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Analysis of the Effect of Zero-Emission Vehicle Policies: State-Level Incentives and the California Zero-Emission Vehicle Regulations

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Introduction

The U.S. Energy Information Administration (EIA) contracted with Leidos to analyze the effect of California zero-emission vehicle regulations (ZEVR) and state-level incentives on zero-emission and plug-in hybrid vehicle sales.

Leidos worked to review the effect of state-level incentives by:

- Conducting a review on the available incentives on zero-emission vehicles and related transitional vehicle types such has plug-in hybrid electric vehicles
- Quantifying the effective monetary value of these different incentives
- Evaluating the combined values of these incentives in each state on an example sale of a Nissan Leaf and Chevrolet Volt

Leidos worked to project the effect of the California ZEVR by:

- Reviewing California's mid-term review, credit reports from adopting states, and historical sales trends and credit balances
- Developing an Excel based model to project sales under potential scenarios and compliance pathways through 2025 based on AEO2017 projections

Recognizing that historical data for adoption of these vehicles is limited, the number and type of available zero-emission and plug-in hybrid electric vehicle models is increasing, and capabilities are changing rapidly, Leidos recommended further study as more data become available. Suggested further study includes:

- Expanding the ZEVR projections to include hydrogen fuel cell vehicles
- Improving the granularity of the state level analysis to a monthly level

EIA plans to use this report to improve projections for sales of these vehicle types and modeling methodology for the ZEVR in the *Annual Energy Outlook 2018.* Example modeling improvements will include credit banking and spending, and the Section 177 state alternative compliance pathway. Through this added capability, EIA can examine various compliance pathways through different bank utilization rates and sales strategies.

Appendix A

Analysis of the Effect of Zero-Emission Vehicle Policies:

State-Level Incentives and the California Zero Emission Vehicle Regulations

Final Draft

Submitted:

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List of Abbreviations

ARB – Air Resources Board of the California Environmental Protection Agency

ATPZEV -- Advances technology partial zero emission vehicle

CBCR – Ratio of total 2025 credit balance to total 2026 credit requirement

CCR – California Code of Regulations

EVSE -- Electric vehicle supply equipment

FCEV – Fuel cell electric vehicle

HOV -- High-occupancy vehicle

ICCT -- International Council on Clean Transportation

IVM – Intermediate-size vehicle manufacturer

KBB – Kelly Blue Book

LDV – Light-duty vehicle

LVM – Large-size vehicle manufacturer

MY – Model year

NEV – Neighborhood electric vehicle

PHEV – Plug-in hybrid electric vehicle

PZEV -- Partial zero emission vehicle

S177 – Section 177 of the Clean Air Act

SVM -- Small-size vehicle manufacturer

TZEV – Transitional zero emission vehicle

VTTS -- Value of travel time savings

YoY – Year-on-year

ZEV – Zero emission vehicle

ZEVR – California zero emission vehicle regulations

ZP – Combined ZEVs and PHEVs

1 Introduction

1.1 Objective and Approach

The objective of this report is to assess the effect of state-level policies on the sales of zero-emission vehicles (ZEVs) and plug-in hybrid electric vehicles (PHEVs). Two analysis approaches are applied. The first approach assesses the potential effect of state-level incentives through quantification of the monetary value of ZEV and PHEV incentives and comparison of these values to state-level sales of these vehicles. The second approach focuses on the effect of California ZEV regulations on sales in California and in the nine other states that have adopted these regulations. ZEV and PHEV sales in these ten states are projected through 2025 under a variety of scenarios based on the regulations and associated historic trends in sales and credit balances earned under these regulations.

1.2 Policy Goals that Support ZEV and PHEV Adoption

Key multi-state drivers of ZEV and PHEV adoption are the California Zero Emission Vehicle Regulations,[1] abbreviated as the "ZEVR" in this report. These regulations are part of California's Advanced Clean Cars (ACC) program, and were established with the intent to support and accelerate the numbers of PHEVs and ZEVs in California. Under Section 177 of the Clean Air Act, other states are given the option to adopt California's standards to help achieve federal air quality requirements. Nine states have fully adopted the ZEVR: Connecticut, Massachusetts, Maryland, Maine, New Jersey, New York, Oregon, Rhode Island, and Vermont. Together, the ten ZEVR states represent more than a quarter of total annual light-duty vehicle sales in the United States.

The adoption of ZEVs and PHEVs provides a means to achieve policy goals to reduce emissions from the transportation sector. An example of ZEV policies beyond the ZEVR that support emissions reductions is seen in California Executive Order B-16-2012 (March 23, 2012), which establishes a target to reduce Greenhouse Gas (GHG) emissions from transportation by 80% in 2050 compared to 1990 levels. This order also outlines measures to support ZEV deployment and directs state agencies to establish benchmarks to achieve no less than 1.5 million "ZEVs" on the road by 2025, where "ZEVs" includes both ZEVs and PHEVs. California Executive Order B-30-2015 further establishes an interim statewide target to reduce GHG by 40% in 2030 compared to 1990 levels. These targets are reinforced in legislation (Chapter 547, Statutes of 2015, Senate Bill 350, De Leon), which concluded that the GHG reduction goals in the Executive Orders will require widespread transportation electrification, and the Charge Ahead California Initiative, Senate Bill 1275 (De León, Chapter 530, Statutes of 2014), which sets a target to place in service 1 million ZEVs and near ZEVs by January 1, 2023.

Beyond California, a collective target of at least 3.3 million ZEVs and PHEVs on the road by 2025 was agreed to in the *State ZEV Programs Memorandum of Understanding* (MOU).[2] The MOU was signed in 2013 by the governors of California and seven of the nine other states that have adopted the ZEVR (i.e., all but Maine and New Jersey). The MOU states that "accelerating the ZEV market is a critical strategy for achieving our goals to reduce transportation-related air pollution, including criteria air pollutants, mobile source air toxics and GHGs, enhance energy diversity, save consumers money, and promote

[1] Title 13 of the California Code of Regulation (CCR), Sections 1962.1 and 1962.2

[2] 2013. State Zero Emission Vehicle Programs Memorandum of Understanding. http://www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf/

economic growth." This was followed by the *Multi-State ZEV Action Plan*,[3] which lists eleven actions to encourage the ZEV market through facilitating both the purchase and lease of vehicles, and planning and investing in ZEV infrastructure. The partner states have subsequently developed these actions to varying extents. State-level actions to encourage ZEV adoption are also found in many states that are not part of the MOU.

The ZEVR encourages ZEV and near-ZEV sales through a "negative" incentive in the form of monetary penalties for manufacturers that fail to obtain the required level of ZEV and near-ZEV sales credits. Other ZEV incentives are generally positive incentives that reward the purchase or use of ZEVs and PHEVs. Many of these positive incentives, as taken by both ZEVR states and other states, are described in the following section.

2 State ZEV Incentive Analysis

The purpose of this analysis is to assess the impact of state government incentives on ZEV and PHEV price, value, and sales. Many states offer incentives to promote ZEV and PHEV adoption. These incentives include financial subsidies, such as rebates, tax exemptions, grants, and loans, as well as incentives for vehicle use, such as free parking, high occupancy vehicle (HOV) lane access, and emission inspection exemptions. There are also incentives that target electric vehicle supply equipment (EVSE) such as rebates and tax credits for installing charging equipment. The incentives target various end-users including individual vehicle owners, vehicle fleets, vehicle and parts manufacturers, and alternative fuel producers. Most incentives are available to a broad spectrum of end-users, including both individuals and fleets.

This analysis applies methodologies to quantify the monetary value of statewide ZEV and PHEV incentives that target both individual and fleet owners. The more limited number of incentives that only target fleets are not included. The assessed incentives include the technology categories of all-electric (battery) vehicles, plug-in hybrid electric vehicles, and hydrogen fuel cell vehicles. The analysis also includes incentives for the purchase of home electric vehicle supply equipment (EVSE).

For the current analysis, methods for the monetization of specific consumer-oriented U.S. state-level incentives, developed in a 2014 white paper by the International Council on Clean Transportation (*ICCT White Paper*),[4] are applied and modified where appropriate.

2.1 Valuation Methods

The primary source for identification of state-level incentives in this analysis was the U.S. Department of Energy Alternative Fuels Data Center (AFDC) database.[5] Additional sources were used to obtain more detailed descriptions of incentives as needed, including individual state level departments of environment and transportation.

This analysis includes 54 individual state-level direct incentives offered by 30 states as of December 2016. These include 19 incentives for vehicle purchase or lease, including rebates and tax credits, and 27 incentives for vehicle use, including HOV lane exemptions, state vehicle inspection exemptions, and free public parking. The analysis also includes 8 incentives that offset the cost of installing home EVSE. An

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[3] 2014. Multi-State Zev Action Plan. http://www.mass.gov/eea/docs/dep/air/community/zevplan14.pdf

[4] Jin, L., Searle, S., and Lutsey, N. (2014). Evaluation of State-Level U.S. Electric Vehicle Incentives. *ICCT White Paper*. Retrieved December 1, 2016, from http://www.theicct.org/sites/default/files/publications/ICCT_state-EV-incentives_20141030.pdf

[5] U.S. Department of Energy Alternative Fuels Data Center. 2016. http://www.afdc.energy.gov/

additional type of incentive, free public electric vehicle charging, was not quantified as it was determined not to be a significant contributor to state-level incentive value. While a study published in 2013 suggests the majority of vehicle charging is done at home or at work,[6] which would limit the value of free public charging, these patterns may be changing, particularly with the development of fast recharging.

In many cases the value of an incentive, particularly purchase incentives, is calculated based on vehicle characteristics such as technology type, battery capacity, range, or a combination of characteristics. In order to provide a consistent comparison across states and vehicle types, incentives for ZEVs are estimated based on the purchase of a model year 2016 (MY2016) Nissan Leaf SV and incentives for PHEVs on the purchase of a MY2016 Chevrolet Volt. The relevant characteristics for these vehicles are shown in Table 1 below.

Table 1. Characteristics of sample vehicles

Characteristic	2016 Nissan LEAF SV	2016 Chevrolet Volt LT
MSRP	$34,200	$33,170
Battery Capacity (kWh)	30	18.4
Range (miles)	107	53 battery-only 420 total

While many of the reviewed incentives applied to both ZEVs and PHEVs, there were some exceptions. For example, South Carolina offered an income tax credit that only applied to PHEV purchases, and a sales tax exemption that only applied to hydrogen fuel cell vehicles. Several states had incentives that only applied to ZEVs, most of which were emission test exemptions. New Jersey offered a sales and use tax exemption incentive to only ZEVs.

The sections below describe the methodology for quantifying each type of incentive.

2.1.1 Rebates

Nine states offered monetary rebates for the purchase or lease of a ZEV or PHEV. Rebate amounts ranged from $1,500 for the purchase of a PHEV in Delaware to $3,500 for the purchase of a ZEV, also in Delaware. A $3,500 rebate was offered in Texas, although it applied to the replacement of a higher emissions vehicle with any type of cleaner vehicle, including conventional propulsion systems. Further, the Texas incentive limited eligibility on the basis of income and age of the replaced vehicle. Nonetheless, it is included in this analysis.

Some states allow purchasers to individually submit rebate applications. In these cases, the rebate is received as a paper check or a direct deposit with a delivery time ranging from 10 days to six weeks after application approval. Other states, such as Texas, require the dealer to file the rebate application. In these cases, the dealer receives the rebate on behalf of the purchaser and subtracts the rebate amount from the sale price of the vehicle or from the monthly payments. Still other states allow the purchaser to choose whether they receive the rebate individually or request the rebate through the dealer. One

[6] Idaho National Laboratory. Plugged In: How Americans Charge Their Electric Vehicles. Findings from the largest plug-in electric vehicle infrastructure demonstration in the world. 2013. https://avt.inl.gov/sites/default/files/pdf/arra/SummaryReport.pdf

state, California, calculates rebate amounts based on the purchaser's gross annual income in addition to vehicle characteristics, and purchasers are not eligible for rebates if their incomes are above the thresholds set by the program.[7] For the purpose of this analysis, the incentive value was quantified assuming a single filer with a gross annual income less than $150,000, which would be eligible for the rebate.

2.1.2 Tax Credits

Five states, Colorado, Louisiana, Maryland, South Carolina, and Utah, offered tax credits for the purchase or lease of a ZEV or PHEV. As noted above, South Carolina was the only state to offer a tax credit only for PHEVs. Similar to the rebate programs, tax credit amounts varied depending on vehicle characteristics. However, an income tax credit reduces a purchaser's tax liability on a dollar-for-dollar basis. Therefore, depending on the purchaser's individual tax liability, they may not receive the full tax credit amount. Two states, Colorado and Louisiana, offered refundable income tax credits. This means if the amount of the tax credit exceeds the purchaser's tax liability, the additional amount will be refunded to the tax payer. Maryland offered an excise tax credit that allowed a credit for the full amount of the excise tax imposed on qualified ZEVs and PHEVs. In the remaining states with tax credits (South Carolina and Utah), the full tax credit would have been received for at least a median household income and average tax deduction in those states.[8] For the purpose of this analysis, all values for tax credits are shown as the maximum possible value. Tax credit amounts ranged from $1,000 for the purchase or lease of a PHEV in Utah to $6,000 towards the purchase of a ZEV in Colorado. The vehicle characteristics and formulas for calculating tax credit amounts varied by state. For example, Colorado's tax credit is calculated as the actual cost incurred to purchase or lease the vehicle multiplied by the battery capacity and divided by 100, not to exceed $6,000. Using this formula and cap, many PHEVs and ZEVs would qualify for the maximum credit.

2.1.3 State Sales Tax Exemption

Three states, New Jersey, South Carolina, and Washington, and the District of Columbia, exempted ZEVs and/or PHEVs from state sales tax. New Jersey exempted only ZEVs and South Carolina only exempted hydrogen fuel cell vehicles. Sales tax exemption incentive values varied based on vehicle price and the amount of sales tax that would have been applied without the incentive. This incentive is calculated by multiplying the state sales tax percentage by the purchase price of a ZEV or PHEV.

2.1.4 Free Parking

Three states, Arizona, Hawaii, and Nevada, offered free parking for drivers of ZEVs and PHEVs. Arizona's free parking program only applies to designated carpool operator parking spaces, as such, it is not included in this analysis because it is thought to benefit a relatively small number of users. The benefits of parking incentives are assumed to be limited to major metropolitan areas, which is where most public street parking is utilized. For valuation in this analysis, Honolulu is used to represent metropolitan areas in Hawaii, and Las Vegas and Reno is used to represent metropolitan areas in Nevada. The value of the free parking incentive is calculated as follows:

$$V_s = R_s \times P_s \times H \times Y$$

[7] The income cap does not apply to the purchase of fuel cell electric vehicles.

[8] Median Income from U.S. Census Bureau. State taxes calculated using http://taxformcalculator.com/state_tax.html. Average tax deduction from Wall Street Journal (2010) https://www.wsj.com/articles/SB10001424127887323852904578128950616756728

Where:

V_s = Value of parking incentive for state s
R_s = Average hourly parking rate for state s
P_s = Percentage of population that is metropolitan for state s
H = Average hours parked per year
Y = Years of vehicle ownership

The average hourly parking rate is estimated based on city-specific rates of public metered parking spaces as reported at Parkopedia.com. The average hours parked per year is calculated with the assumed use of 5 hours of public parking per week, which is the same assumption used in the *ICCT White Paper*. The original source of this assumption is a 2009 Honolulu parking survey. No studies were found with more recent data on average public parking time in metropolitan areas. The average length of vehicle ownership is assumed to be five years based on average ownership of new light-duty vehicles as reported by IHS Automotive.[9]

Although the average parking fees in both states were similar ($0.75 per hour in Honolulu and $1.00 per hour in Las Vegas and Reno), the free parking incentive in Hawaii is more than twice as valuable on a statewide basis than in Nevada primarily because a larger fraction of the population of Hawaii lives in metropolitan areas.

2.1.5 Inspection Exemption

As of December 2016, 33 states and the District of Columbia required vehicle emission inspections.[10] Of these, 13 states exempted ZEVs from the inspection program. Only one of these states, North Carolina, also exempted PHEVs. The benefits of this incentive include the value of the avoided inspection fees and the value of the time saved by avoiding inspection. Both of these benefits are summed over the length of vehicle ownership. However, many states delay the requirement for emissions inspection for the first three to four years after the model year and this delay is included in the valuation for this incentive. After the delay period, if any, most state inspection programs require annual or bi-annual inspections with fees ranging from $20 to $40. The average time to complete an inspection is assumed to be 30 minutes. The value of this incentive did not vary widely across states and is relatively small compared to other incentives offered.

2.1.6 High Occupancy Vehicle (HOV) Lane Access

Twelve states offered ZEVs and PHEVs access to HOV lanes regardless of the number of passengers in the vehicle. The primary benefit of this incentive is the time saved by avoiding congestion on non-HOV travel lanes. While travel time savings may also reduce vehicle operating costs, these costs are assumed to be marginal and are not included in the analysis. The value of HOV access is estimated as the product of the fraction of the state population living in areas with HOV lanes, the Value of Travel Time Savings (VTTS), and Time Savings. Each of these three factors is further described below.

The fraction of the state population living in areas with HOV lanes is estimated with the assumption that HOV lanes are only in major metropolitan areas. As such, the fraction of the population that benefit

[9] Business Wire. July 29, 2015. IHS Automotive - Length Of Vehicle Ownership 2005-15 (Graphic: Business Wire). The Street. https://www.thestreet.com/story/13235449/1/ihs-automotive--length-of-vehicle-ownership-2005-15-graphic-business-wire.html

[10] American Automobile Association. 2016. Digest of Motor Laws. Emissions Inspection. http://drivinglaws.aaa.com/tag/emissions-inspection/

from this incentive is the ratio of the state's metropolitan population to its total population. Population data for major metropolitan areas for each state were obtained from the U.S. Census Bureau.

VTTS is calculated following the U.S. Department of Transportation's (DOT*) Guidance on Valuation of Travel Time in Economic Analysis*.[11] Using this method, VTTS is the sum of local and intercity travel time savings, where each of these is the product of the following:

- *Median hourly household income* – median annual household income divided by 2080 work-hours per year. State median incomes used in this analysis are from the U.S. Census Bureau.
- *Value of personal travel time* – The DOT estimates the value of personal travel time as a percentage of the median hourly household income where intercity travel time is valued at 70% of the hourly income and local travel is valued at 50% of the hourly income. This distinction is based on the assumption that the value of travel time increases with distance.
- *Travel type proportion* – each type of travel, local and intercity, is assigned a proportion of total travel. Considering ZEV range limitations, it was assumed that 70% of ZEV driving time is local travel and 30% is intercity travel.

Time Savings is estimated as the product of travel time to work, the ratio of peak travel time to free-flow travel time, and an HOV relief factor as shown in the following equation:

$$S_s = T_s \times R_s \times F$$

Where:

Ss = Time savings for state s
Ts = Travel time to work for state s
Rs = Ratio of peak travel time to free-flow travel time for state s
F = HOV relief factor

Travel time to work is from the U.S. Census Bureau's American Community Survey (ACS) Mean Travel Time to Work[12] in which travel time to work refers to total minutes to and from work per week. The ratio of peak-period travel time[13] to free-flow travel time is the Travel Time Index as reported in the DOT Federal Highway Administration's Urban Congestion Report[14] where HOV lane travel is assumed to be the same as free flow travel. The HOV Relief Factor is a rough approximation to account for the fact that only a fraction of work travel time is relieved by HOV lanes. This analysis used a factor of 20% for all metropolitan areas. This factor may be modified as more data on HOV lane utilization is identified.

The value of HOV lane access was much higher in states that have large metropolitan areas with longer travel times and greater differences in Travel Time Index. For example, the value of this incentive in California, New York, and Hawaii was more than double that of most other states that offered this incentive.

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[11] US Department of Transportation. Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis. https://www.transportation.gov/sites/dot.dev/files/docs/vot_guidance_092811c.pdf.
[12] U.S. Census Bureau. Mean Travel Time to Work. https://www.census.gov/quickfacts/meta/long_LFE305214.htm.
[13] Peak period travel time is based on weekday morning and evening peak periods of 6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m., respectively.
[14] DOT Federal Highway Administration. Travel Time Index. http://www.ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm.

2.1.7 Electric Vehicle Supply Equipment (EVSE) Incentives

Eight states offered rebates or tax credits for the purchase and installation of residential EVSE. The value of this incentive is based on the purchase and installation of Level 2 EVSE, which is assumed to be a typical residential installation. Level 2 equipment provides charging through a dedicated 240V AC plug and usually requires professional installation.

According to a 2014 study by the Rocky Mountain Institute, the cost of a typical home Level 2 EVSE installation is approximately $1,200.[15] The cost of the charging station equipment itself accounts for about half of this cost. Professional installation by an electrician accounts for the remaining cost, which typically includes the cost of materials and labor necessary to install a 240V circuit from an existing breaker panel.

Depending on the incentive structure, the value of EVSE incentives is calculated as either the fixed amount of the offered rebate or tax credit, or the offered percentage of the installation cost. Some examples of EVSE incentives include a $500 rebate in Delaware for installation of residential Level 2 charging stations, and tax credit in the District of Columbia for 50% of the costs for purchase and installation of residential EVSE, with a maximum credit of $1,000.

2.2 Valuation Results

Figure 1 shows the estimated value of state level ZEV incentives for the 20 states with the highest combined ZEV incentive values as of December 2016 with ZEVR states indicated by a box around the state name. Two ZEVR states, Maine and Vermont, did not offer consumer-oriented incentives as of December 2016 and are therefore not shown on this chart.

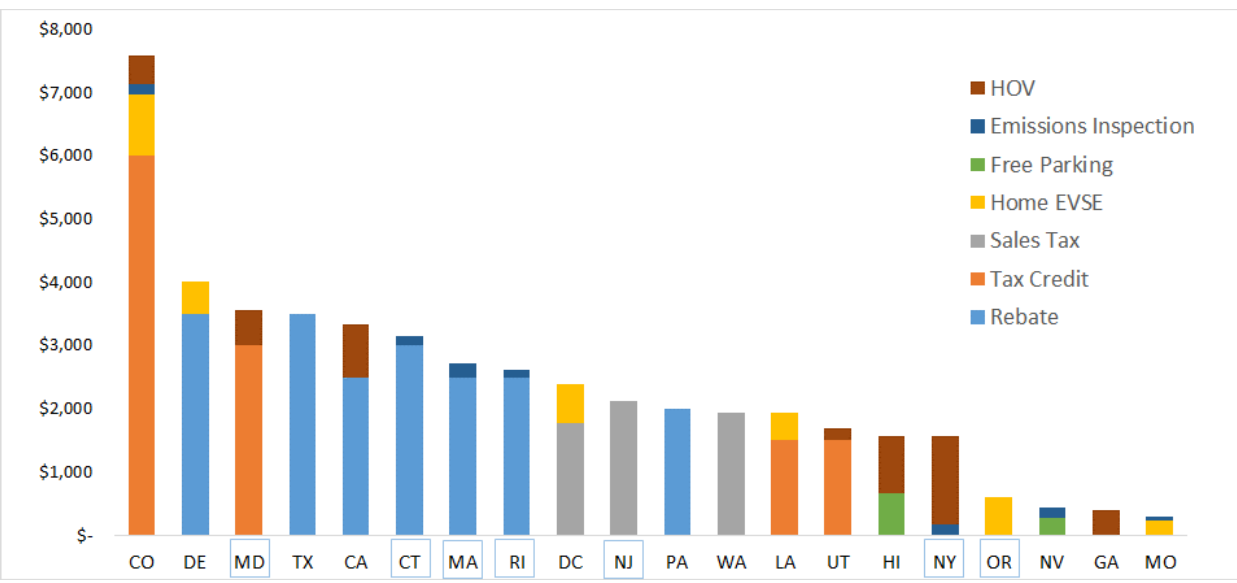

Figure 1. Value of state level ZEV incentives

[15] The Rocky Mountain Institute. Pulling Back the Veil on EV Charging Station Costs. http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs.

Rebates and tax credits made up the largest share of incentive value across states. Colorado had the highest direct incentive with a $6,000 tax credit offered for purchasing ZEVs and most PHEVs. State sales tax exemptions also accounted for a large share of incentive value.

Figure 2 shows the estimated value of state-level PHEV incentives for the 20 states with the highest combined PHEV incentive values as of December 2016 with ZEVR states indicated by a box around the state name. As with ZEV incentives, rebates, tax credits, and sales tax exemptions made up the majority of incentive value for PHEVs. New Jersey, a ZEVR state, had a sales tax exemption that only applied to ZEVs and therefore does not appear in this chart.

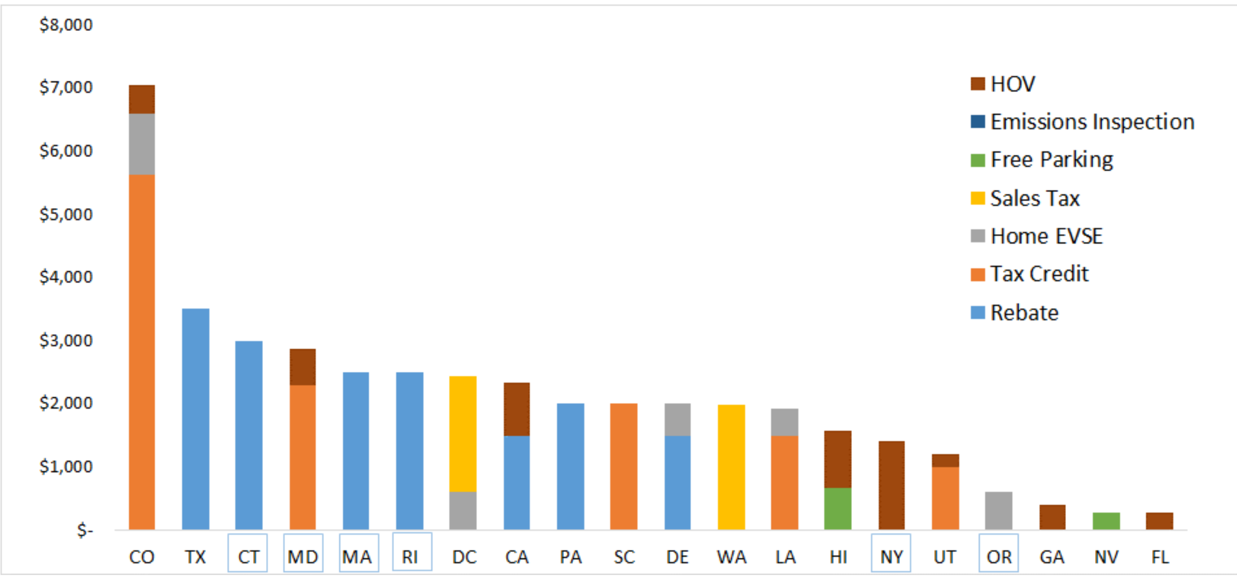

Figure 2. Value of state level PHEV incentives

2.3 Incentive Impact on Prices

The impact of incentives on vehicle price was assessed by calculating the average price for a MY2016 Nissan Leaf (a ZEV model) and a MY2016 Chevrolet Volt (a PHEV model), including registration, taxes, and direct monetary incentives for purchases in each state. The price that a consumer ultimately pays for a vehicle varies from state to state and even from dealer to dealer. The manufacturer suggested retail price (MSRP), or the price the consumer sees on the "window sticker" of a vehicle, does not show the variety of discounts typically offered by manufacturers to dealers or customers. The two most common discounts offered to dealers are Dealer Holdback and Dealer Cash Incentives. The Dealer Holdback is a percentage of the invoice price a manufacturer pays to the dealer. The Dealer Holdback is designed to supplement a dealer's cash flow and offset variable expenses. Edmunds estimates that a typical holdback is approximately two percent of the total vehicle invoice, however, it varies across manufacturers and can range from zero to three percent.[16] Dealer Cash Incentives are provided by manufactures on a regional basis, often to generate sales on specific models. These incentives are

[16] Reed, Philip. July 30, 2013. Dealer holdback, what it is and how it works. Edmunds. https://www.edmunds.com/car-buying/dealer-holdback/

proprietary information, as such, there is very little data on the actual amounts that manufacturers offer to dealers in the form of holdbacks and cash incentives. In addition, the sticker price does not reflect tax, title, license, or registration fees. These fees vary from state to state and can collectively add a significant amount to the final price of the vehicle.

The average vehicle sales price for a MY2016 vehicle in metropolitan areas in each state was obtained from Kelley Blue Book (KBB).[17] The KBB sales prices are the average of actual transactions in a region and include the sticker price and destination fee, but do not include title, registration, and other fees or incentives. State sales tax and dealer documentation fees from Edmunds,[18] as well as state registration fees from the National Conference of State Legislatures[19] were added to the average vehicle sales prices to calculate the total vehicle price to the consumer before incentives.

Average vehicle prices before fees did not vary significantly from state to state for either vehicle. The nationwide average sales price for a MY2016 Nissan Leaf SV, including destination charge but not including taxes and fees, was $32,398. The average price for a MY2016 Chevrolet Volt was $31,371. The highest price for the Nissan Leaf before taxes and fees was in Hawaii, at $32,681, and the lowest price was in Georgia, at $31,632. The highest price before taxes for the Chevrolet Volt was in Rhode Island, at $31,732, and the lowest was in Georgia at $30,702. Taxes were the largest and most highly variable additional cost with a nationwide average tax of $2,332. Taxes ranged from over $3,800 in Arkansas to under $1,500 in Hawaii. Four states, Delaware, New Hampshire, Montana, and Oregon, do not charge sales tax on vehicles as part of state law. Other states, including New Jersey, South Carolina, Washington, and the District of Columbia, offered incentives that exempt ZEV and PHEV purchasers from sales tax. With the addition of taxes and fees, Arizona had the highest average price for both for the Nissan Leaf, at $37,130, and the Chevrolet Volt, at $36,803. Oregon showed the lowest price for both vehicles at $32,334 for the Nissan Leaf and $31,428 for the Chevrolet Volt.

The final cost to the consumer for both vehicles in each state was calculated with the addition of the Federal income tax credit and the value of state incentives, as described above. Figure 3 shows the cost of a 2016 Nissan Leaf SV before and after incentives in the twenty states with the lowest price after incentives.

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[17] Kelley Blue Book Co. 2016. https://www.kbb.com/

[18] Reed, Philip. March 15, 2016. What New Car Fees Should You Pay? Edmunds. https://www.edmunds.com/car-buying/what-fees-should-you-pay.html#chart.

[19] National Conference of State Legislatures. January 31, 2017. Registration and title fees by state. http://www.ncsl.org/research/transportation/registration-and-title-fees-by-state.aspx.

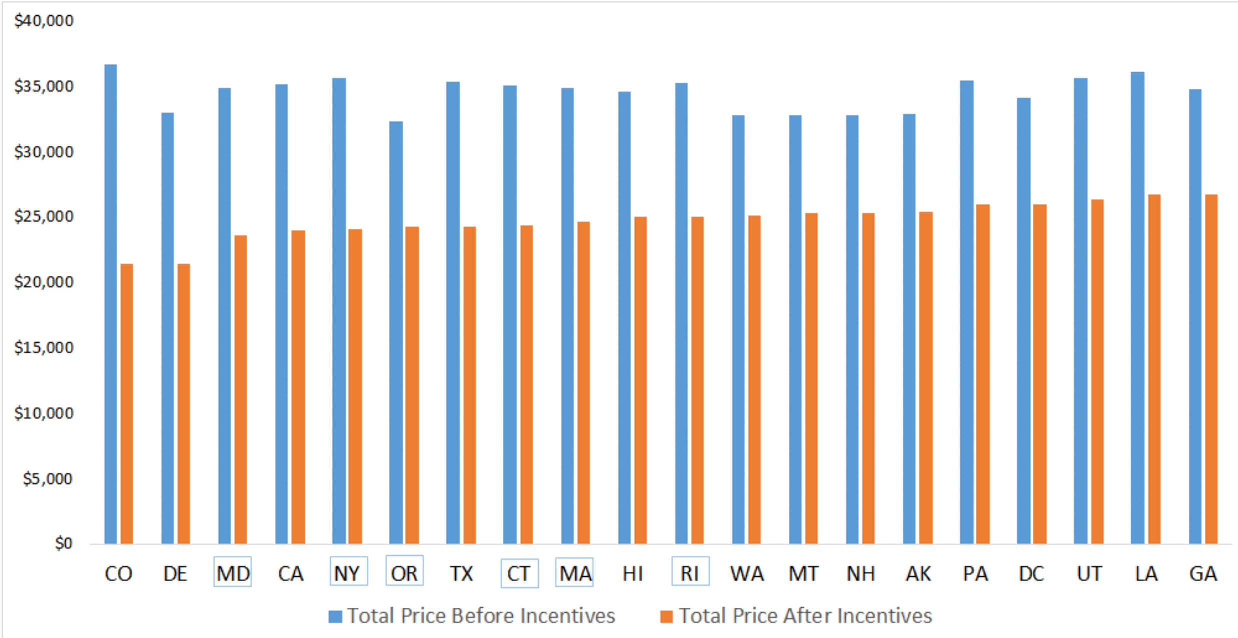

Figure 3. Cost of 2016 Nissan Leaf SV before and after incentives (ZEVR states are indicated by boxes around the state name)

For the Nissan Leaf, the state with the lowest cost after incentives was Colorado. This state had the second-highest cost before incentives (after Arizona), however, the large direct ZEV incentive available in that state reduced the final cost significantly. The state with the next lowest cost after incentives was Delaware. This state offered a significant ZEV purchase incentive as well as no state sales tax, making this one of the lowest cost states before and after incentives. Notably, these two states are not ZEVR states. Arizona had the highest cost before and after incentives due to relatively high sales tax and fees and relatively low-value incentives.

Figure 4 shows the cost of a MY2016 Chevrolet Volt before and after incentives in the twenty states with the lowest post-incentive price. The state with the lowest price after incentives was Colorado, and the state with the highest price was Arizona. Colorado remained the lowest-price state after incentives for both the Nissan Leaf and the Chevrolet Volt due to the large tax credit that applied to both ZEVs and PHEVs.

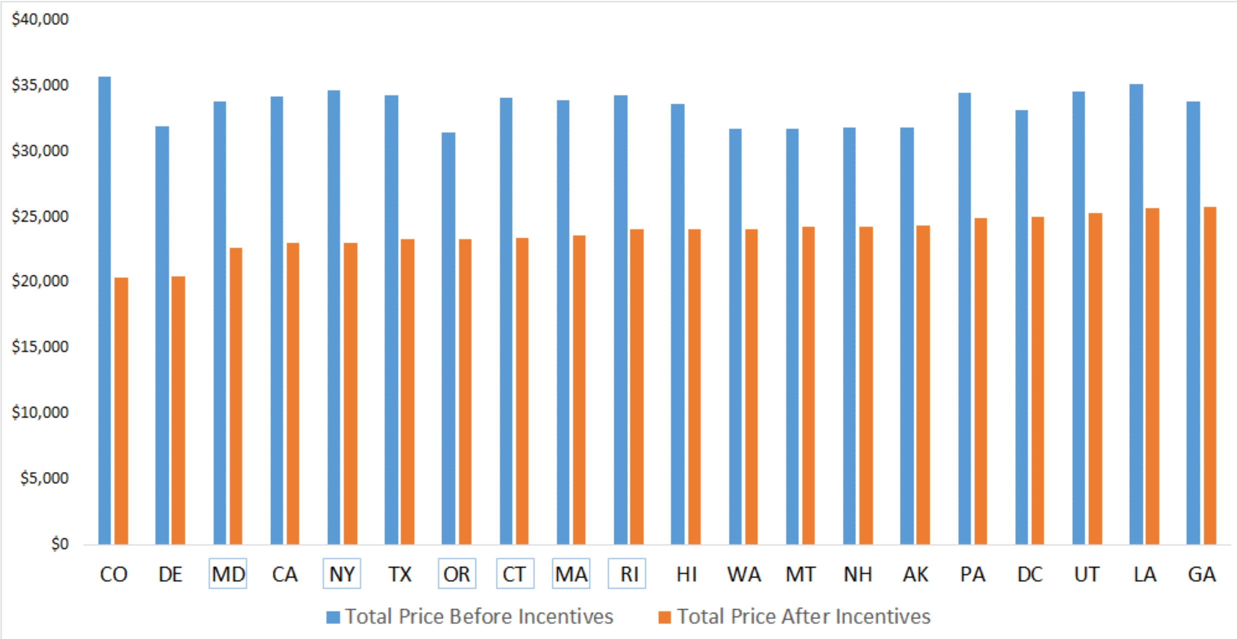

Figure 4. Cost of 2016 Chevrolet Volt before and after incentives (ZEVR states are indicated by boxes around the state name)

2.4 Incentive Impact on Sales

State-by-state valuations of ZEV incentives available as of December 2016 were compared to 2016 state-level market share for ZEVs and PHEVs. Market share data represent the percentage of new vehicle sales in 2016 and are from the Alliance of Automobile Manufacturers.[20] Figure 5 shows the twenty states with the largest ZEV incentive values along with their 2016 market share for ZEVs. Figure 6 shows the twenty states with the highest PHEV incentive values along with their 2016 market share for PHEV. Market shares are shown as circles.

[20] Auto Alliance. 2017. ZEV sales dashboard. https://autoalliance.org/energy-environment/zev-sales-dashboard/

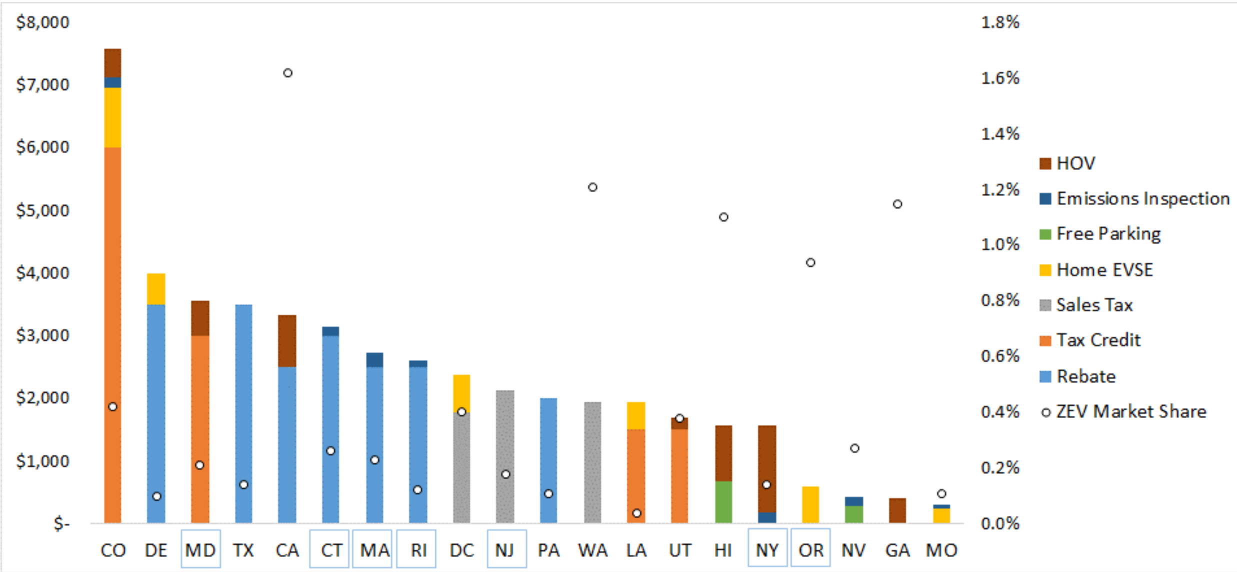

Figure 5. ZEV 2016 incentive value and market share

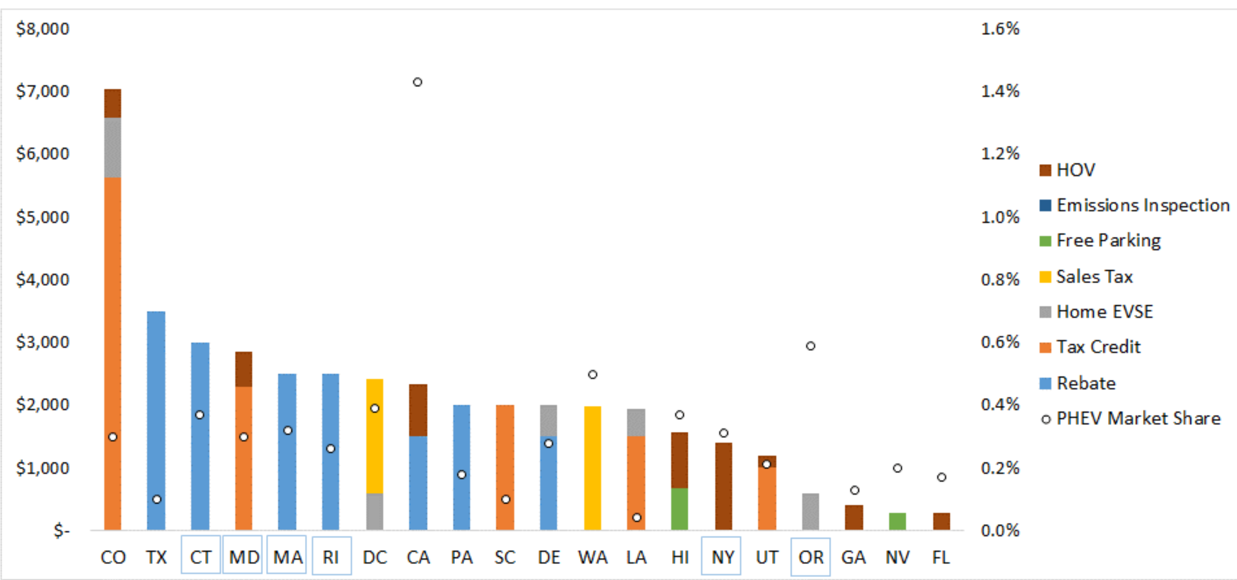

Figure 6 PHEV 2016 incentive value and market share

As seen in Figure 5 and Figure 6, the valuation of state-level ZEV incentives was not well correlated with market share of ZEVs and PHEVs in 2016. For example, the four states with the highest ZEV market shares, Washington, Oregon, Hawaii, and Georgia, had relatively low ZEV incentive values. Oregon had one of the lowest incentive values, offering only a modest EVSE rebate, yet had one of the higher ZEV and PHEV market shares. Oregon credits their high adoption rates primarily to their extensive and wellplanned public EVSE network.[21] This is also the case in Washington, which had a much higher ZEV and PHEV market share than states that offered more valuable incentives. These states, along with California, highlight the regional nature of ZEV and PHEV adoption trends. The west coast has a comparably robust electric vehicle charging network with thousands of Level 2 charging stations and dozens of direct current (DC) fast chargers, particularly along the Interstate 5 corridor through Washington, Oregon, and California. Availability of charging stations appears to be a strong driver for ZEV and PHEV adoption in this region. Hawaii also had high ZEV and PHEV market share, while ranking relatively low for incentive value. Hawaii has some unique drivers for ZEV and PHEV adoption, such as inherently limited driving distances and the highest gasoline prices in the country, in addition to a relatively robust EVSE infrastructure. In some cases, the 2016 incentives may not reflect prior incentives that were discontinued before 2016. This is the case with ZEV sales in Georgia, which had a low 2016 incentive value yet had one of the highest ZEV market shares. This is due primarily to a large ZEV rebate program that ended in July 2015.

In contrast, states such as Texas and Colorado had low ZEV and PHEV market share relative to the value of their incentives. In Texas, this may be due to the structure of the rebate program which, as discussed above, had much stricter eligibility requirements than most other states. Colorado's tax credit program only began in mid-2016, which may explain the low market share. This is also the case in Delaware, which began offering rebates for ZEVs in November 2016, and shows a low 2016 ZEV market share.

Comparing sales and incentives over time shows that incentives, particularly rebates and tax credits, do have a direct impact on sales, at least in some states. For example, Figure 7 below shows monthly sales of ZEVs and PHEVs in Georgia from January 2013 to October 2016. A steep decline in ZEV sales is seen in July 2015, when the ZEV rebate was discontinued.

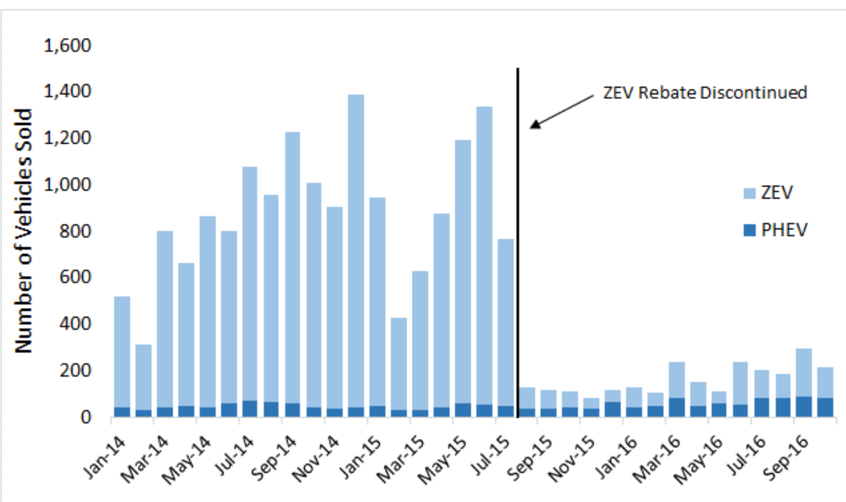

Figure 7 Monthly ZEV and PHEV sales in Georgia from January 2014 to October 2016

[21] Connor, Patrick. November 26, 2014. Oregon Proves Key To Electric Car Adoption Isn't Necessarily Purchase Incentives. Transport Evolved. https://transportevolved.com/2014/11/26/oregon-proves-key-electric-car-adoption-isnt-necessarily-purchase-incentives/

In contrast, monthly sales data for Rhode Island (Figure 8) do not show as clear an effect in response to the beginning of a PHEV rebate program in February 2015.

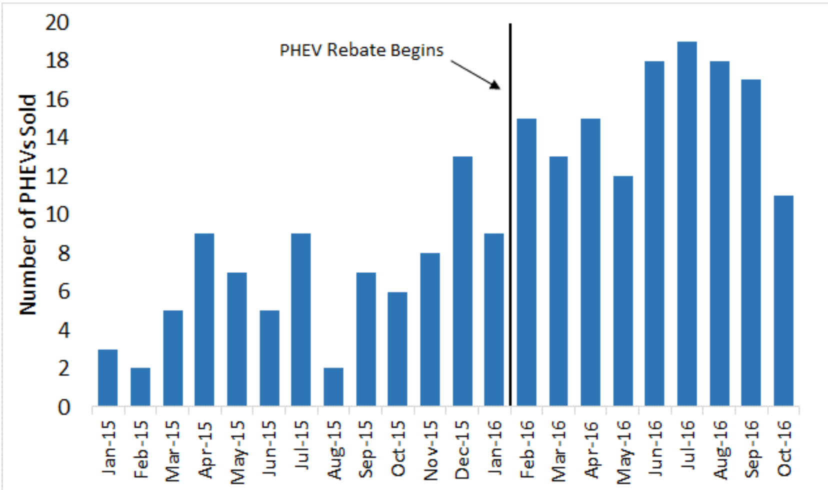

Figure 8 Monthly ZEV and PHEV sales in Rhode Island from January 2015 to October 2016

As seen below, the correlation between total incentive value and market share is low. The correlation coefficient for total incentive value and market share is 0.1 for ZEVs and 0.2 for PHEVs. Figure 9 shows scatter plots of incentive value and market share for ZEVs and PHEVs.

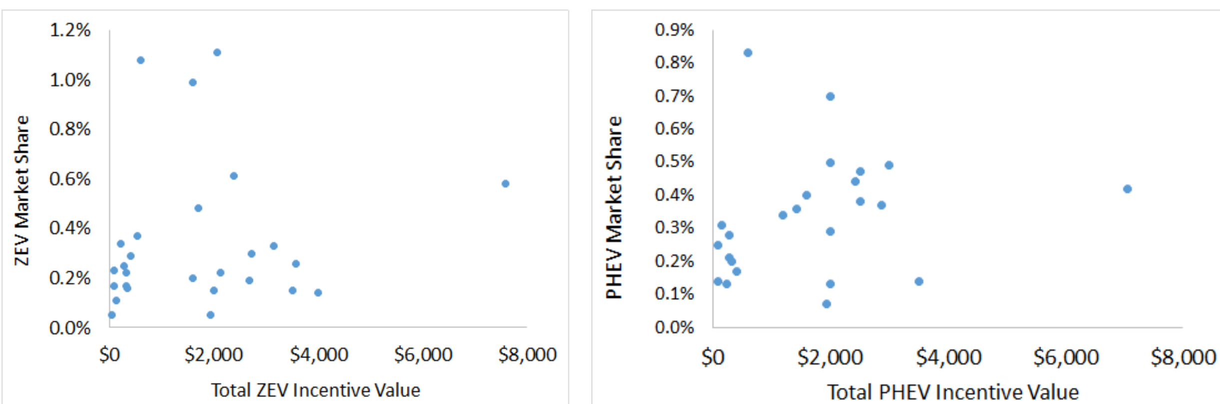

Figure 9 Total 2016 incentive value and market share in states that offer ZEV and PHEV incentives

The *ICCT White Paper*, from which the methodologies in this analysis are derived, found a strong positive correlation between total incentive value and sales for both ZEVs and PHEVs in 2013. However, the current study did not find a strong correlation between total incentive value and sales or market share in 2016. This may be due to the greater number of ZEV and PHEV models available in 2016 compared with 2013, suggesting a greater variety of auto dealers that need to be informed of the incentives. A 2013 UC Davis study found that many dealers in California were not aware of the various incentives at the state level, and for those that were, the incentives introduced multiple levels of uncertainty and risk.[22] A more recent 2016 study of the vehicle shopping experience found that dealers failed to discuss available state rebates about 33 percent of the time.[23]

Overall, this analysis suggests that, while state incentives appear to play a role in ZEV and PHEV adoption rates, measurement of the significance of an incentive on sales requires data granularity on at least a monthly basis, and may also need to account for lags in development of incentive awareness as well as other factors.

3 Sales Projections in Zero Emission Vehicle Regulation (ZEVR) States

ZEV and PHEV sales are assumed to be largely driven by regulations in the 10 states that have adopted Title 13 of the California Code of Regulations (CCR), Sections 1962.1 and 1962.2, which are referred to as the Zero Emission Vehicle Regulations (ZEVR) in this report. In addition to California, the ZEVR states include nine states that are referred to as S177 states because as allowed under Section 177 of the Clean Air Act, they have chosen to adopt California regulations to help achieve federal air quality requirements. The S177 states are: Connecticut, Massachusetts, Maryland, Maine, New Jersey, New York, Oregon, Rhode Island, and Vermont.

The ZEV and PHEV sales projections in this report are based on the ZEVR and associated historic trends in sales and credit balances earned under the ZEVR. While incentives directed at ZEV and PHEV buyers (as described in Section 2) may assist manufacturers in achieving ZEVR compliance, these incentives are not directly included in the sales projections in this report other than how they may have affected historic sales trends. Note that the defined, simplified trends applied in the sales modeling do not capture potential changes over the forecast period such as changes in state-level programs or manufacturer strategies. In addition to simplifications and potential changes in trends, many complexities of the ZEVR are represented with basic assumptions. Collectively, the presented ZEV and PHEV sales forecasts are best considered as reasoned projections that provide an appropriate range of ZEV and PHEV sales through 2025, but no single scenario is viewed as substantially more probable than the others.

A high-level introduction to the ZEVR follows, after which the rules for awarding credits per vehicle and assumptions of vehicle electric range, which are used to calculate credits per vehicle, are presented in Section 3.2. An overview of rules for determining credit requirements and a projection of the number of required credits by state through 2025 is in Section 3.3. Section 3.4 assesses available state ZEV credit reports, uses data from these reports to project credit balances through 2017, and evaluates the portion of state sales by manufacturer size class. In Section 3.5, publicly available sales data is used to assess ZEV and PHEV sales in the ZEVR states, project sales through 2017, and project the split of sales between ZEV and PHEV through 2025. The final section (Section 3.6) explains the methods applied for ZEV and PHEV sales projections beyond 2017, and then presents sales at the state level in each of the ZEVR states through 2025 under several compliance scenarios.

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[22] Cahill, E., Davies-Shawhyde, J., and Turrentine, T. October 2014. *New Car Dealers and Retail Innovation in California's Plug-In Electric Vehicle Market*. UC Davis Institute of Transportation Studies. https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2353

[23] Sierra Club. 2016. REV UP Electric Vehicles. Multi-State Study of the Electric Vehicle Shopping Experience. https://www.sierraclub.org/sites/www.sierraclub.org/files/uploads-wysiwig/1371%20Rev%20Up%20EVs%20Report_09_web%20FINAL.pdf

3.1 Introduction to the ZEVR

The purpose of the ZEVR is to encourage the adoption of vehicles that do not produce tailpipe emissions. These regulations are directed at manufacturers of light-duty vehicles with annual California sales above a set threshold. Each year, qualified manufacturers must be able to show a required minimum number of credits. These credits are generated from the sale of vehicles that meet the applicable clean vehicle definitions, where the number of credits earned per sale varies with technology and capability. The current version of the ZEVR is largely defined by the 2012 amendments, to which further amendments have been added. The ZEVR has a complex rule structure designed to offer manufactures flexibility in the paths they may take to achieve compliance, allowing each manufacturer to develop their preferred mix of compliant technologies.

The ZEVR methods for calculation of the minimum number of credits needed per year is based on set percentages and the total number of light-duty vehicles (LDVs) the manufacturer produced and delivered for sale in California. Throughout the ZEVR, "production" refers to "production delivered for sale", which in this report is considered to be equivalent to sales. Flexibilities in the types and timing of credit-earning sales are provided in the ZEVR by allowing manufacturers to bank credit surpluses for later use, transfer (sell or buy) credits, and make up credit shortfalls within specified timeframes. Further flexibility is allowed in the technology mix of credit earning sales. As a result, there are many possible compliance approaches, each of which can result in different numbers of vehicle sales needed to achieve the minimum number of required credits.

Due in part to advancements in battery performance and cost, electric vehicle driving range capability has exceeded expectation, and the automobile industry has on average produced a larger number of vehicles that earn more credits per vehicle than was anticipated when the rules were adopted in 2012. This has allowed the production of a smaller number of vehicles to achieve the required number of credits, along with a larger number of banked credits that may be used in future years. As a result, a smaller number of ZEVs and near-ZEVs may be placed on the road than was projected in the summary of the 2012 regulations developed by the California Air Resources Board's (ARB) prior to adoption of the current ZEVR.[24]

3.2 Credit Types and Value Estimation

The types of credits in the ZEVR are summarized below followed by review of the rules defining the number of credits awarded per vehicle, estimation of the average range of ZEVs and PHEVs, and descriptions of credit from travel and credit from sources other than ZEV and PHEV sales.

3.2.1 Types of Credit-Earning Vehicles

The quantity and type of sales needed for compliance with the ZEVR are determined by the types of credits that can be earned and the ZEVR methods for setting credit values. Most of the credits used to comply are from the sale of ZEVs and near-ZEVs. Table 2 lists and describes vehicle types in the ZEVR and common names for sub-types. ZEVs include two sub-types: battery electric vehicles (BEV) propelled by energy stored in a battery pack, and fuel cell electric vehicles (FCEV) with on-board fuel cells that convert chemical energy from hydrogen into electric energy for vehicle propulsion. The other technologies listed in Table 2 are collectively referred to as near-ZEVs in this report. The most common

[24] Air Resources Board, California Environmental Protection Agency. 2011. Advanced Clean Cars Summary. https://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf

near-ZEVs are Partial ZEVs (PZEV), Advances Technology ZEVs (ATPZEV), Transitional ZEVs (TZEV), and Neighborhood electric vehicles (NEV).

Table 2 ZEV and near-ZEV vehicle types

VEHICLE TYPE AND SUB-TYPE
ZEV *(Zero-emission Electric Vehicle)* FCEV - Fuel Cell Electric Vehicle, converts hydrogen to electricity for propulsion BEV -- Battery Electric Vehicle, uses electricity stored in batteries for propulsion
PZEV *(Partial ZEV)* Conventional vehicle (low emissions)
AT PZEV *(Advanced Technology PZEV)* Gaseous – propulsion from an internal combustion engine that typically consumes natural gas vehicle HEV -- Hybrid Electric Vehicle, with propulsion from both battery-stored electricity and a combustion engine that typically consumes conventional gasoline
BEVx -- a BEV with a range extending, combustion ignition engine. Referred to as Type 1.5 and Type IIx in the ZEVR.
TZEV *(Transitional ZEV)* PHEV -- Plug-in hybrid electric vehicle, a HEV with a battery pack that is able to be charged through a plug in connection to an external electricity source (i.e., the power grid) BEVx – a BEV with a range extending, "limp-home" combustion ignition engine HICE -- Hydrogen internal combustion engine
NEV *(Neighborhood Electric Vehicle -short range, low speed)*

BEVx are not further addressed in this report because their market share has been relatively small, and is expected to decline further over the forecast period. PHEVs are the primary type of TZEV, and are expected to represent most of the sales in this category throughout the forecast period. Thus, while the ZEVR refers to requirements for TZEV credits, the projected earnings of TZEV credits are modeled as the sale of exclusively PHEVs. Both sales and credits are projected for ZEVs and PHEVs through 2025, while only credits are projected for PZEVs, ATPZEVs, and NEVs because PZEV and ATPZEV sales are not eligible for generating new credits as of 2018, and new NEV sales are expected to be small compared to historic balances.

Most ZEV credits earned to date are from the sale of BEVs. While BEV dominance of the ZEV category is expected to continue, FCEV share is anticipated to increase as the nascent hydrogen refueling infrastructure further develops. California leads the nation in numbers of FCEV on the road and hydrogen refueling stations, with 20 stations operating in mid-2016,[25] suggesting this is where most of the FCEV sales will occur through 2025. In the Eastern states, hydrogen refueling infrastructure is in earlier stages of development, with plans for a corridor of refueling stations from Boston to New York

[25] Air Resources Board, California Environmental Protection Agency. July 2016. 2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf

City[26] that will encourage FCEV sales. But overall, FCEV sales are expected to remain a small portion of ZEV sales through 2025, and thus are not separately delineated in this report.

3.2.2 Credit per Vehicle Rules

Prior to 2018, credits per ZEV are based on the vehicle subcategory as defined by vehicle range and fast recharging capability.[27] Credits per PHEV are also based on technological capabilities with an allowance for vehicle miles traveled determined through a prescribed method.[28] The methods for calculating credits per vehicle change in 2018, with the maximum possible number of credits per vehicle falling from nine to four. This decline occurs along with a drop in credit requirements, followed by credit requirement increases in subsequent years as discussed in Section 3.3. In this report, vehicle sales and credit balances through 2017 are estimated from trends in historic sales and credit balances, while sales estimates from 2018 onward apply the applicable ZEVR credit per vehicle formulae to convert the target number of earned credits over the forecast period to vehicle sales.

From 2018 onward, credits per ZEV delivered for sale are calculated with a single formula that uses the Urban Dynamometer Driving Schedule (UDDS) All-Electric Range (AER) as follows:[29]

$$\text{Credit per ZEV} = 0.01 \text{ x AER} + 0.50$$

where credits per ZEV are capped at 4.0. This formula does not apply to NEVs, which are assigned 0.15 credits in 2018 and later years. From 2018 onward, PHEV credits are calculated using the following formula with a cap of 1.10 (equivalent to 80 miles):[30]

$$\text{Credit per TZEV} = (0.01) \text{ x EAER} + 0.30$$

where EAER is the UDDS Equivalent All-Electric Range. An additional 0.2 credits are earned by PHEVs that achieve an AER of at least 10 miles under the US06 drive cycle. To achieve an AER, PHEVs cannot blend the use of the electric and internal combustion propulsion systems under conditions of high power demand, rather, the battery pack is fully depleted before the internal combustion engine can engage.[31] Non-blended systems are also referred to as "US06 capable", in reference to the more aggressive (higher speed and more rapid accelerations) US06 drive cycle under which their AER is determined. US06 PHEVs are viewed as next-generation vehicles and as such, are expected to have higher average EAER than prior generations.

3.2.3 Average ZEV and PHEV Range

Trends in ZEV and PHEV ranges are used to project average ranges over the forecast period, which are used to calculate credits per vehicle from 2018 onward (Section 3.2.2). Under the ZEVR, the ranges of ZEV and TZEV models are tested using the UDDS drive cycle and specified California test procedures.[32] Ranges per vehicle model determined with the California procedures are not generally available, but

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[26] Edelstein, Stephen. April 8, 2016. Sites of four Northeast hydrogen fueling stations announced by Air Liquide. Green Car Reports. http://www.greencarreports.com/news/1103307_sites-of-four-northeast-hydrogen-fueling-stations-announced-by-air-liquide

[27] ZEV credits per vehicle are described in CCR 1962.1(d)(5)(B) and (C)

[28] TZEV credits per vehicle are described in CCR 1962.1(c)(2), CCR 1962.1(c) (3) and CCR 1962.1(c) (4)(B)

[29] The credit per ZEV formula for 2018 onward is in CCR 1962.2 (d)(1)(A)

[30] The credit per TZEV formula for 2018 onward is in CCR 1962.2 (c)(3)(A)

[31] Air Resources Board, California Environmental Protection Agency, 2017. California's Advanced Clean Cars Midterm Review, Summary Report for the Technical Analysis of the Light Duty Vehicle Standards *(ARB Midterm Review)*. https://www.arb.ca.gov/msprog/acc/mtr/acc_mtr_finalreport_full.pdf , Page H-1.

[32] ZEV test procedures listed in CCR 1962.2 (d)(1)(A), TZEV test procedures listed in CCR 1962.2 (c)(3)(A)

ranges determined with the EPA test procedures[33] are shown on the EPA fuel economy label.[34] To estimate the UDDS all-electric range from the EPA label range, a factor of 1.428 is applied.[35]

The average ranges of annual PHEV and ZEV sales from 2012 through 2016 were estimated from EPA label ranges[36] weighted by national annual sales by model as reported by Inside EVs.[37] Each marker in Figure 10 represents the average calendar-year label range for a ZEV model that was sold in the corresponding year. The calendar year range for each model is estimated as the average reported range for the current and subsequent model years and for available model options that affect this range (e.g., battery pack size, motor size and number, etc.). For a given model, minimal variation was found among the calendar year offerings except for Tesla models. For example, in calendar year 2016, the label range for a Tesla Model S varied from 210 to 315 miles among the available model years and battery pack and motor options.

A lack of publicly available sales data by model option limits the precision of average range estimates for ZEV sales, nevertheless, as seen in Figure 10, average range per model exhibits a bimodal distribution. Tesla model averages and the 2017 Chevrolet Bolt have ranges in excess of 220 miles, and all other models having label ranges between 60 and 110 miles. Sub-group averages and market share are shown in Table 3. Other manufactures are expected to launch new ZEV models with ranges greater than 200 miles over the next few years. Table 3 also shows the sales-weighted average label range per ZEV range group along with the percentage of ZEV sales represented by each of these groups.

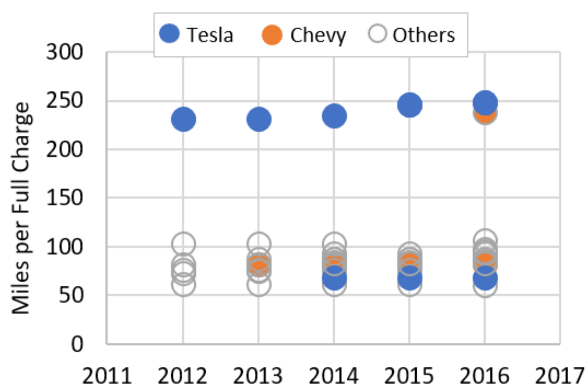

Figure 10. ZEV range: Tesla, Chevrolet, and others. (Each point represents a ZEV-model average range for the calendar year

Table 3. Weighted average label range, share of ZEV range groups for calendar years 2012 through 2016

	*Sales-Weighted Average Range**		*% of ZEV Sales*	
	<200 mi	*>200mi*	*<200 mi*	*>200mi*
2012	73	229	81%	19%
2013	77	229	63%	37%
2014	84	255	75%	25%
2015	83	255	64%	36%
2016	96	256	44%	56%

** For each year, average label range for each model is weighted by sales.*

[33]Test procedures for EPA label ranges are described at https://www.epa.gov/fuel-economy/fuel-economy-testing-and-data

[34] The EPA/DOT-required window label for new vehicles that display fuel economy and annual fuel cost. For BEV and PHEV, this label also shows all-electric driving range.

[35] *ARB Midterm Review*, 2017. Page A-11.

[36] EPA fuel economy labels were viewed at http://www.fueleconomy.gov/feg/

[37] Inside EVs. 2017. Monthly plug-in scorecard. http://insideevs.com/monthly-plug-in-sales-scorecard/

PHEV average range was estimated using a method similar to that used for ZEVs where the calendar year average range of each PHEV model was weighted by sales as reported by Inside EVs. PHEV ranges varied from 11 to 53 miles as seen in Figure 11. EPA fuel economy labels do not indicate US06 capability, but the Chevy Volt and the Toyota Prius Prime are reported to be US06 PHEVs.[38] As next-generation technology, US06 PHEV models tend to have higher range than most basic PHEVs, as seen in Figure 11 and Table 4. Over the next several years, other manufacturers are expected to introduce US06 PHEVs that will also have greater label all-electric range. Range improvements are projected separately for basic and US06 PHEVs to allow better estimation of average credits per PHEV due to the additional credit that can be earned by US06 PHEVs.

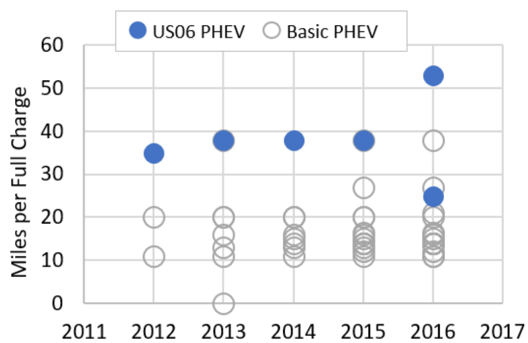

Figure 11. Range of PHEV models (Each point represents a ZEV-model average range for the calendar year

Table 4 Weighted average label range, share of PHEV range groups for calendar years 2012 through 2016

	*Sales-Weighted Average Range**		*% of ZEV Sales*	
	Basic	*US 06*	*Basic*	*US 06*
2012	12	35	39%	61%
2013	16	38	53%	47%
2014	16	38	65%	35%
2015	20	32	64%	36%
2016	19	51	66%	34%

** For each year, average label range for each model is weighted by sales.*

The ranges and percentages of ZEV and PHEV sales shown in Table 3 and Table 4 are used as historical references for the projection of average ZEV and PHEV label ranges through 2025 (Figure 12). Range improvements in the < 200 mile range BEV group are projected to follow historic trends. For the >200 mile range BEV group, the 2016 average range is applied throughout the forecast period because after adjustment of EPA label range to UDDS range, the ZEV credit cap is reached with an EPA label range of 245 miles. Thus, while there may be range increases in this subgroup, these improvements will not increase credits per vehicle.

From 2018 to 2025, the average range of basic PHEVs is increased by 1 mile each year, and US06 PHEV average range is increased by 0.5 miles each year. A lower rate of increase in average range is projected for US06 PHEVs because as additional manufacturers begin to offer US06 PHEVs, their initial models of this type are expected to have relatively low ranges for this subcategory. Figure 13 shows the projected share of BEVs that will have >200 miles range, and the share of PHEVs that will be US06 PHEVs. The share of BEVs with >200 miles range is capped at 80% to allow for a potential submarket to counter high range BEVs with large battery packs that do not provide sufficient benefit relative to the cost.

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[38] *ARB Midterm Review*, 2017. Page H-1.

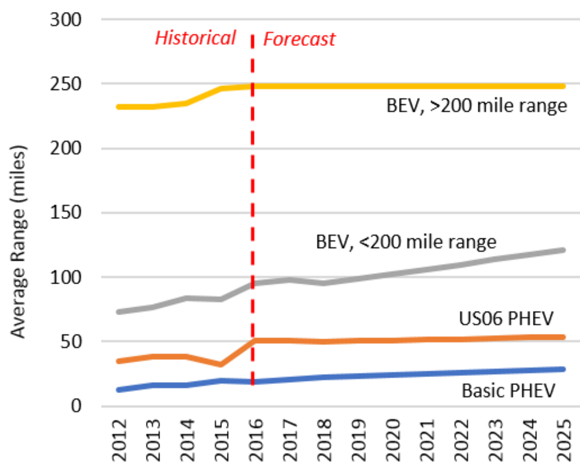

Figure 12. Average electric range for PHEVs and BEVs

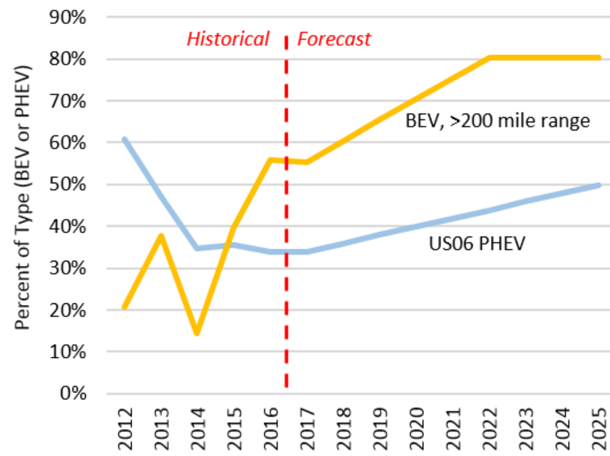

Figure 13. Percent of ZEVs that are BEV >200 mile range and percent of PHEVs that are US06 PHEVs

3.2.4 Credit Travel

Under what is commonly referred to as the "travel provision", the ZEVR allows credits earned for BEVs and FCEVs in any ZEVR state be given credit in other ZEVR states at a value proportional to the LDV sales in each S177 state relative to California sales through model year 2017. [39] Manufacturers must apply for credit travel prior to 2018. Beginning in 2018, only FCEV credits are allowed to travel. Credit travel increases the total number of credits generated by a single sale. For example, in 2016, one fully traveled credit, meaning a credit that travels to the greatest extent possible enabling it to be counted proportionately in all ZEVR states, is estimated to earn a collective total of 2.47 credits. The value of a fully traveled credit changes each year based on the relative proportion of production in each S177 state compared to California. The LDV sales forecast used in this report suggests that a single fully traveled 2016 credit may provide a total of 2.47 credits, and between 2018 and 2025, a single fully traveled credit may provide between 2.39 and 2.45 credits. But, for credits earned in states other than California, travel reduces credit value in the state in which it was earned, so it may not be desirable to travel all credits.

3.2.5 Other Types of Credits

The ZEVR allows limited use of other types of credits. One of these is the use of greenhouse gas (GHG) over compliance credits. With advance notice of plans to use GHG over-compliance credits, these credits may fulfill up to 50% of the minimum ZEV requirements in 2018 and 2019, falling to 40%, 30%, and 0% in 2020 through 2022, respectively.[40] In the *ARB Midterm Review* scenarios,[41] GHG-ZEV over compliance credits are estimated to be used by 10% to 20% of large manufacturers.[42] In this report, it is assumed that 15% of large manufacturers will use the maximum allowable GHG over-compliance credits. GHG over-compliance credits are subtracted from total estimated credit requirements in the appropriate

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[39] The travel provision prior to 2018 is in CCR 1962.1(d)(5)(E). The provision for 2018 and later years is in CCR 1962.2(d)(5)(E).

[40] Rules for the use of GHG over-compliance credits are in CCR 1962.2(g)(6)(C)

[41] *ARB Midterm Review*.2017. Page A-19.

[42] Manufacturers were to inform ARB of their intent to use GHG credits no later than December 31, 2016, allowing reasonable estimation of the number of GHG-ZEV credits that may be used.

years since these credits essentially reduce the number of ZEVs and PHEVs that need to be sold. Other alternative means of earning ZEV credits are assumed to be a very small portion of credit earnings and are not accounted for in the sales estimations presented in this report. These alternative credits include: medium-duty vehicle credits from ZEVs and TZEVs; transportation system credits; advanced technology demonstration program credits; and hydrogen internal combustion engine credits.

3.3 Credit Requirements

Credit-type categories correspond to the vehicle-type categories shown above in Table 2. The number of total credits required and the minimum number of ZEV credits required is determined based on vehicle model year and manufacturer size. Small manufacturers have no credit requirements, but they can sell any earned credits to intermediate or large manufacturers. The ZEVR rules distinguish three size classes of manufacturers based on their previous California sales of combined light and medium-duty vehicles: Large Vehicle Manufacturers (LVM), Intermediate Vehicle Manufacturers (IVM), and Small Vehicle Manufacturers (SVM). The definitions for these size classes change in 2018. Current and post-2017 definitions and rule distinctions for the size classes are shown in Table 5.

Table 5. ZEVR manufacturer size class definitions and credit requirement distinctions

Manufacturer Size Class	2012 to 2017		2018 to 2020		2021 Onward	
	LDV Sales	Credit Distinction	LDV Sales, Global Revenue	Credit Distinction	LDV Sales	Credit Distinction
Large Volume Manufacturer (LVM)	> 60,000	Minimum %ZEV credits	> 20,000 sales >$40 billion	Minimum %ZEV credits	> 20,000	Minimum %ZEV credits
Intermediate Volume Manufacturer (IVM)	4,501 to 60,000	Can meet full requirement with PZEV credits	4,501 to 20,000	Can meet full requirement with TZEV credits	*No change*	
Small Volume Manufacturer (SVM)	≤ 4,500	Not subject to ZEV rules	*No change*		*No change*	

In the Section 177 states that have adopted the ZEVR, manufacturers have notified regulators of their intent to follow either the basic path for credit requirements, or an optional path. The optional S177 Path has higher requirements in 2016 and 2017, and lower requirements in 2018 through 2020. Both of these paths are discussed below, followed by a state-by-state estimation of credit requirements through 2025.

3.3.1 Basic Path

Credit requirements for large and intermediate-sized manufacturers are calculated in each ZEVR state as percentages of LDV production in the state measured as a three-year floating average of the second, third, and fourth prior years. Figure 14 shows total credit requirements as a percentage of production. Sub-portions are shown for the minimum total requirement that must be met with ZEV credits (applicable only to large manufacturers) and the maximum amount of the total requirement that can be met by near-ZEV credit categories. Each type of credit has different capabilities for use to fulfill other credit-type categories. ZEV credits may be used in all categories; TZEV may be used in all but ZEV categories; AT PZEV may be used in PZEV categories; while PZEV credits can only be used in the PZEV category. The actual types of credits used by manufacturers are considered private strategic information, thus how closely credit use follows the distribution of credit types shown in Figure 14 is not publicly known. The drop in the total credit requirement seen in 2018 along with the merging of PZEV and ATPZEV categories in 2018 and subsequent years corresponds with the 2018 rule changes.

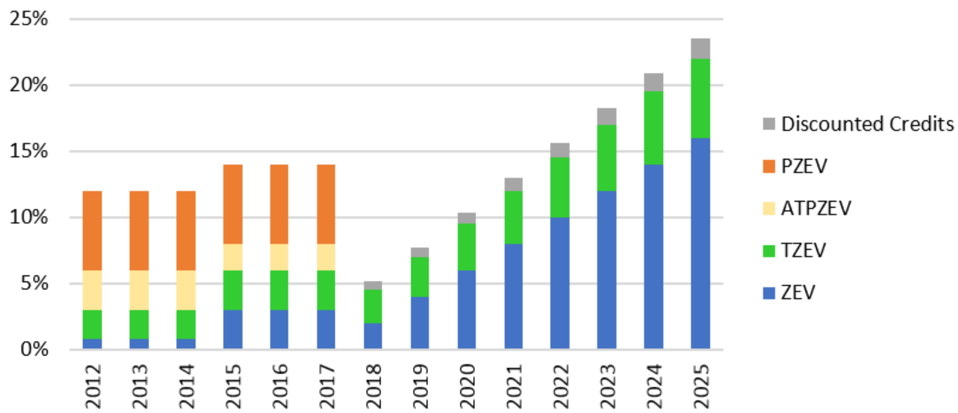

Figure 14. Large vehicle manufacturer credit requirements: minimum ZEV, maximum of near-ZEV credit use (Discounted credits are combined PZEV and ATPZEV credits)

3.3.2 Optional S177 Path

Manufacturers were able to choose an "Optional S177 State Compliance Path" under which more credits are required in S177 states in 2016 and 2017 and less credits are required in 2018 through 2020. [43] The 2016 and 2017 credit increases cannot use traveled credits. As part of the optional path, manufacturers are allowed to transfer credits among states in East and West regional pools (separated by the Mississippi River) from 2016 through 2021. The intent of pooling is to facilitate vehicle sales in the geographical areas with highest ZEV demand – from a manufacturer standpoint, it allows focus on rapid increases in sales in more limited areas. A 30% premium is applied to credits that are transferred between the regional pools, while there are no penalties for transfers within the same regional pool. Oregon is the only state in the West pool, since California is excluded from the Optional S177 Path. Manufacturers were required to inform ARB of their choice to pursue the Optional S177 State Compliance Path by September 1, 2016. The ZEV Compliance Calculator[44] released in 2017 indicates that 90% of large vehicle manufacturers have chosen the Optional S177 path while no intermediate vehicle manufacturers have done so.

3.3.3 Estimated Requirements through 2025

State-by-state credit requirements are calculated as the product of the percentage requirement in the ZEVR and the volume of production delivered for sale in each state. As previously stated, in this report, production delivered for sale is considered to be equivalent to sales. Production is calculated as a three-year rolling average of the second, third, and fourth prior-year LDV sales.[45] This estimation method

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[43] Requirements under the optional S177 path are described in CCR 1962.2(d)(5)(E)2

[44] Air Resources Board, California Environmental Protection Agency. 2017. ZEV Compliance Calculator Tool (Excel file). https://www.arb.ca.gov/msprog/zevprog/zevcalculator/zevcalculator_2017.xlsx

[45] Calculation of production delivered for sale is described in CCR 1962.1(b)(1)(B)

assumes LDV production will not decrease.[46] In this report, required credits are estimated from LDV sales as forecast in the AEO2017 Reference case[47] and adjusted based on production data provided in ZEV credit reports. Appendix A provides more detail on the LDV sales forecast used to estimate LDV production. Estimates of credit requirements were adjusted as appropriate by share of production represented by manufacturers that have opted for the Optional S177 Path (Section 3.3.2), share of manufacturers that have indicated they will be using GHG over-compliance credits (Section 3.2.5), and by manufacturer size class (Section 3.4.4).

Figure 15 and Table 6 show estimated total required credits for the ZEVR states. In 2018, approximately 46% of the total required credits are in California, decreasing to 41% in 2025. With minimal change between 2018 and 2025, the two Eastern states with the largest credit requirements, New York and New Jersey, represent 36% and 25%, respectively, of total Eastern credit requirements. Massachusetts, Maryland, and Connecticut have medium-sized requirements, with each state representing between 8% and 13% of total Eastern requirements. Maine, Rhode Island, and Vermont have small-sized requirements, with each state representing between 2% to 3% of total Eastern credit requirements. Differences between each state's share of total required credits and their share of minimum required ZEV credits are less than 1%.

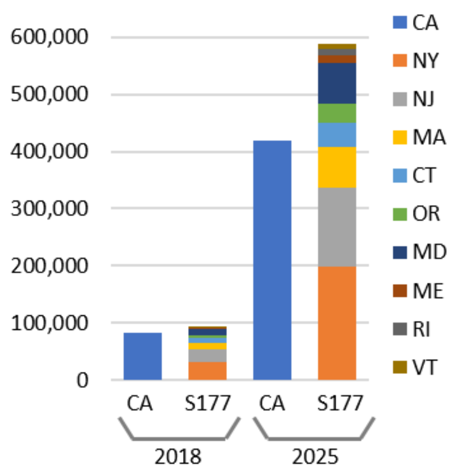

Figure 15. Total required credits, 2018 and 2025

Table 6. Estimated total required credits in 2018 (thousands)

Category	State	Total Credits
WEST		
	California	80.3
	Oregon	5.0
EAST		
Large	New York	31.9
	New Jersey	21.5
Medium	Massachusetts	11.7
	Maryland	10.8
	Connecticut	6.7
Small	Maine	2.1
	Rhode Island	1.7
	Vermont	1.4

Total credits required across all ZEVR states increase between five- and six-fold from 2018 to 2025. In contrast, the minimum ZEV credit requirement increases more than 12-fold over the same period in most states.

[46] Manufactures can choose to calculate their credit requirement based on the current model year production as described in CCR 1962.2(b)(1)(D), which would presumably be chosen in the event of a decline in LDV production.
[47] U.S. Energy Information Administration (EIA), 2017. Light-Duty Vehicle Sales by Technology Type. Annual Energy Outlook 2017 (AEO2017). https://www.eia.gov/outlooks/aeo/

3.4 Credit Reports, Balances, and Size Classes

The ZEVR calls for each state to develop annual ZEV credit reports. These credit reports provide historical credit balances by manufacturer. This report uses the historic credit balances to assess trends in credit balances by credit type and state through 2017. Credit balances in 2017 are an essential risk mitigation measure since credit requirements increase at a greater rate starting in 2018 than in the past. Credit reports also provide a list of large and intermediate manufacturers for the reported year,[48] in addition to LDV vehicle production by manufacturer. Production data from the credit reports is used to estimate credit requirements (which also depend on manufacturer size class), and to predict changes in manufacturer size classes through 2025.

3.4.1 Available Credit Reports

California ZEV Credit Reports are available online. The most recent report, for model year 2015, was released in October 2016.[49] Credit reports for other states are not consistently available online as a result of differing agreements between each state and vehicle manufacturers, in addition to delays collating the relevant data in some states. However, many of the unpublished state reports can be obtained by request from the appropriate state agency. Table 7 shows the years for which credit reports were obtained for each state, and indicates if the report included both production and credit balance data, or just credit balance data.

Table 7 Zero Emission Vehicle Credit Reports Used for this Project.

● = credit balances and production data
○ = only credit balance data

	2012	2013	2014	2015
California	●	●	●	●
New York			●	●
New Jersey		●	●	●
Massachusetts		●	●	●
Maryland	○	○	●	●
Oregon			●	
Connecticut			○	●
Maine		○	●	●
Rhode Island			●	●
Vermont				●

3.4.2 Credit Balance Differences Among the States

Historically, manufacturers have carried credit balances as a result of selling more ZEVs and near-ZEVs in a year than what was needed for compliance. These banked credits reduce manufacturer risk of falling out of compliance due to below-target sales in future years. A build-up of banked credits prior to 2018

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[48] For any given year, the list of large and intermediate manufacturers is the same in all states because size class is determined based on manufacturer sales in California.

[49] Air Resources Board, Californian Environmental Protection Agency, October17, 2016. 2015 Zero Emission Vehicle Credits. https://www.arb.ca.gov/msprog/zevprog/zevcredits/2015zevcredits.htm

may be particularly desirable given the more rapid increase in credit requirements from 2018 through 2025. The ratio of total credit balances to estimated credit requirements based on the available ZEV credit reports is shown in Figure 16. In 2015, credit balances, which include historic credit surpluses from prior years, were between 3.5 and 7.5 times greater than the model year credit requirement.

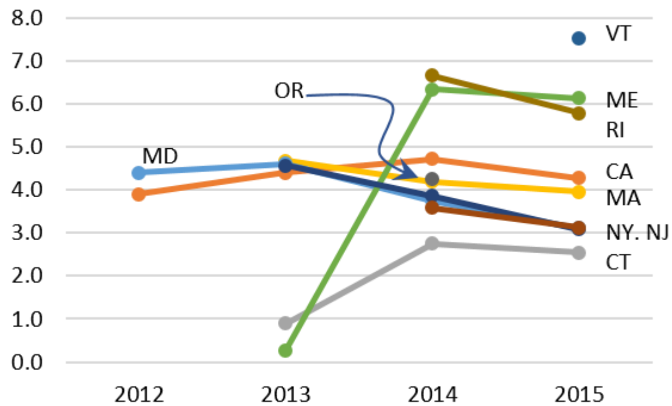

Figure 16. Ratio of total credit balances to credit requirements, 2012 to 2015

The proportions of the different types of banked ZEV credits vary among the ZEVR states. This reflects differences in the types of surplus earned credits in each state, and suggests there may also be differences in the proportions of credit types used to meet the requirements in each state. The following summary of trends in credit types that comprise total balances is based on review of the states for which there is more than one year of credit balance data, as shown in Figure 17.

- The share of ZEV credits in total balances is growing, and NEV and ATPZEV credits are declining.
- The share of PZEV and TZEV credits is constant or slightly declining.
- Relatively high portions of ATPZEV and PZEV credits in New Jersey and California suggest these states will be most affected by the discounting of these credits in 2018.
- NEV credit share is greatest in New York and Massachusetts, at 26% and 24% of the 2015 balance, respectively. In the other states, NEV share is 10% or less. Most NEV credits were earned prior to 2012 from sales of low-speed, low range vehicles for use on campuses and other localized areas.
- ZEV credit share in 2015 is greatest in Rhode Island (51%), followed by Maryland (48%), Vermont (46%), and Oregon (40% in 2014). ZEV credits compose 36% to 38% of credit balances in all other states in 2015. The high portion of banked ZEV credits in Rhode Island and Vermont likely represent travel credits considering the low number of ZEV sales in these states and the inability to otherwise exchange credits among states until 2016.
- TZEV share of banked credits is greatest in Vermont (29%), followed by Rhode Island (27%), Oregon (23%), and Maine (22%). In all other states, TZEV credits compose 13% or less of total credit balances in 2015.

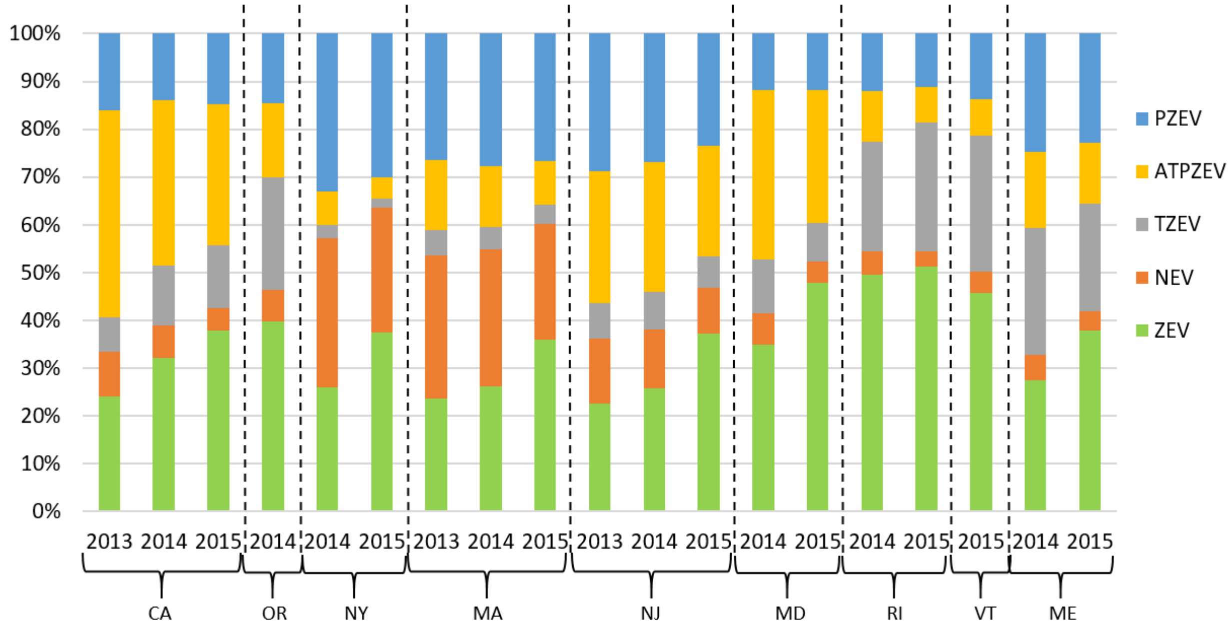

Figure 17. Share of credit types in state credit balances

3.4.3 Estimation of Credit Balances through 2017

Credit balances beyond the last credit reports (MY 2015) were estimated from trends in historic credit balances.[50] Figure 18 shows reported credit balances (when available) through 2015, and projected balances for 2016 and 2017. Note that in 2015, credit requirements increased from 0.79% to 3% of production, and there are no further changes in requirements until 2018. As such, the use of a linear trend from 2013 through 2015 to project 2016 and 2017 balances may yield conservative estimates.

[50] In both the *ARB Midterm Review* and the NDRC report at https://www.nrdc.org/sites/default/files/media-uploads/nrdc_commissioned_zev_report_july_2016_0.pdf), credit balances are estimated from trends in sales in conjunction with the number of credits per vehicle and assumptions on the amount of ZEV credit use for requirements that can be met with near-ZEV credits. But detailed data on average credits per vehicle by state and year is not publicly available, nor are details available on the credit types used to meet requirement portions that can be met with near-ZEV credits, hence the more direct method of using balance trends was preferred for this report despite incomplete balance data for some states.

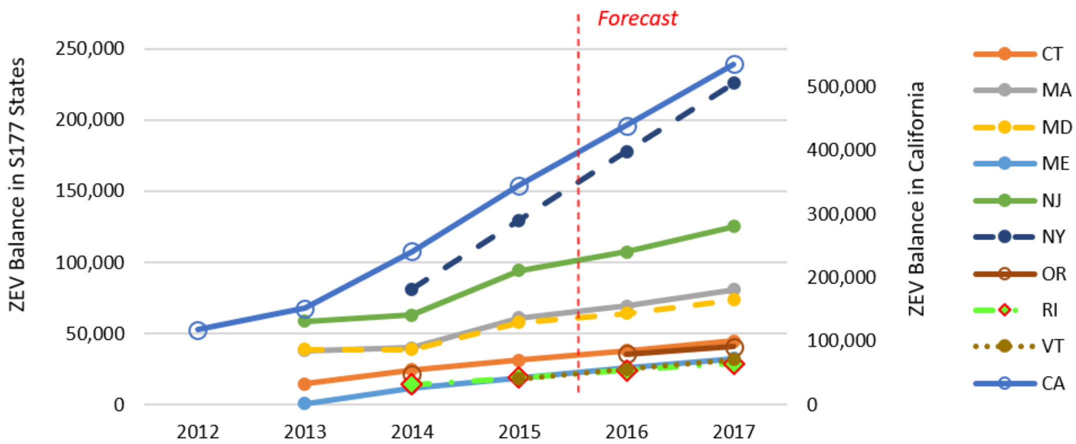

Figure 18. ZEV credit balances

While historic credit balances include both surplus credits earned in the state and credits traveled to the state, the *ARB Midterm Review* notes that credit travel has lagged behind credit earnings.[51] The delay in traveling credits suggests that some manufactures may wait until 2017 to fully travel credits earned in prior years, creating a potential surge in 2017 balances. This surge, however, may be reduced if some credits do not fully travel.

Since travel does not reduce credit value in California, it is always advantageous to fully travel credits earned in California to the S177 states. But a manufacturer anticipating greater difficulty meeting future requirements in a particular S177 state may choose to not travel credits from that state. There may be a particular reluctance to travel credits from states with much lower credit requirements than other states because traveled credits retain very little of their original value in these states. In the states identified in Table 6, above, as having a "small" number of required credits, credits that travel out will retain only 2 to 3% of their earned value in these states. While a larger view of the benefit to industry-wide credits encourages travel, traveling out credits results in a higher sales need in some states, which may be viewed as increasing risk beyond the benefit of traveling all credits.

The use of travel credits to eliminate risk of ZEV credit non-compliance in small states through 2025 is suggested from a comparison of ZEV sales and credit balances (Table 8). Credits earned per ZEV sold prior to 2018 range from 2 to 7 credits, and ARB estimates that in 2015, the average ZEV sold in California earned 3.29 credits.[52] The 2015 ZEV credit balances in the small states (Maine, Rhode Island, and Vermont) are more than 10 times greater than the credits that would be earned if all the ZEVs sold in these states between 2012 and 2015 were 7-credit vehicles (i.e., Tesla models). If credit balances continue their rate of growth through 2017, ZEV balances will be sufficient to meet the minimum ZEV requirements through 2024 in Maine and Rhode Island, and through 2025 in Vermont. This suggests the possibility of delaying the need to have ZEV sales in these smallest states, allowing a concentration of sales efforts in other Eastern states through the first half of the 2020's.[53] It also suggests that in the

[51] *ARB Midterm Report*. 2017. Page A-8.
[52] Ibid., page A-7.
[53] If no ZEV balances were available in ME, VT, and RI, between 1,500 and 2,500 ZEV sales would be needed in each of these states in 2025 – the current regulations have the same percentage requirements for subsequent years.

redistribution of East Pool credits that may occur from 2016 through 2021, there may be minimal transfer of ZEV credits from these small states.

Table 8. 2015 ZEV credit balance, cumulative 2012 to 2015 ZEV sales, and ratios of total 2015 credit balance to cumulative ZEV sales and to total 2015 credit requirements

		2015 Balance	2012 to 2015 Sales	Balance/ Sales*	Balance/ Total Requirement
WEST					
	California	345,054	88,962	3.9	1.6
	Oregon**	31,823	4,476	7.1	1.9
EAST					
Large	New York	129,510	3,710	34.9	1.2
	New Jersey	94,188	2,877	32.7	1.2
Medium	Massachusetts	60,983	2,400	25.4	1.4
	Maryland	57,721	2,075	27.8	1.5
	Connecticut	31,088	1,310	23.7	1.2
Small	Maine	18,520	173	107.1	2.3
	Rhode Island	18,961	157	120.8	3.0
	Vermont	17,994	229	78.6	3.4

** A balance/sales value near the estimated average credits per ZEV of 3.3 is thought to suggest minimal travel-in credits, although it may also occur when the value of travel-in credits is nearly the same as the value of travel-out credits.*

*** Oregon 2015 credit balance is estimated from reported 2014 balance and balance growth relative to Maryland, which had similar relative ZEV sales growth between 2014 and 2015.*

Overall, there is uncertainty in both the extent to which pre-2017 credits will travel and in the portion of travel that may have already occurred. As such, the estimation of 2016 and 2017 credit balances based on trends in historic credit balances (as in this report) provides a relatively conservative estimate of balances that does not incorporate a potential 2017 surge in travel credits.

3.4.4 Manufacturer Size Classes and Market Share

The size class of major manufacturers is assigned based on their production as listed in California ZEV credit reports. The market share of each manufacturer in each state is estimated based on the credit report data for the state, and manufacturers of the same size class are then lumped together to determine market share by size class in each state. Many of the current IVMs are expected to transition to the LVM class under the 2018 rules, resulting in a greater portion of required credits that will need to be fulfilled by ZEV sales. The rules for transferring between IVM and LVM classes require that a manufacturer have five consecutive three-year averages of qualifying sales (including both light and medium duty vehicles) that exceed 20,000, and a global revenue in excess of $40 billion in 2018, 2019, and 2020. Manufacturers that meet the sales qualification but not the global revenue qualification will need to meet LVM rules the year after exceeding the sales threshold for five consecutive years that begin after 2020 (i.e., the soonest they would need to meet LVM requirements is in 2026). Table 9 shows the size class of manufacturers in 2015, and anticipated sizes classes in 2018 and 2026, no changes are anticipated in the between years.

Table 9. Current and projected size class by manufacturer

L = Large; I = Intermediate; S = Small [a]

Manufacturer	2015	2018	2026
Chrysler Group	L	L	L
Ford	L	L	L
GM	L	L	L
Honda	L	L	L
Nissan	L	L	L
Toyota	L	L	L
Volkswagen	I	L	L
Hyundai	I	L	L
BMW	I	L	L
KIA	I	L	L
Mercedes Benz	I	L	L
Subaru	I	I	L
Mazda	I	I	L
Jaguar Land Rover	I	I	I
Mitsubishi [b]	S	L	L
Volvo	S	I	I
Tesla	S	I	L

a. This list only includes small manufactures expected to change their size class during the forecast period.

b. Assumes Nissan's purchase of Mitsubishi is completed by 2018.

Table 10 shows the proportion of state LDV sales that were sold by LVMs in 2015 based on vehicles delivered for sale in the 2015 ZEV Credit Reports (2014 for Oregon). 2015 production as shown by manufacturer in the 2015 credit reports was used to estimate the portion of production that will be by LVMs in 2018, when several of the current IVMs transition to LVM status. For the sales forecast scenarios in this report, LVM market share in 2015 is held constant in 2016 and 2017, and LVM market share estimated for 2018 is held constant for the remainder of the forecast period.

Table 10. LVM market share by state, 2015 and 2018

	2015 *	2018
California	72%	94%
Connecticut	66%	86%
Massachusetts	79%	90%
Maryland	74%	92%
Maine	76%	86%
New Jersey	70%	92%
New York	75%	93%
Oregon	70%	88%
Rhode Island	69%	90%
Vermont	75%	85%

** Based on 2015 credit reports from each state except Oregon, which is based on their 2014 credit report.*

3.5 Sales through 2017

ZEV and PHEV sales through 2017 are used as a basis for forecasting sales through 2025 in Section 3.6. The relative share of ZEV and PHEV sales is also important for assessing trends in the market share of these two technologies, which as discussed in Section 3.2.2, have significantly different credit earning potential per vehicle. As such, market share trends will be used in the sales forecasting described in Section 3.6.

3.5.1 Sales by State

ZEV and PHEV sales data were obtained from the Auto Alliance ZEV Sales Dashboard,[54] which reports sales by state through 2016. Sales in 2017 are estimated as a linear trend of sales from 2013 through 2016. The linear trend did not include 2012 sales due to the relatively few ZEV and PHEV models available in 2012. As seen in Figure 19 and Figure 20, year-on-year ZEV sales were reduced in 2014 in Connecticut, Maryland, New Jersey, and New York. Year-on-year declines in PHEV sales have been more prominent, with reductions in 2014 in Connecticut, Massachusetts, Maine, New Jersey, New York, Rhode Island, and Vermont. The following year saw PHEV sales reductions in California, Maryland, Oregon, and Rhode Island. Year-on-year sales declines suggest the importance of retaining generous credit balances to assure compliance, particularly with the annual increase in credit requirements from 2018 through 2025.

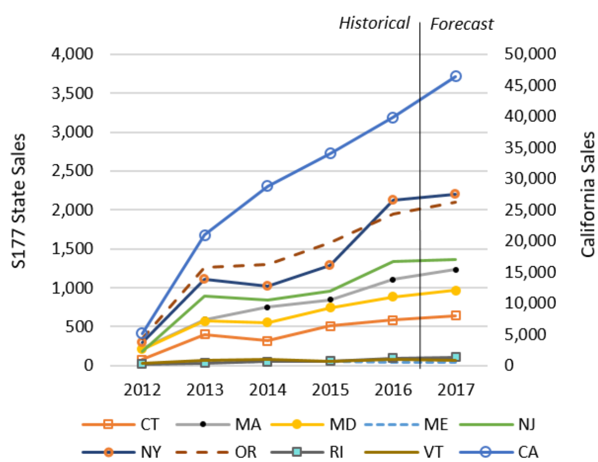

Figure 19. ZEV sales by state, 2012 to 2017

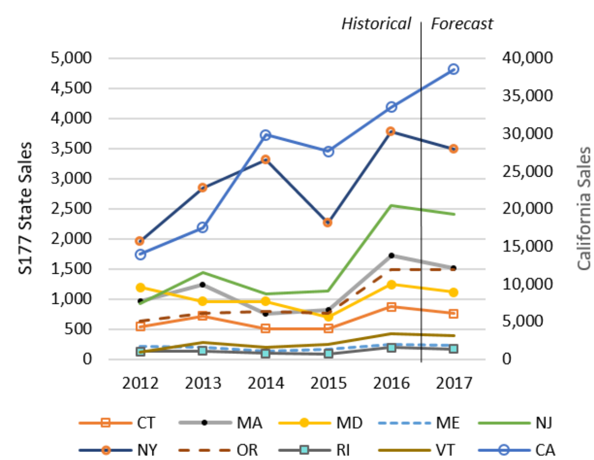

Figure 20. PHEV sales by state, 2012 to 2017

3.5.2 ZEV to PHEV Sales Ratio

For sales forecasting, the ratio of ZEV sales to combined ZEV and PHEV sales (ZP sales) is used to divide estimated sales among these technologies. Figure 21 shows the historic ratio of ZEV to ZP sales through 2016, with an average of the four prior years used to estimate the ratio for 2017, and subsequent years

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[54] Auto Alliance, 2017. ZEV Sales Dashboard. https://autoalliance.org/energy-environment/zev-sales-dashboard/

shown with annual increases in the ZEV share of the ZP market of 2% of the prior year ratio. This rate of increase is one of the base assumptions for the sales projections in this report

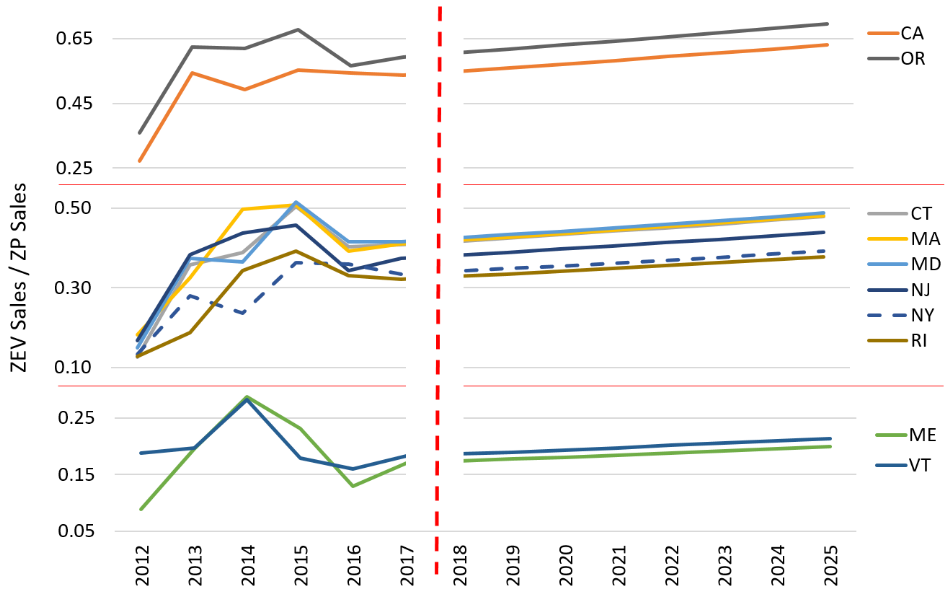

Figure 21. ZEV share of the ZP market: 2012 to 2016 historic data, 2017 average of prior years, 2018 onward estimated with increases of 2% per year

As particularly seen for Maine and Vermont in the lower graph of Figure 21, an assumption that ZEV share of ZP sales is increasing may be viewed as tenuous. Nonetheless, the more rapid increase in minimum ZEV credit requirements versus credit requirements that can be met with TZEV credits suggests that ZEV share of ZP sales will increase. To meet ZEVR requirements with the minimum number of ZEV credits using average credits per vehicle based on the average ranges shown in Figure 12, above, ZEV share of ZP sales would need to be 0.13 in 2018 versus 0.37 in 2025, assuming with no banked credits or credit transfers.

Other considerations also suggest that the ZEV share of the ZP market should increase over the longer term. A manufacturer's choice of the types of vehicles to produce likely considers the expected per vehicle cost and possible profitability versus credit earning potential. From an automotive business standpoint, sales volume and the number of years since a major re-design are typically important factors in the profitability of a particular model. Both of these factors challenge the profitability of ZEVs and PHEVs at this stage of their development. The ZEVR endeavors to push technology development, and presumably long-term profitability, by enticing compliance through a penalty of $5,000 per required credit that is not achieved.[55] This suggests a ZEV worth 4 credits in 2018 (i.e., an EPA label range of at least 245 miles) could be sold at a loss of up to $20,000 before the loss would exceed the penalty of noncompliance. In contrast, no more than $5,500 could be lost on a TZEV as a result of the 1.10 credit cap on these vehicles in 2018. The lower margin for loss in conjunction with the greater required sales volume may discourage TZEV production, particularly if a manufacturer is able to produce and sell a 4-credit ZEV within the acceptable loss range. Over the longer term, prices of ZEV components (i.e., battery packs, motor drives) are expected to decline as production efficiencies improve.

[55] Penalties are in addressed in CCR 1962.2(g)(8)

3.6 Sales Estimation for 2018 through 2025

As an emerging technology, ZEVs and PHEVs are expected to have technology improvement and cost reductions throughout the forecast period. While technology may experience major jumps beyond gradual improvements and stimulate sales, unforeseen failures and issues may dampen them. Although these types of unpredictable events are not included in this analysis, risk mitigation is accounted for, as discussed in the next subsection. This is followed by a description of the sales estimation method for 2018 through 2025, and sales projections under several scenarios.

3.6.1 Accounting for Risk Mitigation

An underlying assumption of the Excel-based sales model used in this analysis is that the ZEVR is a key driver of ZEV and PHEV sales in ZEVR states. Further, the inconsistent, and sometimes negative year-on-year growth in ZEV and PHEV sales (seen above in Figure 19 and Figure 20) presents a risk for manufacturers, particularly given the annual increases in credit requirements from 2018 through 2025. The low number of ZEV and PHEV models offered by each manufacture also presents non-compliance risk. A technological issue or otherwise poor market acceptance of just one ZEV or PHEV model that results in significant sales reductions can have a greater effect on compliance achievement when few models are offered.

In addition to reduction of ZEVR non-compliance risks, annual sales in excess of requirements may be part of strategies by some manufacturers to increase their long-term auto market share through establishing a higher market share of ZEVs and PHEVs. Government incentives for ZEVs are offered in countries ranging from China, South Korea, and India, to European Union members, indicating global interest in electric-powered drivetrains. Potential pro-ZEV market strategies beyond ZEVR compliance are not included in this analysis.

Recognizing the historical and likely future holdings of significant credit balances to assure ZEVR compliance, the sales model developed for this analysis forecasts ZEV and PHEV sales from 2018 through 2025 based on the ZEVR with an input variable for the ratio of the 2025 year-end credit balance to the 2026 credit requirements (CBCR). CBCR is a means to mitigate the risks of lower than expected sales. While a manufacturer can opt to set their credit requirements based on their current year LDV sales rather than the rolling average of prior years, this option does not provide relief when the sales drop is only in ZEV or PHEV sales.

The magnitude of credit balances is expected to decline over the 2018 to 2025 period due to both maturing of the market (reduced risk) and increased requirements. In the *ARB Midterm Review*,[56] it is noted that in addressing “compliance margins to ensure compliance given uncertainties . . . manufacturers . . . typically expressed targets of one to two years depending on their tolerance for risk.”

3.6.2 Base Assumptions

Unless noted otherwise, the ZEV and PHEV sales scenarios in this report use the following assumptions:

1. ***CBCR (ratio of 2025 credit balances to 2026 credit requirements)*** – CBCR is set at 1.5, which is the midpoint of the compliance margins manufacturers are reported to be targeting.[57]

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[56] *ARB Midterm Review.* 2017. Page A-9.
[57] Ibid.

2. ***Minimum allowable year-on-year (YoY) growth for combined ZEV and PHEV (ZP) sales*** – minimum allowable YoY sales growth is set at 4%. This minimum is applied when the combination of credit balances and historic sales relative to requirements are substantial enough to allow achievement of the target CBCR with less than the set minimum growth. In the scenarios in this study, the minimum YoY is only applied to California. A 4% YoY sales increase is roughly half of the growth rate that would be needed in California to maintain a linear trend of ZP sales from 2013 to 2016, onward to 2025, and results in a CBCR of about 2.
3. ***LDV sales forecast*** – the LDV sales forecast is used to calculate required credits. It is based on the AEO2017 Reference case as adjusted by production data provided in ZEV credit reports, as further described in Appendix A.
4. **Average credits per vehicle type** – average credit per vehicle type for each year from 2018 through 2025 are estimated from the ZEVR credit formulae for 2018 onward, using estimated annual improvements in average range as shown in Section 3.2.3, Figure 12.
5. **LVM market share** – LVM market share throughout the forecast period is held constant at the shares projected for 2018, as shown in Section 3.4.4, Table 10.
6. **East pool credit redistribution** -- East pool credit balances and sales in 2018 through 2021 are redistributed among all East pool states according to the proportion of East pool credit requirements represented by each state.
7. ***Ratio of ZEV to ZP sales (ZEV/ZP)*** – the ZEV share of the ZP market increases annually at a rate of 2% of the prior year ZEV to ZP ratio (i.e., the ratio is multiplied by 1.02 each year).

3.6.3 Sales Estimation Method for 2018 to 2025

Combined ZEV and PHEV (ZP) sales projections from 2018 through 2025 are estimated as:

$$\textit{Need-to-Earn Credits} = \qquad \text{Equ. 1}$$

$$\sum_{2018}^{2025} \textit{Required Credits} + \textit{CBCR}\,(\textit{Required Credits}_{2026}) - \textit{Historic Credit Balance}$$

Where,

$$\textit{Historic Credit Balance} = \qquad \text{Equ. 2}$$

$$\textit{ZEV Balance}_{2017} + \textit{TZEV Balance}_{2017} + \textit{Discounted PZEV Balance}_{2017} + \textit{Discounted ATPZEV Balance}_{2017} + \textit{Allowable NEV Use}$$

CBCR refers to the ratio of 2025 credit balances to 2026 credit requirements, and,

$$\textit{Allowable NEV Use} = \sum_{2018}^{2025} 25\%\ \textit{Required TZEV Credits} \times \frac{\textit{NEV Balance}_{2017}}{\textit{Production Portion}_{2015}} \qquad \text{Equ. 3}$$

In all states, discounted PZEV and ATPZEV balances are projected to be fully used by the end of 2019 or 2020. This is in consideration of their maximum allowable use per year of 25% of the TZEV requirements adjusted by the portion of production that has PZEV or ATPZEV balances in 2015. As such, total historic discounted PZEV and ATPZEV balances are used in the above equation for Historic Credit Balances. In contrast, for NEV balances, Massachusetts and New York are projected to have 2017 NEV balances that exceed allowable NEV use during the 2018 through 2025 period and as such, are represented as "Allowable NEV Credit Use" in the calculation of Historic Credit Balances.

Although no new credits need to be earned while sufficient historic credits are available, production risks are generally thought to be reduced with consistent, small increases in production versus large increases such as would be needed if there were no sales while historic credits were used. As such, annual sales are modeled based on a calculated constant YoY growth in ZP sales for each state under each scenario. For each state under each scenario, YoY growth in ZP sales is determined based on total needed credits after redistribution under East Pool scenarios.

Pooling under the Optional S177 State Path is not applied to the West because California is excluded from the Optional Path, leaving only Oregon in the West Pool. Credit exchanges between the East and West pool are allowed between 2016 and 2021 with a 30% premium. In recent years, ZEV sales in Oregon have been around 35% of ZEV sales in the East Pool, but ZEV minimum requirements in Oregon are around 5% of East Pool requirements. This suggests a relatively strong initial growth in sales in Oregon, but a relatively small potential market compared to the East pool. Overall, while the transfer of credits from Oregon to the East pool may be part of the credit strategy for some manufactures, the size of the Oregon market is not thought to be large enough to substantially influence sales in the East Pool throughout the forecast period, and is not included in the modeled sales.

For each state, sales from 2018 through 2025 are set to provide earned credits equal to need-to-earn credits,

where $a = ZP\ Sales_{2017}$, and $x = YoY$ sales growth,

$$ZP\ Sales_{2018} = a + ax \qquad \textit{Equ.4}$$

$$ZP\ Sales_{2019} = a + 2ax + ax^2 \qquad \textit{Equ. 5}$$

$$\vdots$$

$$ZP\ Sales_{2025} = a + 8ax + 28ax^2 + 56ax^3 + 70ax^4 + 56ax^5 + 28ax^6 + 8ax^7 + ax^8 \quad \textit{Equ. 6}$$

It follows that,

$$ZEV\ Sales = ZP\ Sales \times ZEV\ Market\ Share \qquad \textit{Equ. 7}$$

Where ZEV Market Share is a scenario variable based on historic share as shown in Figure 21. Further,

$$PHEV\ Sales = ZP\ Sales - ZEV\ Sales \qquad \textit{Equ. 8}$$

A minimum YoY is set to prevent showing negative growth in California. The Excel goal seek function, which iteratively tests input values for a given formula to find a set result, is used to estimate YoY with the goal of Need-to-Earn Credits (Equ. 1.) set to result in Earned Credits where:

$$Earned\ Credits\ = \qquad \textit{Equ. 9}$$

$$\sum_{2018}^{2025} ZEV\ Sales\ \times\ CPV_{ZEV}\ +\ \sum_{2018}^{2025} PHEV\ Sales\ \times\ CPV_{PHEV}$$

The goal seek path from YoY sales growth to Earned Credits is shown in Figure 22, alongside the goal of Need to Earn Credits.

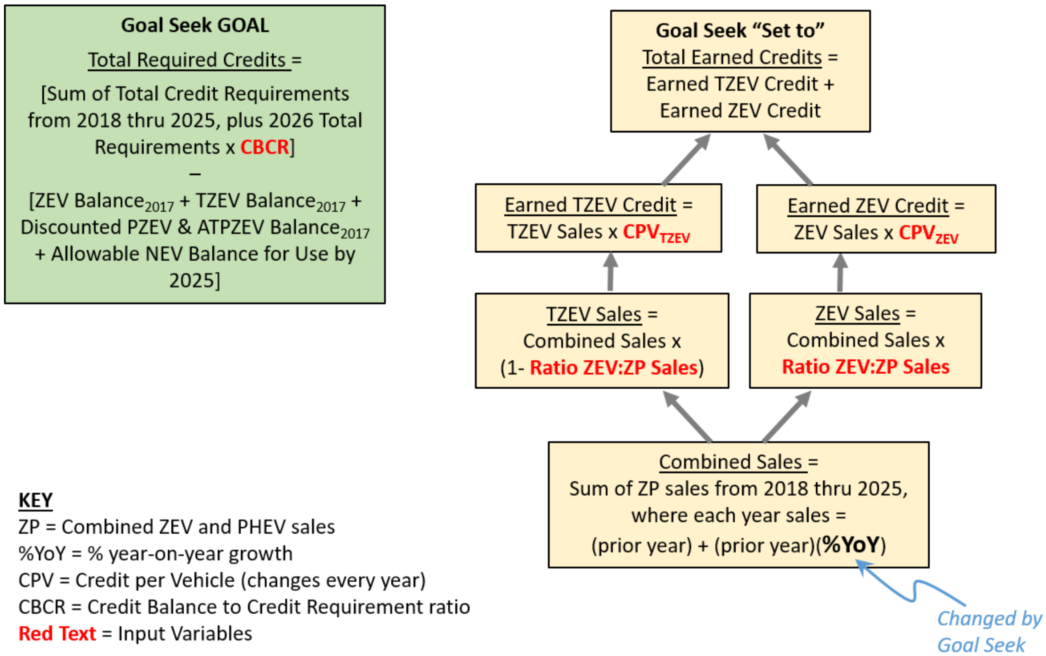

Figure 22. Use of goal seek to estimate percent year-on-year sales growth

3.6.4 Sales Forecast with Base Assumptions

ZEV and PHEV sales under a scenario using all the base assumptions listed in Sections 3.6.2 are shown in Figure 23 and Figure 24, respectively. Table 11 shows cumulative sales, and average ZEV/ZP and %YoY ZP sales growth from 2018 through 2025 for each state. In California, as a result of relatively high historic sales, associated credit balances, and high ZEV/ZP sales, ZP sales growth over the forecast period is at the minimum allowed, 4% YoY growth.

Figure 23. ZEV sales, base case assumptions

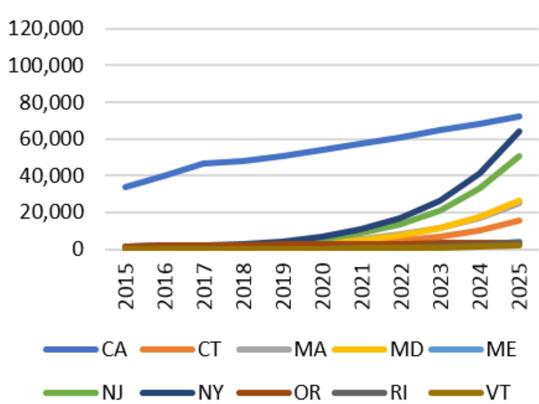

Figure 24. PHEV sales, base case assumptions

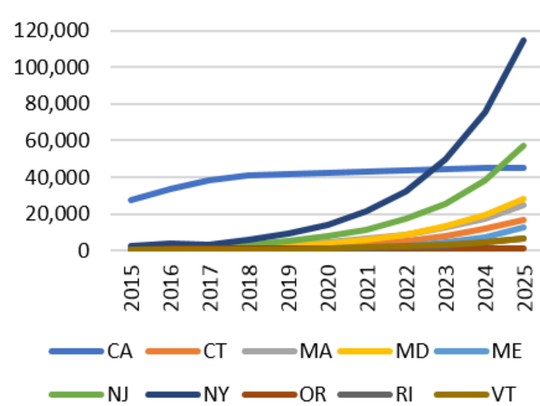

Table 11. Cumulative sales and average ZEV/ZP sales and %YoY ZP sales growth from 2018 to 2025

	Cumulative Sales *(thousand)*			Average	
	ZEV	PHEV	ZP	**ZEV/ZP**	**%YoY**
CA	477	347	824	0.58	4%
CT	45	52	97	0.45	48%
MA	76	82	158	0.47	44%
MD	74	84	158	0.45	51%
ME	10	31	41	0.23	67%
NJ	141	168	309	0.44	52%
NY	176	328	504	0.34	54%
OR	36	17	53	0.67	13%
RI	10	18	28	0.34	58%
VT	6	21	27	0.22	45%

Under the base assumptions, ZEV and PHEV sales in New York grow much faster than in California in terms of %YoY growth, and annual New York PHEV sales exceed California PHEV sales in 2023. By 2025, annual New York ZEV sales are nearly as high as California ZEV sales, and annual New York PHEV sales are more than double California PHEV sales. Several factors cause the loss of California dominance of the ZP market. The minimum sales growth applied to California allows continued increases in end-of-year ZEV balances (after meeting credit requirements) through the early 2020's. Although total credits estimated to be earned from 2025 sales represent only about 50% of the targeted CBCR, the shortfall is made up with prior-earned credits. At the end of 2025, the California credit balance under this scenario is estimated to be about twice the total credit requirements in 2026 (i.e., a CBCR of 2.0 versus the target of 1.5). The low growth in California PHEV sales in Figure 24 is a result of both the 4% growth rate for ZP sales and the growing market share for ZEVs, which in this scenario is 54% of the ZP market in 2018, increasing annually by 2% of the prior-year share to 62% in 2025, with corresponding decreases in PHEV market share.

The total credit requirement in New York is about half the total requirement in California. In the base-assumptions scenario, New York uses the last of its historic (pre-2018) credits in 2022, and in subsequent years earns just enough credits to meet the target CBCR. The high PHEV sales shown for New York are due in part to the relatively low historic ZEV share of the ZP market. In this scenario, ZEV sales comprise 32% of the New York ZP market in 2018, increasing annually by 2% of prior-year share to 36% by 2025, with corresponding decreases in PHEV market share. The result is an average %YoY ZP sales growth of 54% in New York, versus 4% in California. It should be recognized that higher ZEV/ZP ratios would reduce sales growth, and the actual rate of increase in the ZEV/ZP ratio may vary among the states. The base assumption of ZEV/ZP sales increases that are 2% of the prior year ratio yields lower annual increases in states such as New York, where the current ZEV share of ZP sales is relatively low.

Under the base assumptions, three states have 2018 ZEV shares of ZP sales that are equal to or lower than New York's, these states are Rhode Island, Maine, and Vermont, with 2018 ZEV shares of the ZP sales of 32%, 22%, and 21%, respectively. As suggested in Section 3.4.3, the relatively high ZEV credits in these three smallest states may be part of a strategy to build up ZEV balances in these states with travel credits, and perhaps also with transfer credits under the Optional S177 path, to levels that allow ZEV compliance through 2025 with reduced sales. The high sales growth needed in these states under the base assumptions scenario suggests the appeal of strategies to reduce the need for sales in the smaller

Eastern states, which would allow more focus on ZEV sales in the medium and large Eastern states. Sales focus may then shift to the three small states in the mid 2020's, after the ZEV market is better established in the other Eastern states.

3.6.5 Effect of East Pool Redistribution on Sales Forecast

Two sets of scenarios were examined to assess the possible effects on sales from East pool credit redistribution, as allowed from 2016 through 2021 under the optional S177 path. Redistribution was applied to both historic credits (earned prior to 2018) and credits earned from new sales during the applicable years. Descriptions of the first set of scenarios follow, with each scenario given a short name for reference in presentation of the results:

- "No Redistribution" – historic credits and new sales credits are not redistributed in the East pool, and historic credits stay in the state where they were in 2017.
- "Requirements"– same as the East pool redistribution described above as a base assumption (i.e., East pool credits are redistributed among all East pool states according to the proportion of East pool credit requirements represented by each state).
- "Catch-Up" – credit redistribution is based on both proportionate credit requirements and the historic relative rate of sales whereby if a state's sales portion is 2% higher than their requirements portion in the East pool, the Catch-Up portion is 2% lower than the requirements portion. A minimum allowed redistribution portion of 0.5% is set to prevent a reallocation that results in a negative balance.

Table 12 shows cumulative sales from 2018 through 2025 in each state under these three scenarios, and Figure 26 displays the differences in cumulative sales with East pool credit redistributions compared to the scenario with no credit redistribution (the zero-line in Figure 26). East states with relatively high credit balances at the end of 2017 relative to other states in the East pool, particularly the small states (i.e., Vermont, Rhode Island, and Maine), have reduced balances as a result of credit redistribution under the examined scenarios. As a result, the small states need higher cumulative sales from 2018 through 2025. Credit redistribution has an opposite effect on states with relatively low credit balances at the end of 2017 relative to other East pool states, particularly New York and New Jersey. These credit redistribution scenarios result in higher credit balances and lower cumulative sales in the large states.

Table 12 Cumulative sales, 2018 to 2025 (thousands) under East pool redistribution scenarios of "No redistribution", "Requirements", and "Catch-Up"

	West		**East Large**		**East Medium**			**East Small**		
Scenario	CA	OR	NY	NJ	CT	MA	MD	ME	RI	VT
ZEV										
No Redistribution	476.8	35.8	181.6	149.2	45.2	77.5	75.4	5.9	5.1	1.7
Requirements	476.8	35.8	175.7	141.1	45.4	75.8	74.1	9.8	9.9	6.4
Catch-up	476.8	35.8	166.6	135.3	51.1	83.8	79.6	8.7	9.0	6.2
PHEV										
No Redistribution	346.9	16.9	338.4	177.8	52.2	83.4	85.4	18.7	9.4	5.8
Requirements	346.9	16.9	327.6	168.3	52.4	81.6	84.0	31.2	18.1	21.3
Catch-up	346.9	16.9	310.8	161.5	58.9	90.0	90.0	27.8	16.5	20.9

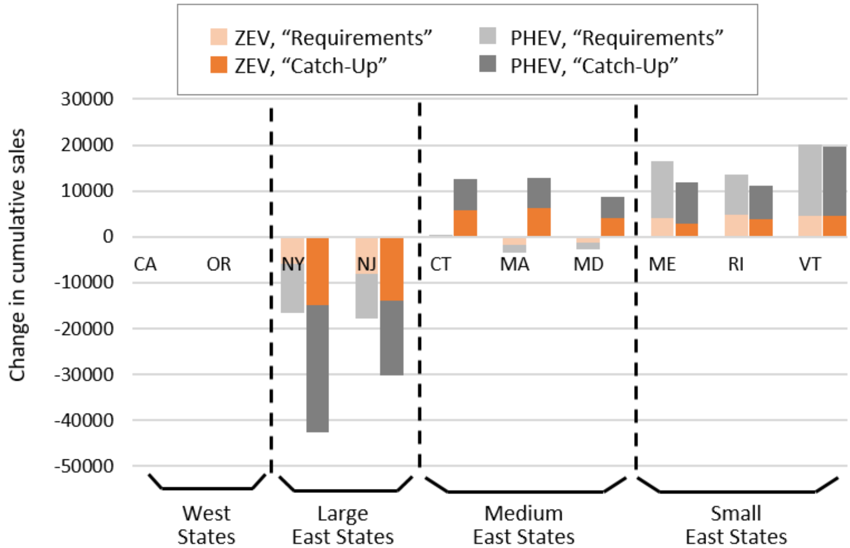

Figure 25. Change in cumulative sales with East pool redistribution under "Requirements" and "Catch-up" scenarios compared to the "No redistribution" scenario (zero-line)

The second set of scenarios to assess the possible effects on sales from East pool credit redistribution are described below, with each scenario given a short name for reference in presentation of the results:

- "All East" – same as the East pool redistribution described above as a base assumption and for the "Requirements" scenario (i.e., East pool credits are redistributed among all East pool states according to the proportion of East pool credit requirements represented by each state).
- "Large-Medium" – credit redistribution among only the large and medium east pool states, with redistribution to each state based their proportionate credit requirements.
- "Surge + Large-Medium" – East state credit redistribution as in the "Large-Medium" scenario with higher ZEV credit balances at the beginning of 2018, such as would occur if 15% of the 2016 ZEV balances travel to all states prior to the end of 2025.[58]

Table 13 shows cumulative sales from 2018 through 2025 in each state under these three scenarios. Figure 26 displays the differences in cumulative sales with East pool credit redistributions under the Large-Medium and Surge + Large-Medium scenarios compared to credit redistribution under the All East scenario (the zero-line in Figure 26).

[58] In the *ARB Midterm Review*, it is suggested that as of 2016, a significant number of ZEV credits have not traveled.

Table 13 Cumulative ZP sales, 2018 to 2025 (thousands), under East pool redistribution scenarios of “All East”, “Large-Medium”, and “Surge + Large-Medium”

	West		**East Large**		**East Medium**			**East Small**		
Scenario	CA	OR	NY	NJ	CT	MA	MD	ME	RI	VT
ZEV										
All-East	476.8	35.8	175.7	141.1	45.4	75.8	74.1	9.8	9.9	6.4
Large-Med	476.8	35.8	181.7	145.7	46.8	78.4	76.5	5.9	5.1	1.7
Surge + Large-Med	476.8	32.9	167.4	134.6	43.6	72.4	70.9	5.1	4.3	1.2
PHEV										
All-East	346.9	16.9	327.6	168.3	52.4	81.6	84.0	31.2	18.1	21.3
Large-Med	346.9	16.9	338.5	173.7	54.0	84.3	86.6	18.8	9.4	5.8
Surge + Large-Med	346.9	15.6	312.2	160.7	50.4	78.0	80.3	16.3	8.0	4.1

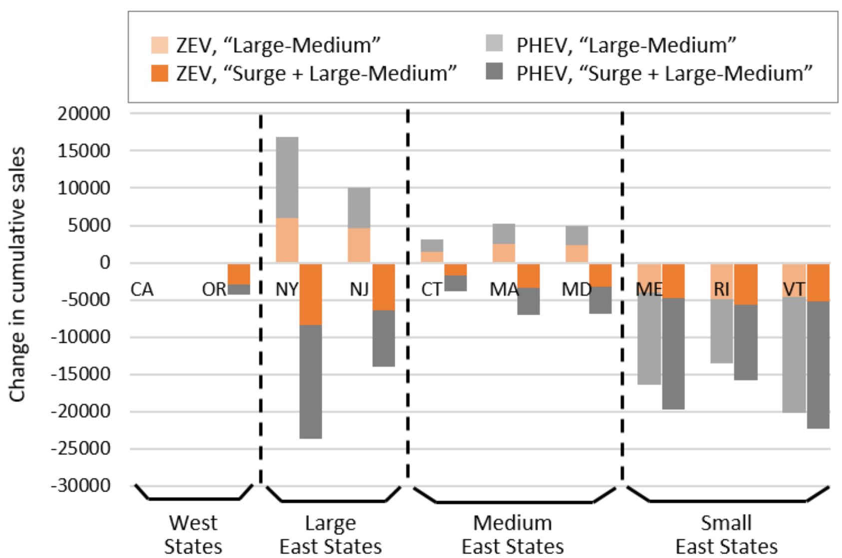

Figure 26. Change in cumulative sales with East pool credit redistribution under “Large-Medium” and “Surge + Large-Medium” scenarios compared to the “All East” scenario (zero-line)

As was seen in the first set of scenarios, redistribution of small-state credit balances (“All States” scenario, Figure 27) results in substantially higher sales in the small states compared to the sales needed in these states when their credits are not redistributed (“Large-Medium” scenario, Figure 27). Under the same scenarios, sales increases in medium and large states due to an absence of credits from small states, but these increases are small compared to sales needed in the large and medium states (“All States” and “Large-Medium” scenarios, Figure 28 and Figure 29). A surge in 2017 credit balances could reduce sales in medium and small states by more than the benefit of redistributed credits from small states (“Surge + Large-Medium” and “All States” scenarios, Figure 26, Figure 28, and Figure 29), although it should be recognized that surge magnitude is uncertain.

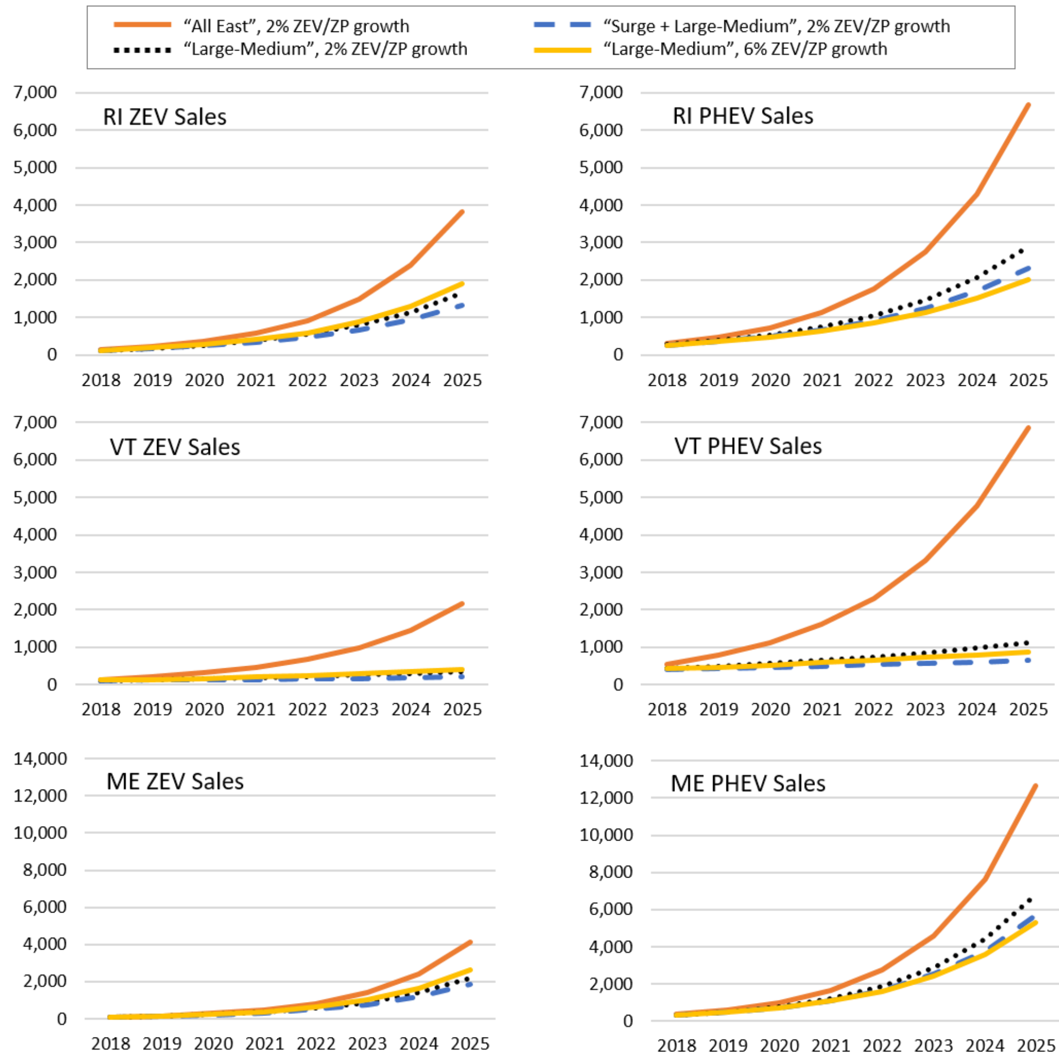

Figure 27. Small Eastern states: ZEV and PHEV sales under "All States" and "Large-Medium" credit redistribution scenarios; "Large-Medium" redistribution scenario with 2% and 6% annual ZEV/ZP growth; and "Large-Medium" redistribution scenario with and without a 2017 credit surge

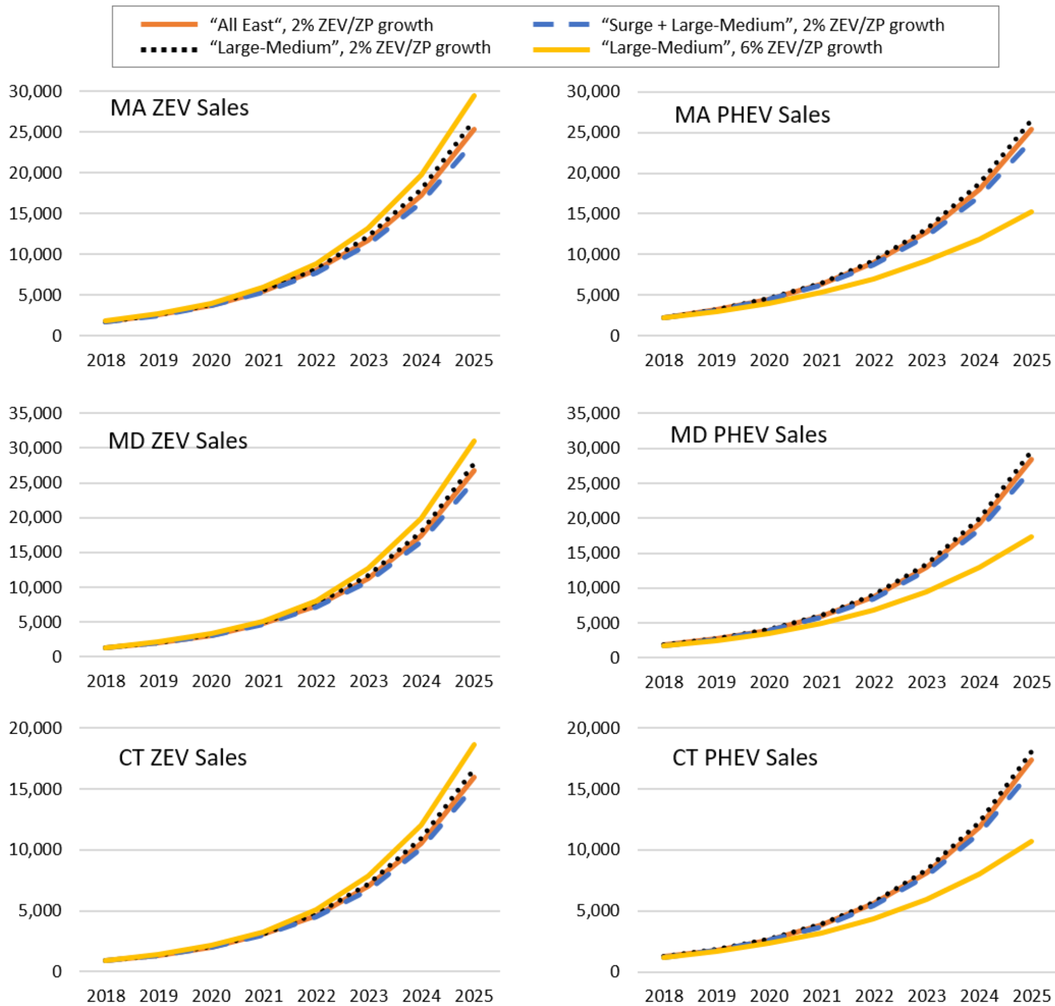

Figure 28. Medium Eastern states: ZEV and PHEV sales under "All States" and "Large-Medium" credit redistribution scenarios; "Large-Medium" redistribution scenario with 2% and 6% annual ZEV/ZP growth; and "Large-Medium" redistribution scenario with and without a 2017 credit surge

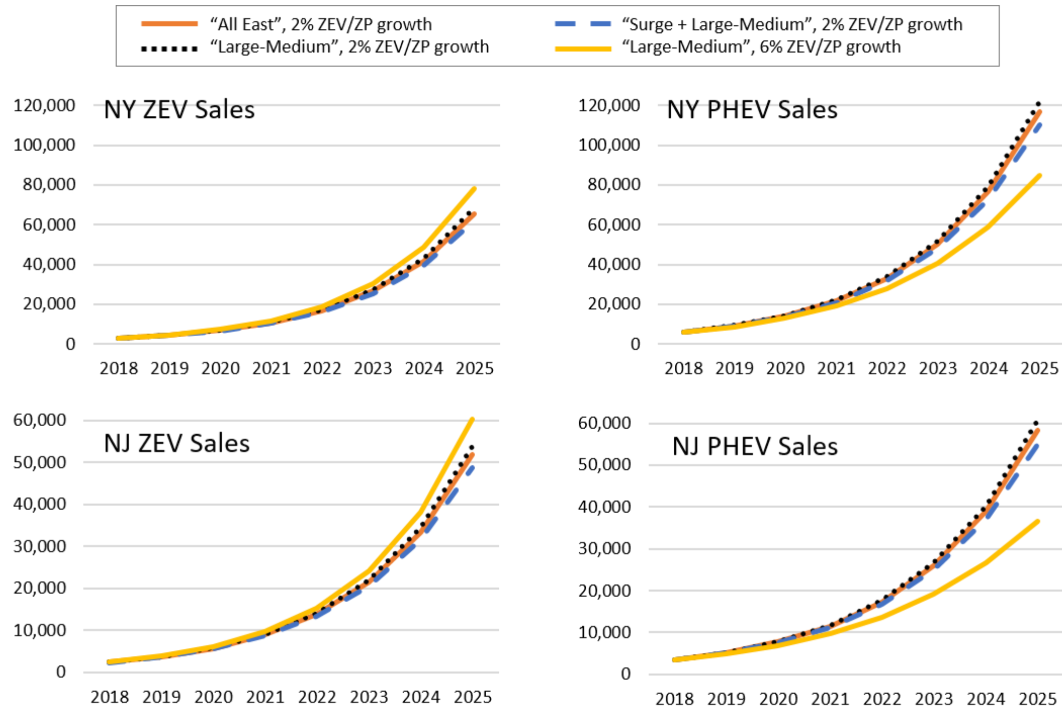

Figure 29. Large Eastern states: ZEV and PHEV sales under "All States" and "Large-Medium" credit redistribution scenarios; "Large-Medium" redistribution scenario with 2% and 6% annual ZEV/ZP growth; and "Large-Medium" redistribution scenario with and without a 2017 credit surge

3.6.6 Effect of ZEV Share of the ZP Market on Sales Forecast

The effect of more rapid growth in ZEV share of the ZP market was examined by changing the rate of annual growth in the ZEV share of ZP sales (ZEV/ZP). Under the base assumptions, ZEV/ZP increases annually by 2% of the prior year ratio. Annual growth in ZEV/ZP of 2% (black dotted line) and 6% (solid yellow line) of prior year ratios can be compared for the Eastern states under the same pool redistribution assumptions in Figure 27, Figure 28, and Figure 29, above. With a higher rate of growth in ZEV/ZP, PHEV sales decrease by more than ZEV sales increase as a result of the higher average credits per ZEV than per PHEV. Sales changes due to ZEV/ZP growth rate changes are generally greater in the medium and large Eastern states than in the small Eastern states. This is due to the combination of lower historic ZEV/ZP in smaller states and the scenario description of ZEV/ZP growth as a percentage of the prior year ratio. The scenario definition assumes proportionate growth in ZEV sales share among the states rather a growth rate that is independent of the historic ZEV/ZP.

Figure 30 shows annual ZEV and PHEV sales in California and Oregon under scenarios with 6% and 2% annual increases in ZEV/ZP, with the later also shown with and without a 2017 surge in credit balances (the same as "Surge + Large-Medium" in Section 3.6.5). A 2017 surge in credit balances does not change ZEV and PHEV sales projections for California because ZP sales growth in California uses the minimum of 4% YoY ZP sales growth. When this minimum is disregarded, the average %YoY growth in California ZP sales (with all other base assumptions retained) is 1%. This growth rate decreases to negative 1% under the credit surge scenario, indicating that ZEVR compliance in California could be achieved with slight decreases in year-on-year sales.

Similar to what is seen in the Eastern states, the credit surge scenario reduces both ZEV and PHEV sales in Oregon (Figure 30), while an increase in the rate of ZEV/ZP growth increases ZEV sales and decreases PHEV sales.

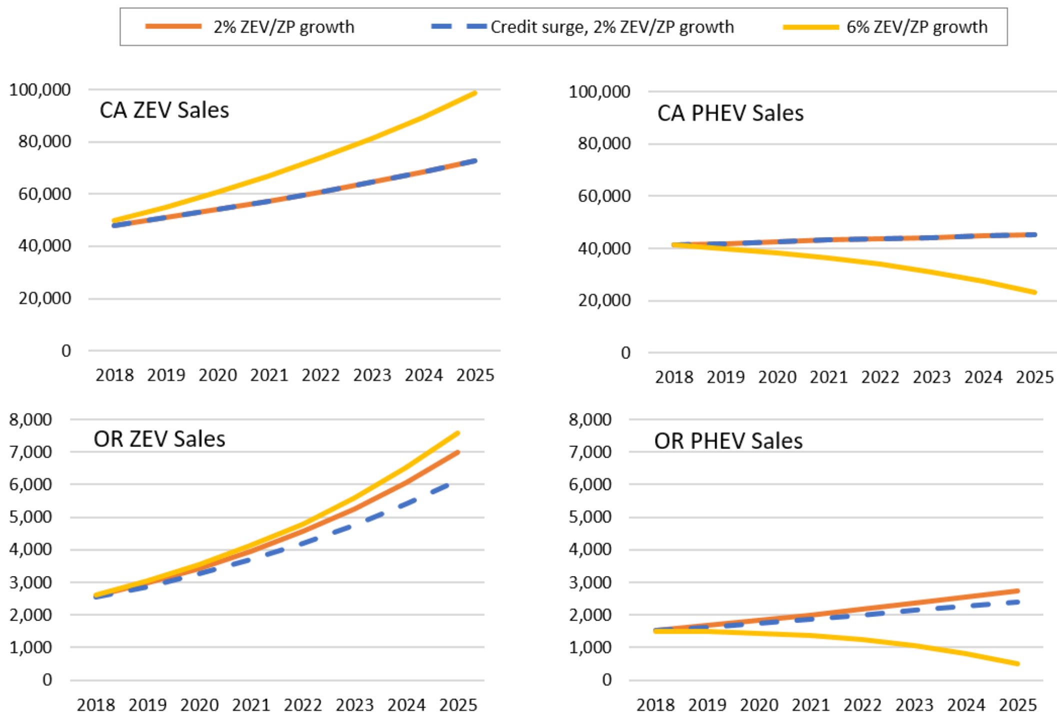

Figure 30. Western states: ZEV and PHEV sales under scenarios of 2% annual ZEV/ZP growth with and without a 2017 credit surge; and a scenario of 6% annual ZEV/ZP growth without a surge

3.6.7 Collective Scenarios

None of the scenarios presented in this analysis is viewed as substantially more probable than the others. Collectively, the presented ZEV and PHEV sales forecasts provide a reasoned range of possible ZEV and PHEV sales in each ZEVR state through 2025.

In the Eastern states, compliance with ZEVR requirements is expected to drive ZEV and PHEV sales throughout the forecast period, forcing substantial average year-on-year sales increases. Figure 31, shows average percent annual ZEV and PHEV sales growth from 2018 through 2025, with the error bars representing the range of annual growth projections under the tested scenarios. Most of the Eastern states will need annual sales growth that averages between 40% and 60% over the forecast period. Actual annual year-on-year sales increases are likely to vary substantially in all states. For example, from 2012 to 2016, year-on-year combined ZEV and PHEV sales growth in California varied from 5%to 100%, with an average of 44%. Some of this variation has been attributed to the cycle launching and discontinuing models,[59] which is particularly notable with fewer available models. Large percentage

[59] *ARB Midterm Review*.2017. Page B-9.

increases in annual production and sales may be more challenging when ZEV and PHEV sales are higher and proportionate increases represent a larger magnitude.

In Oregon, sales increases needed to meet credit requirements are modest compared to the Eastern states as a result of relatively high historic ZEV sales in Oregon. If rapid sales growth is easier to achieve in Oregon, manufacturers that have opted for the Optional S177 Path under the ZEVR may choose to transfer some credits from Oregon to Eastern states during the allowed period (i.e., 2016 through 2021), despite the 30% premium applied to these transfers (a scenario that is not modeled in this study).

In California, the ZEVR requirements may serve to limit potential reductions in ZEV and PHEV sales as new production is directed to other states. Assuming a California sales growth rate of 4% per year for combined ZEV and PHEVs, collective annual average ZEV and PHEV sales growth among all the ZEVR states is estimated to be between 20% and 30% throughout the 8-year forecast period.

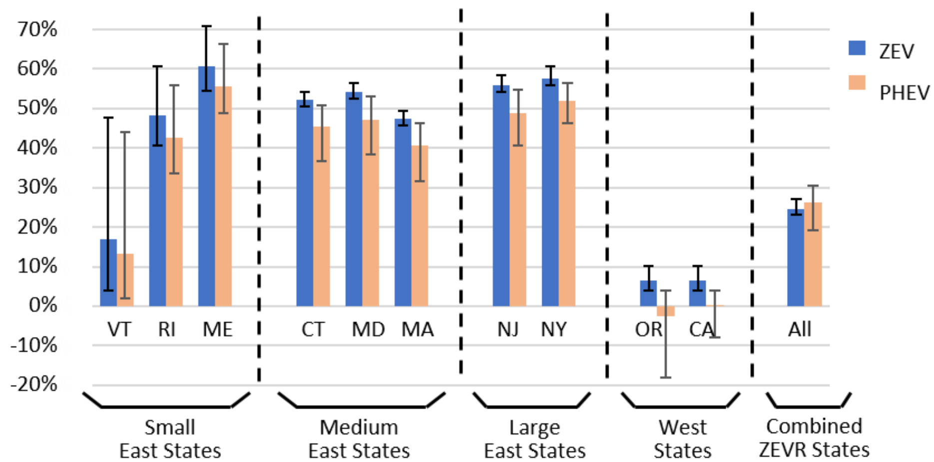

Figure 31. Average and range of year-on-year ZEV and PHEV sales growth from 2018 through 2025 under the tested scenarios

The range of cumulative sales from 2018 through 2025 for the tested scenarios is indicated by the error bars shown in Figure 32. For large and medium Eastern states, PHEV sales are highest under the scenario with no growth in ZEV share of ZP sales, while both the highest ZEV sales and the lowest PHEV sales are under the scenario with the highest growth in ZEV share of ZP sales. This suggests that cumulative ZP sales in the medium and large Eastern states may be particularly sensitive to the split between ZEV and PHEV sales.

For the small East states, highest ZEV and PHEV sales are under the scenario with credit redistribution (from 2016 through 2021) among all East states proportionate to their credit requirements. Both ZEV and PHEV sales are lower under the scenarios that exclude small states from credit redistribution within the Eastern pool. The size of these sales reductions relative to the requirements in Vermont and Rhode Island, in particular, suggests the possibility of using travel and transfer credits to delay the need for ZEV and PHEV sales in these states until the mid-2020's. The ZEVR credit requirements continue beyond 2025, so ZEV and PHEV sales increases in these states will still ultimately be needed.

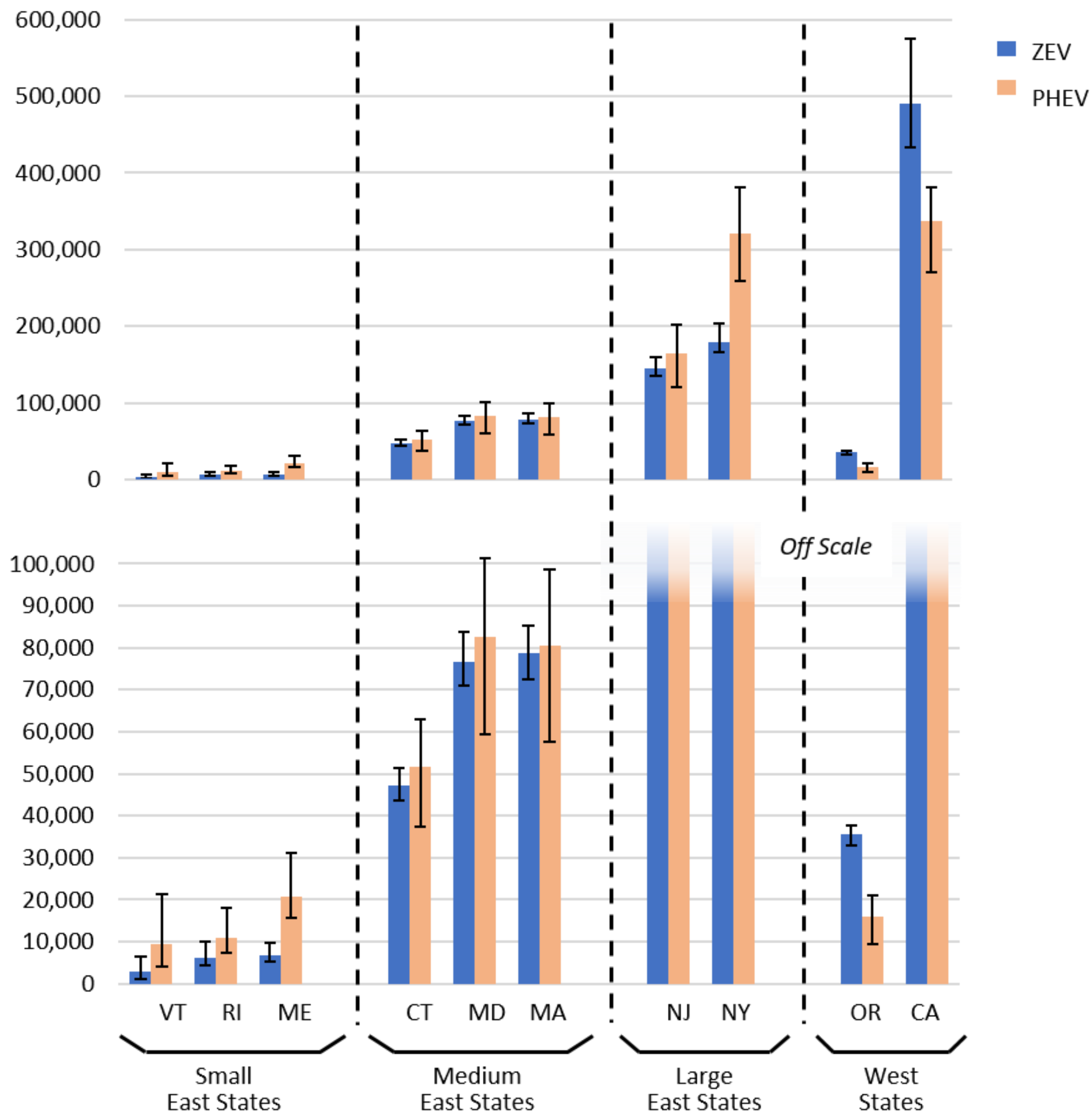

Figure 32. Cumulative ZEV and PHEV sales from 2018 to 2025 under the tested scenarios

In closing, with respect to future modeling of FCEV sales, which are not distinguished within the ZEV sales in this study, the BEV market is expected to expand to largely meet the ZEV requirements for 2025 onward with a relatively small portion of ZEV sales that will be FCEV. This suggests the possibility that unlike BEVs and PHEVs, FCEV sales growth may be better projected by new technology adoption factors other than the ZEVR.

Appendix – Light-Duty Vehicle Sales Forecast

Estimation of the ZEV credit requirement is based on a rolling average of three prior years of vehicle production delivered for sale. Thus, required credits (both total and minimum pure ZEV) are estimated from LDV sales as forecast in the AEO2017 Reference case.[60] These sales are provided for nine census regions that collectively represent the entire country. Regional sales are adjusted to state sales by applying the ratio of state vehicle registrations to regional vehicle registrations as reported for 2014 by the Federal Highway Administration (FHWA).[61] A constant ratio of state-to-regional 2014 sales is used throughout the modeling period. Sales are further adjusted based on historic sales as indicated by production reported in the state ZEV Credit Reports. As seen in Figure 33, reported state production is within 10% of sales as estimated from AEO2017 regional sales and FHWA state registrations for six states of the ten ZEVR states. A 10% deviation is exceeded for the remaining four states, with the greatest deviation for Oregon, where reported production in 2014 was 28% higher than estimated.

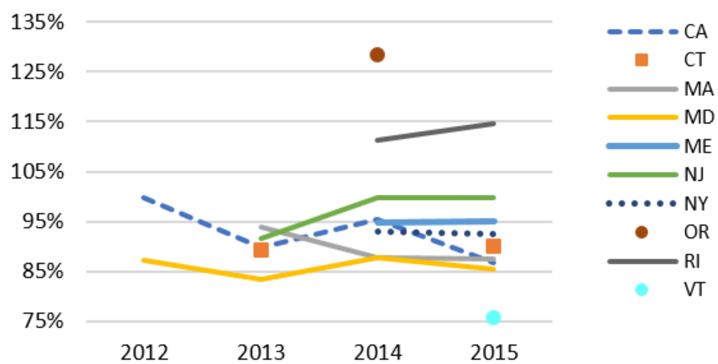

Figure 33. AEO2017-based LDV sales as percent of state credit report production delivered for sale

As seen in Figure 34, historical annual LDV sales in the ZEVR states are more volatile than forecast sales, not because the future is certain to be smoother, but rather because the greatest causes of variation are often not predictable. ZEV and PHEV sales forecasts in this report are built on the underlying assumption of gradual year-on-year changes in LDV sales shown in Figure 34, in which the automotive manufacturing industry does not experience conditions or events that cause substantial changes in total LDV sales.

[60] U.S. Energy Information Administration, January 5, 2017. Annual Energy Outlook 2017 with projections to 2050. https://www.eia.gov/outlooks/aeo/

[61] Federal Highway Administration, US Department of Transportation. December 2015. State Motor-Vehicle Registrations – 2014. http://www.fhwa.dot.gov/policyinformation/statistics/2014/mv1.cfm

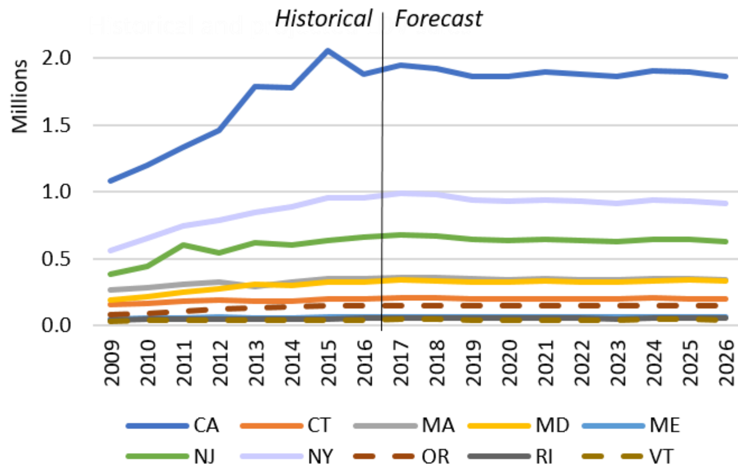

Figure 34. Light-duty vehicle sales for ZEVR states, 2009 to 2026

Figure 34 also shows the relative amounts of total LDV sales among the ZEVR states. California represents roughly 40% of the total LDV sales in ZEVR states, followed by New York at 20%, New Jersey at 15%, and the remaining seven states collectively represent about 25% of LDV sales in ZEVR states.