2045 and 2050 renewable energy projections as part of the HDV work, so these were used to extend the GREET/eGRID grid emissions factors out to 2050.

For the BAU scenario, EPA projections of emissions reductions for 2040-2050 from their December 2021 LDV GHG rule were used. In-use ZEV population was extended to 2050 using EPA's estimated 17.2% ZEV sales ceiling for model years 2026 and beyond. Likewise, to model the ACC II scenario (with implementation in model year 2027), we used CARB-provided projections of emissions and ZEV population extending out to 2050. The projections of in-use ZEV fractions beginning in calendar year 2047 were capped at CARB-estimated levels for that year. The ZEV efficiency values used in the calculation of electricity consumption were frozen at 2040 levels in both the BAU and ACC II scenarios. COBRA modeling was not conducted for 2050. Table 6 provides the cumulative emissions reductions for $NO_x$, $PM_{2.5}$, and $CO_2e$ through 2050, and Table 7 provides the ZEV population estimates through 2050.

**Table 6.** Cumulative emissions reductions in New Jersey through 2050.

| Time Period | Cumulative Emissions Reductions | | |
|---|---|---|---|
| | $NO_x$ (U.S. tons) | $PM_{2.5}$ (U.S. tons) | $CO_2e$ (MMT)* |
| 2025-2030 | 881 | 59 | 8.2 |
| 2025-2040 | 8,886 | 649 | 94.2 |
| 2025-2050 | 25,998 | 1,755 | 269.7 |

**Table 7.** Projected ZEV population in New Jersey through 2050.

| Year | Total LDV Population | BAU ZEVs | ACC II ZEVs |
|---|---|---|---|
| 2030 | 6,358,132 | 507,483 | 895,500 |
| 2040 | 6,486,445 | 1,115,669 | 4,221,415 |
| 2050 | 6,617,348 | 1,139,694 | 5,899,717 |

[18] New Jersey Data available at https://theicct.org/benefits-ca-multi-state-reg-data/.

## A.2 Rhode Island Calendar Year 2030 COBRA Analysis

At the request of Rhode Island and NESCAUM, Sonoma Technology calculated health benefits for calendar year 2030 in COBRA. Emissions data for the BAU and ACC II scenarios were already complete. COBRA was modified to reference calendar year 2030 population and the calendar year 2030 emissions reductions from BAU. Table 8 has the COBRA-estimated health benefits and burdens for both 2030 and 2040 for comparison, in units of millions of 2017 U.S. dollars. After only four model years (2027-2030), the ACC II program still has a net benefit of $13.9 million in Rhode Island and neighboring states.

**Table 8.** Rhode Island ACC II health benefits, 2030 and 2040.

| Analysis Year | Total $NO_x$ Reduction (TPY) | Total $PM_{2.5}$ Reduction (TPY) | In-State Benefit | Out-Of-State Benefit | In-State Burden | Out-Of-State Burden | Net Benefit |
|---|---|---|---|---|---|---|---|
| 2030 | 26 | 3 | 8.1 | 7.0 | -0.6 | -0.6 | 13.9 |
| 2040 | 284 | 26 | 31.1 | 26.5 | 1.4 | 1.7 | 60.7 |

## A.3 PHEV Electric VMT Fraction Sensitivity Analysis

PHEVs can operate on either electricity or petroleum-based fuels (gasoline or diesel). CARB's ACC II regulation allows PHEVs to constitute up to 20% of the required ZEV sales. The emissions reductions from PHEVs relative to conventional vehicles is dependent on the fraction of time (fraction of VMT) that they spend operating on electricity (the eVMT fraction). CARB projects eVMT fractions of 60% for PHEV passenger cars and 49% for PHEV light trucks in model year 2026, increasing to 79% and 74% in model years 2036 and beyond. EPA's fuel economy labeling program uses a related measure known as the "utility factor," representing the fraction of time that PHEVs spend in charge depletion mode, that is, powered primarily by their batteries. EPA's utility factors vary with a vehicle's all-electric range, but they are similar in magnitude to CARB's model year 2026 eVMT factors. Sonoma Technology's emissions projections for both the BAU and ACC II scenarios are based on these estimates.

In December 2022, ICCT released a white paper examining real-world eVMT from existing PHEVs.[19] ICCT found that real-world eVMT may be 26%–56% lower than assumed, and real-world fuel consumption may be 42%–67% higher than assumed within EPA's labeling program for LDV. At the request of ICCT and NESCAUM, Sonoma Technology conducted a sensitivity test with revised PHEV

[19] "Real World Usage of Plug-In Hybrid Vehicles in the United States," ICCT, December 22, 2022, https://theicct.org/publication/real-world-phev-us-dec22/.

eVMT assumptions. ICCT provided alternative average eVMT projections of 34% for PHEV passenger cars and 28% for PHEV light trucks in model year 2026, increasing to 45% and 41% in model year 2040. Sonoma Technology substituted these values in the analysis spreadsheet, using the state of New York as a case study. With this change, the cumulative 2025-2040 emissions reductions for all pollutants were roughly 7% smaller.

While conducting this analysis, we also found that CARB's ACC II emissions inventory projections rely on PHEV sales fractions of roughly 3.3% in model year 2026, increasing to 17.3% in model year 2035, even though sales of up to 20% are permitted under the ACC II rule. In a second sensitivity test, Sonoma Technology recalculated the PHEV population estimates to represent 20% of the ZEV population in each model year. This change resulted in a loss of an additional 1.6%-2.0% from the 2025-2040 cumulative emissions benefits (for a total loss in emissions reduction benefits of approximately 8.6% to 9.0%). This represents a worst-case sensitivity test; a PHEV sales fraction of 20% would not lead to a corresponding in-use PHEV fraction of 20% for many years, until older battery-electric vehicles had been removed from the fleet due to fleet turnover.