# Colorado Zero Emission Vehicle Program Will Deliver Extensive Economic, Health and Environmental Benefits

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*Preface*

All the projections and analysis in this report are based on modeling by Richard Rykowski. Mr. Rykowski holds B.S. and M.S. degrees in Chemical Engineering from the University of Michigan and worked for the U.S. EPA for over 32 years. He played a key role in the development of a number of EPA's vehicle fuel and emissions regulations, including the first phase of the EPA light-duty GHG standards for MY 2012-2016 that was promulgated in 2010. He was a key architect of the EPA OMEGA model that was used in the rulemakings that established the MY 2012-2025 GHG standards. Throughout his career, Mr. Rykowski received many prestigious awards including EPA's Engineer of the Year Award, as well as several Gold and Silver Medals for Meritorious Service. His detailed documentation is included as Appendices A, B, C, and D.

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# Executive Summary

Adoption of Colorado's Zero Emission Vehicle Program would have a broad range of substantial benefits for Coloradans, reducing harmful air pollution and saving consumers money. Based on the analysis set forth in this report and the accompanying technical appendix, adoption of the program will:

- Save Coloradans up to $65 million annually by 2025 and up to $2.2 billion a year by 2040, in economic and pollution benefits;
- Avoid 1 million metric tons of greenhouse gas emissions every year by 2025 and up to 7.6 million tons annually by 2040, equivalent to taking more than 200,000 cars off of Colorado's roads in 2025 and removing nearly 1.6 million cars in 2040;
- Significantly reduce ozone forming pollution and harmful particulate pollution, avoiding up to 10 premature deaths annually and 670 lost work days avoided each year by 2050.

Across Colorado and the nation, climate change has contributed to deadly wildfires, floods, droughts, crop losses and more health harming high ozone days.[1]

Despite the science-based imperative for action, the Trump Administration is attempting to roll back the Environmental Protection Agency's (EPA) historic greenhouse gas (GHG) emissions standards for cars and light trucks that strengthen each year through 2025.

In response, Colorado is taking action to protect the climate benefits that the original national rule would have provided. In 2018, Colorado adopted the Colorado Low Emission Automobile Regulation (CLEAR), which applies more protective criteria and greenhouse gas standards to vehicles sold in Colorado, beginning with the 2022 model year and continuing through model year 2025.

In May 2019, the Colorado Air Quality Control Commission unanimously voted to move forward with a formal hearing to consider adoption of a state Zero Emission Vehicle (ZEV) program — an action that has been adopted by ten other states across the country.[2] This follows Colorado's passage of HB 19-1261, historic legislation setting rigorous climate pollution reduction goals,[3] and an Executive Order from Governor Polis that provides a framework for Colorado to accelerate electrification in its transportation sector.

The ZEV program will put Colorado on a path to achieving greater long-term GHG reductions. It will also help secure vital reductions in criteria pollution, save money due to lower fuel costs, and provide more opportunities for Coloradans to choose clean, zero emitting vehicles. A ZEV program is an important complement to the CLEAR standards and will help position Colorado to secure event greater pollution reductions in the future.

This report examines the vehicle cost, fuel savings, greenhouse gas and criteria emissions reductions, and health-related benefits for three different scenarios under a combined CLEAR and ZEV program, hereafter referred to as the Colorado Advanced Clean Car Program (ACCP). Two

[1] The recent National Climate Assessment concluded that, "Earth's climate is now changing faster than at any point in the history of modern civilization… The evidence of human-caused climate change is overwhelming and continues to strengthen, that the impacts of climate change are intensifying across the country, and that climate-related threats to Americans' physical, social, and economic well-being are rising." USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018. https://nca2018.globalchange.gov/

[2] http://blogs.edf.org/climate411/2019/05/10/colorado-charges-forward-with-zero-emission-vehicle-proposal/

[3] https://www.edf.org/media/colorado-legislature-sends-historic-climate-legislation-governors-desk

of the scenarios analyze the impacts of continuing to increase ZEV requirements through 2025 – applying slightly different assumptions regarding emissions averaging – but assume no increases thereafter. Colorado's adoption of ZEV standards from 2023 through 2025 can also better position the state to realize more rapid, expected growth in ZEV sales post-2025. The third scenario evaluates these likely post-2025 benefits by assuming continued growth in ZEVs out to 2035. As the analysis in this report shows, all of the scenarios provide net benefits to Colorado by 2025, and the benefits grow significantly out to 2050. The table below more fully describes each of these three scenarios.

## Table ES-1
## Three Scenarios for Evaluating Colorado's Adoption of Advanced Clean Car Program

| SCENARIO | DESCRIPTION |
|---|---|
| **SCENARIO 1** | COMBINATION OF THE COLORADO ZEV PROGRAM PLUS THE CLEAR STANDARDS, AND THE ASSUMPTION THAT AUTOMAKERS WILL SEEK TO FULLY EXPLOIT AVERAGING WITH RESPECT TO CLEAR GHG COMPLIANCE, USING ADDITIONAL ZEV SALES TO SELL HIGHER GREENHOUSE GAS EMITTING GASOLINE VEHICLES THAN WOULD BE POSSIBLE ABSENT THE ZEV PROGRAM |
| **SCENARIO 2** | COMBINATION OF THE COLORADO ZEV PROGRAM PLUS THE CLEAR STANDARDS, AND THE ASSUMPTION THAT AUTOMAKERS WILL NOT EXPLOIT ANY GHG AVERAGING WITH THE HIGHER ZEV SALES UNDER THE ZEV PROGRAM |
| **SCENARIO 3** | A POST-2025 ZEV GROWTH SCENARIO BUILDING OFF OF SCENARIO 2, WHERE ZEV MARKET SHARE IS ASSUMED TO GROW BY AN ABSOLUTE 3% PER YEAR FROM 2026-2035 |

The analysis estimates these impacts of an ACCP program against a baseline that assumes the Trump Administration will weaken the current greenhouse gas standards for cars and light trucks as was proposed in EPA's and NHTSA's 2018 Notice of Proposed Rulemaking.[4] While EPA has not yet taken final action on this proposal, for the purposes of this analysis and consistent with recent reporting, we assume that the relaxation of the GHG standards will be significant, maintaining the 2020 standards indefinitely as proposed.

The methodologies underpinning this analysis are consistent with previous analyses conducted by EPA in these areas, such as those used in its original Proposed[5] and Final Determinations[6] regarding the 2022-2025 GHG standards for cars and light trucks. We use the most up-to-date projections of the cost of electric vehicles, as well as the most recent projections of future gasoline prices in the Energy Information Administration's 2019 Annual Energy Outlook. Our primary analysis uses gasoline prices of $3.00 per gallon in 2020, rising slowly to $3.66 per gallon in 2050. Given the inherent volatility of oil prices, we also show results for a high gasoline price sensitivity where gasoline prices are $1-2/gallon higher.

[4] U.S. EPA (August 24, 2018), The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, EPA–HQ–OAR–2018– 0283.
See https://www.govinfo.gov/content/pkg/FR-2018-08-24/pdf/2018-16820.pdf

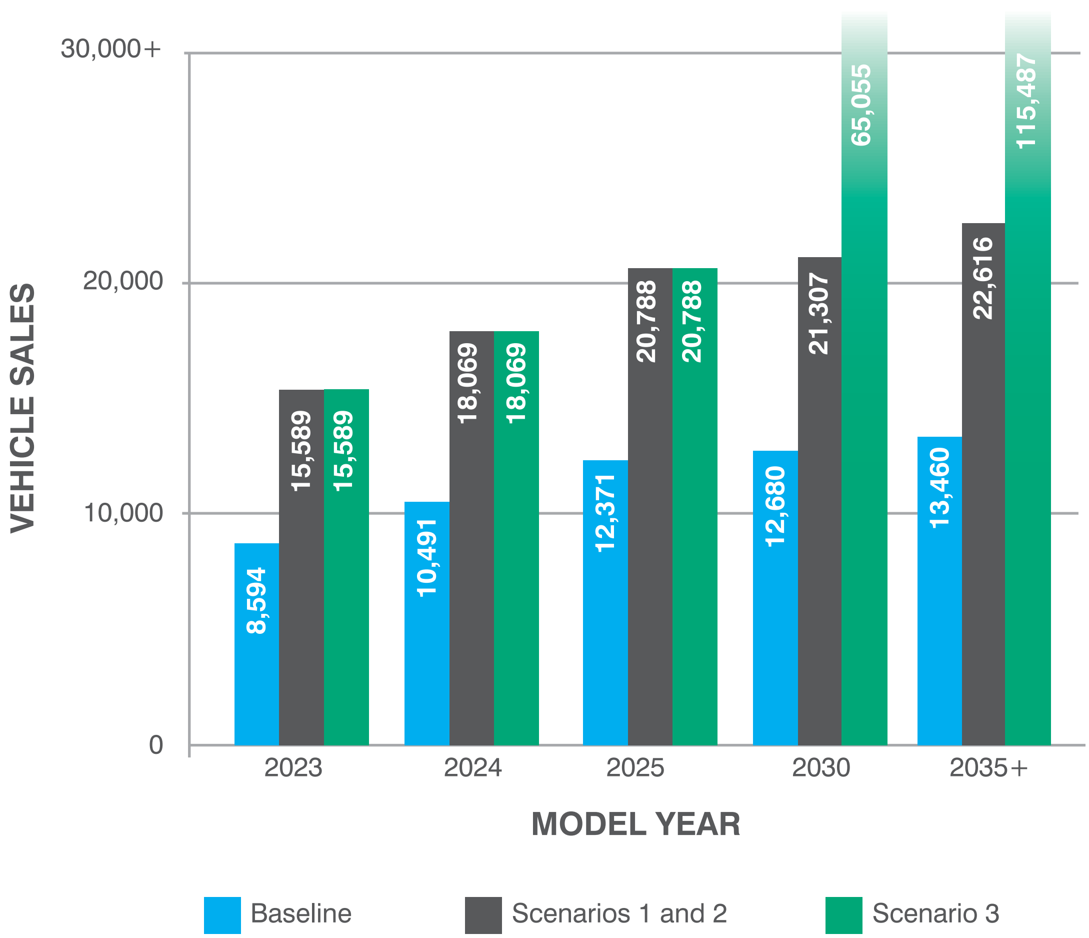
[5] U.S. EPA (November 2016), Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-16-020.
See https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3DO.pdf

[6] U.S. EPA (January 2017), Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, U.S. EPA, EPA-420-R-17-001.
See https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100QQ91.pdf

## Colorado Advanced Clean Car Program Will Increase Zero Emission Vehicle Sales

Adoption of a Colorado ZEV program would result in an increase in electric vehicle sales in the state. As shown in Figure ES-1, our analysis estimates that under all scenarios, Colorado would realize an increase (relative to the baseline) of more than 8,400 ZEV sales by 2025 as a result of adopting a ZEV program. And under Scenario 3, where we assume that ZEV sales will continue to grow past 2025, Colorado could achieve more than 100,000 additional electric vehicle sales by 2035 compared to a baseline where the state does not adopt a ZEV program. These additional sales will deliver significant economic savings to consumers and the state and will help mitigate greenhouse gas and criteria emissions across Colorado.

### Figure ES-1
### Projected ZEV Sales in Colorado Under Colorado Advanced Clean Car Program Scenarios



## Colorado Advanced Clean Car Program Will Deliver Substantial Consumer Savings

Our analysis of the economic impacts of a Colorado ACCP assesses all major variables that affect the aggregate costs of owning and operating a vehicle: vehicle purchase, insurance, fuel, and maintenance costs. We project that the Colorado ACCP will yield significant economic savings, both for individual Coloradans who buy new ZEVs and gasoline vehicles in the future and for the statewide fleet as well. The most important economic projections are summarized in a series of figures below, which are discussed in significantly greater detail in the body of the report as well as in the Appendices.

### Figure ES-2

### Buyers of New ZEVs in 2025 and 2030 Will Realize Large Net Lifetime Savings ($ per Vehicle)

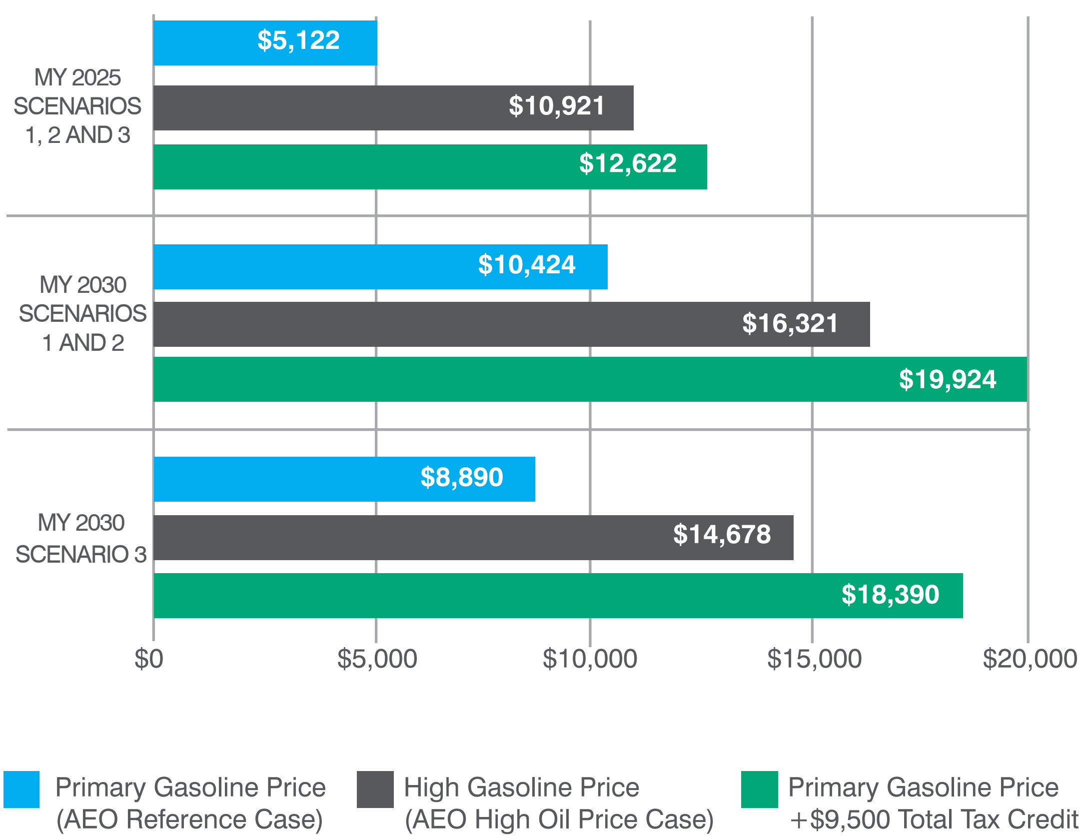



Figure ES-2 shows that, on average, new ZEVs bought in MY 2025 and 2030 due to the ZEV program are projected to yield net lifetime savings for their collective owners relative to the average vehicles in the baseline. In the primary analysis for MY 2025, the net lifetime savings per vehicle will be over $5,000 under all scenarios as lifetime fuel savings more than offset the higher average cost of purchasing a new ZEV. The net lifetime savings for a MY 2030 ZEV increases to about $10,000 (a little more under Scenarios 1 and 2, and a little less under Scenario 3, as PHEVs represent a higher share of the incremental ZEVs under Scenario 3) in the primary analysis as the average new ZEV is projected to be a little less expensive to purchase, relative to the baseline gasoline vehicle, and this savings adds to the substantial fuel savings. With higher gasoline prices, the net lifetime savings increase to nearly $11,000 in MY 2025 and to about $15,000 in MY 2030. The combination of the primary gasoline price and higher tax credits yields net lifetime savings of nearly $13,000 in MY 2025 and almost $20,000 in MY 2030. These higher tax credits would further improve the economic savings for Coloradans who purchase new ZEVs.

## Figure ES-3

## Buyers of New Gasoline Vehicles in 2025 Also Achieve Large Net Lifetime Savings ($ per Vehicle)

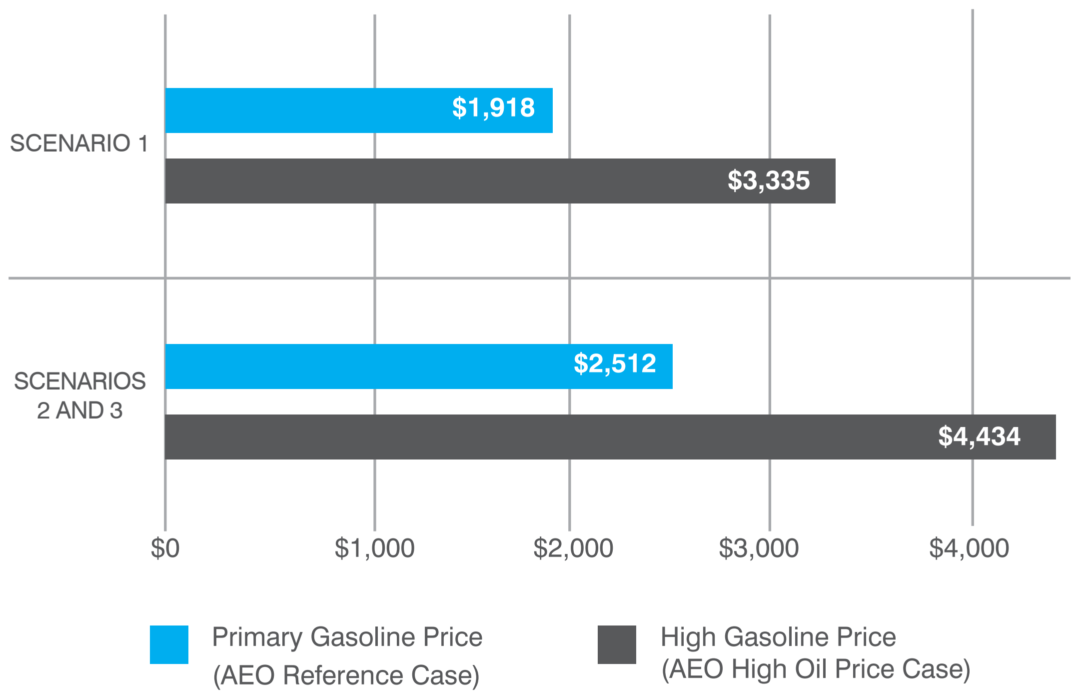
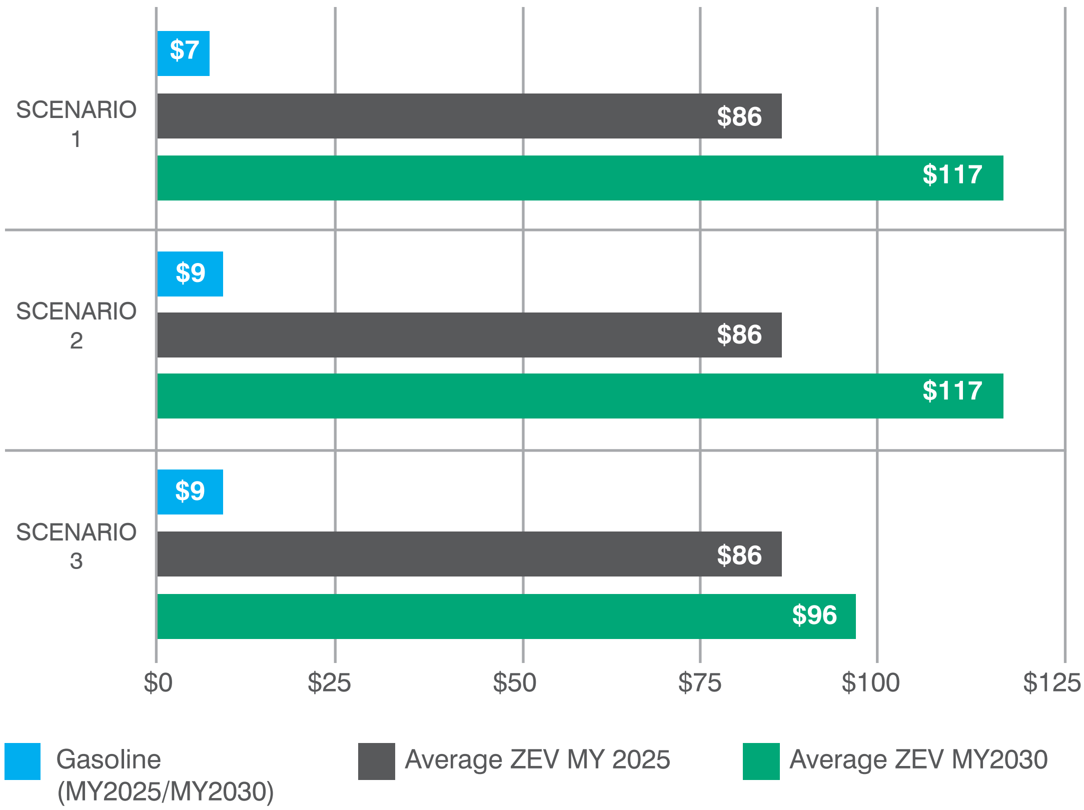



Figure ES-3 shows that the average new gasoline vehicle bought in MY 2025 will provide net lifetime savings for their owners, as the lifetime fuel savings exceeds the higher initial vehicle purchase cost. For Scenario 1, the net lifetime savings would be over $1,900 with the primary gasoline prices and $3,300 with higher gasoline prices. For Scenarios 2 and 3, the extra fuel savings more than offset the higher vehicle prices relative to Scenario 1, and the net lifetime savings increase to over $2,500 with the primary gasoline prices and $4,400 with higher gasoline prices. Scenario 3 does not differ from Scenario 2 in this figure because higher post-2025 ZEV sales do not impact gasoline vehicle economics (price of the vehicle or otherwise).

The projected net lifetime savings projections in Figures ES-2 and ES-3 are most relevant to consumers who purchase new vehicles with cash and drive them for the full vehicle lifetimes. Figure ES-4 provides a more relevant projection of the impact on monthly cash flow for consumers who finance the purchase of new gasoline vehicles or ZEVs with loans in 2025 or 2030 relative to the average vehicles in the baseline.

**Figure ES-4**

## Net Monthly Cash Flow Savings for ZEV and Gasoline Vehicle Buyers With Loans ($ per Month)

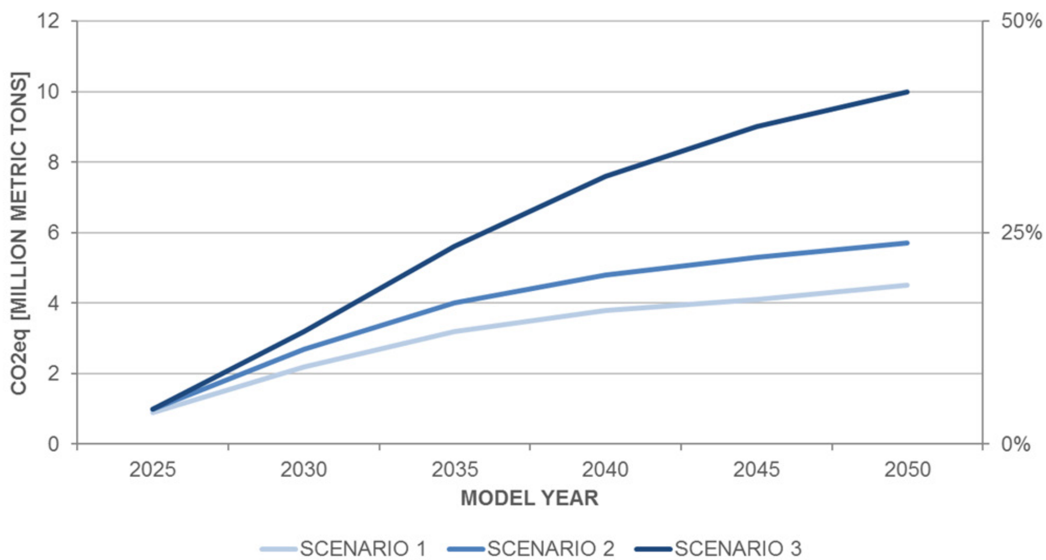



As shown in Figure ES-4, the purchaser of a new gasoline vehicle with a loan in 2025 or 2030 under all three scenarios is projected to see an overall improvement in monthly cash flow of $7-9 dollars as monthly fuel savings more than offset the slightly higher monthly payments due to the more expensive gasoline vehicles (the monthly cash flow savings would be much larger once the loan is paid off). A consumer who buys a new ZEV with a loan in 2025 is projected to realize a monthly savings of $86 under all three scenarios, and in 2030 ZEV buyers are projected to save $96-$117 per month (less under Scenario 3 as we assume that there will be a higher PHEV fraction of incremental ZEV sales under Scenario 3). These projections suggest that, by 2025, there will be a strong economic case for buying ZEVs rather than gasoline vehicles.

## Colorado Advanced Clean Car Program Will Reduce Greenhouse Gas and Criteria Pollution

In addition to the economic benefits, a combined Colorado CLEAR and ZEV program will deliver significant climate and health benefits by reducing greenhouse gas and criteria emissions, including carbon dioxide (CO2), ozone-forming oxides of nitrogen (NOx) and other health-harming pollutants. A Colorado ACCP has the potential to reduce up to 3.2 million tons of greenhouse gas emissions in 2030 and reduce nearly 7.6 million tons in 2040, assuming ZEV sales continue to grow past 2025. That would be equivalent to taking more than 600,000 cars off of Colorado's roads in 2030 and removing nearly 1.6 million cars in 2040.[7] Figure ES-5 shows the greenhouse gas emissions reductions projected under the three modeled scenarios. Scenarios 1 and 2 highlight the immediate reductions through 2040 that an ACCP would achieve, and Scenario 3, which assumes ZEV sales will continue to increase, projects that the program will open the door to even greater reductions through 2050.

### Figure ES-5
### GHG Emissions Reductions Under Colorado Advanced Clean Car Program Scenarios

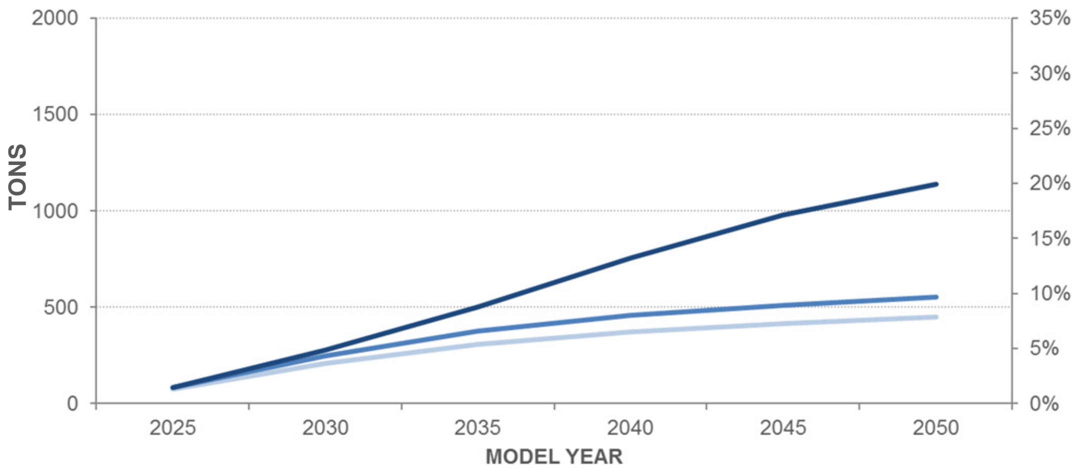



Colorado would also see a significant reduction in health-harming criteria pollution emissions. Figure ES-6 illustrates the additional NOx reductions possible under the three scenarios relative to the baseline. By 2040, a Colorado ACCP could reduce NOx emissions by roughly 370 to 750 tons per year, depending on the scenario. NOx gases react to form smog and acid rain as well as being central to the formation of fine particles ($PM_{2.5}$) and ground level ozone, both of which are associated with adverse health effects. Colorado does not currently meet either the 2008 or 2015 health-based National Ambient Air Quality Standards for ground-level ozone, and the American Lung Association's 2019 State of the Air report ranked Denver the 12th most ozone-polluted city in the nation.[8] Volatile organic compounds (VOCs), another precursor to ozone, could be reduced by

[7] EPA, Greenhouse Gas Equivalencies Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
[8] American Lung Association, State of the Air 2019 (2019). https://www.lung.org/our-initiatives/healthy-air/sota/city-rankings/most-polluted-cities.html

up to 1,200 tons annually by 2040 and $PM_{2.5}$ and sulfur dioxides (SO2) would also be significantly reduced under the ACCP. The particular health benefits of these reductions, including reductions in mortality, are shown in Table 17 below.

## Figure ES-6
## NOx Emissions Reductions Under Colorado Advanced Clean Car Program Scenarios




## Colorado Advanced Clean Car Program Will Benefit Public Health

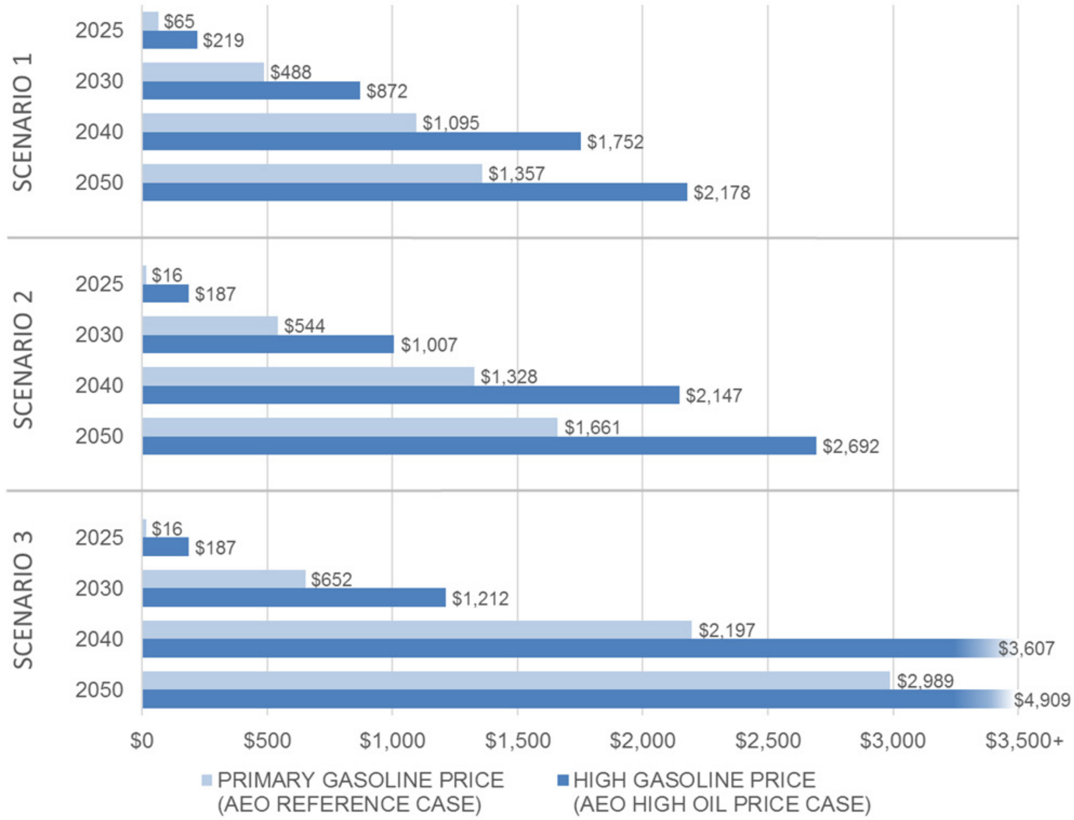
We used EPA's Co-Benefits Risk Assessment (COBRA) screening and mapping tool together with the estimated emission reductions to estimate the monetized value of the health impacts of a Colorado ACCP. In 2050, the annual value of the health benefits of adopting an ACCP ranges from $14 million to over $100 million. All of these health impacts are due to changes in ambient fine particulate matter levels and do not include any value associated with reduced ozone or GHGs, which would further enhance the benefits.

## Colorado Advanced Clean Car Program Will Deliver Net Economic and Pollution Benefits to the State

To evaluate the net economic and pollution impacts of a Colorado ACCP, we combine the vehicle-related economic impacts on consumers (Table 12) with the monetized benefits of the greenhouse gas emissions reductions (Table 14) and monetized ambient PM-related health benefits to society (Table 18). Figure ES-7 summarizes these projected aggregate economic and pollution benefits to Colorado for four forecast years between 2025 and 2050 for each of the three scenarios, relative to the baseline, with both the primary and high future gasoline prices.

## Figure ES-7

## Advanced Clean Car Program Yields Substantial Net Economic and Pollution Benefits to Colorado ($ Millions, Annually)




The net economic and pollution benefits (the majority of which are direct economic benefits to consumers with the remainder being monetized environmental and health benefits) to the state of Colorado are positive under every scenario, and grow substantially over time. In the primary analysis (gasoline price based on AEO reference case) under Scenario 1, the annual statewide benefits are $65 million in 2025, nearly $488 million in 2030, more than $1 billion in 2040, and grow to $1.3 billion in 2050. The statewide benefits under Scenario 2, relative to Scenario 1, are lower in 2025, but higher beginning in 2030. Under Scenario 3, the post-2025 ZEV growth scenario, the annual benefits to Colorado reach nearly $3 billion in 2050. As expected, the net economic and pollution benefits are greater under the high gasoline price scenarios, growing from about $1 billion in 2030 to as high as almost $5 billion in 2050.

# Background

The transportation sector is a significant source of climate destabilizing and health harming pollution in Colorado. Passenger vehicles are currently responsible for more than 19 million tons of annual CO2 emissions across the state, or approximately 21 percent of statewide greenhouse gas emissions.[9] Across the nation, the transportation sector is currently the largest contributor to carbon pollution,[10] with passenger vehicles accounting for more than half of transport emissions.[11]

**Passenger vehicles are currently responsible for more than 19 million tons of annual CO2 emissions across the state, or approximately 21 percent of statewide greenhouse gas emissions**

Climate change is an existential threat to the long-term sustainability of our planet. Colorado is one of the fastest-warming states in the country. The state's annual average temperatures have already increased by two degrees Fahrenheit (F) over the past 30 years, and, absent substantial reductions in emissions, projections show the state's average temperature could rise by five degrees F by 2050.[12]

Rising temperatures have, and will continue to have, harmful implications across the state.[13] For instance, the amount of snowpack measured at most monitoring sites in Colorado in the month of April has declined by 20 to 60 percent since 1955.[14] Colorado is also experiencing reduced rainfall during summer months and longer periods without rain, depleting aquifers and making droughts more severe.[15] Hotter temperatures and an earlier snow melt also lead to drier forests that are at increased risk of wildfires. These patterns are well established and are expected to continue. Colorado is the third-most wildfire-prone state in the United States,[16] with more than half of the state's population living in homes threatened by wildfire.[17] Dry forests also foster the invasive pine beetle, which destroyed more than 3.4 million acres of trees in Colorado between 1996 and 2017, creating additional fuel for fires.[18]

Climate change is inextricably linked to air pollution with harmful health impacts – including pollutants that threaten lung health and lead to asthma attacks, hospitalizations, emergency room visits, and even early death. Rising temperatures increase the formation of ground-level ozone—a key component of smog and a pollutant that aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease.[19] Children, seniors, and people with existing lung or heart problems are especially at risk. Increasing ozone is particularly harmful in areas like Metropolitan Denver and Fort Collins, which already fail to meet national health-based standards for ozone and are ranked in the top 25 most polluted cities in the nation for ozone.[20] The passenger vehicle fleet in Colorado is a significant source of these harmful pollutants. In fact, an air quality report from the National Center for Atmospheric Research (NCAR) found that motor vehicles, together with oil and gas operations, are the largest local contributors to unhealthy ozone levels along

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9 U.S. Energy Information Administration, State Carbon Dioxide Emissions Data, Colorado, Data for 2016, Released October 31, 2018. https://www.eia.gov/environment/emissions/state/ (accessed May 6, 2019)
10 EIA (2019) Annual Energy Outlook 2019, Table A18. https://www.eia.gov/outlooks/aeo/
11 EIA (2019) Annual Energy Outlook 2019, Table A19. https://www.eia.gov/outlooks/aeo/
12 Colorado Health Institute (July 10, 2017) Colorado's Climate and Colorado's Health: Examining the Connection. https://www.coloradohealthinstitute.org/research/colorados-climate-and-colorados-health
13 University of Colorado Boulder and Colorado State University (January 2015) Colorado Climate Change Vulnerability Study, submitted to the Colorado Energy Office. http://wwa.colorado.edu/climate/co2015vulnerability/co_vulnerability_report_2015_final.pdf
14 EPA (August 2016) What Climate Change Means for Colorado. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-co.pdf
15 Id.
16 Insurance Information Institute, Facts and Statistics: Wildfires. See https://www.iii.org/fact-statistic/facts-statistics-wildfires
17 Bruce Finley (December 1, 2018) Climate change clobbers Colorado and the West, unfurling fire, drought, insects and heat, The Denver Post. https://www.denverpost.com/2018/12/01/climate-change-impact-colorado/
18 Colorado Health Institute (July 10, 2017) Colorado's Climate and Colorado's Health: Examining the Connection. See https://www.coloradohealthinstitute.org/research/colorados-climate-and-colorados-health
19 EPA (August 2016) What Climate Change Means for Colorado. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-co.pdf
20 American Lung Association (2019) State of the Air 2019, Most Polluted Cities. https://www.lung.org/our-initiatives/healthy-air/sota/city-rankings/most-polluted-cities.html

the northern Front Range.[21] Communities like Globeville and Elyria-Swansea that are located near major roadways experience greater health risks associated with this pollution, including some of the highest rates of asthma, cancer, cardiovascular disease, diabetes, and obesity in Denver.[22]

At the same time Colorado faces these serious climate and health threats, the Trump Administration is proposing to roll back greenhouse gas standards for passenger vehicles. Absent additional state action, these federal rollbacks would expose Coloradans to substantial additional amounts of this harmful pollution and result in serious health harms. Analysis shows that a rollback of the 2021-2026 and later model year GHG standards to 2020 levels would result in more than 2.5 million additional tons of annual greenhouse gas emissions in Colorado by 2030.[23] Another recent analysis shows that Trump's proposed rollback would have serious health implications for Coloradans. In Colorado alone, the rollback would lead to 286 heart-disease-related and 234 lung-disease-related hospital admissions, and up to 304 more premature deaths by 2050.[24]

Colorado has already taken important steps to mitigate the impacts of the federal reversal. In November 2018, Colorado joined 13 other states in adopting new emissions standards for light-duty vehicles. The Clean Air Act gives California authority to establish vehicle emission standards that are more protective than federal standards, and likewise allows other states, like Colorado, to adopt these standards. The CLEAR standards will apply to vehicles sold in Colorado beginning with the 2022 model year, and according to the state's final economic impact analysis, the standards could reduce GHG emissions by more than 30 million tons cumulatively between 2022 and 2031.[25] The program will also significantly decrease other types of air pollution that cause serious heart and lung diseases,[26] all while reducing fuel consumption in new cars and saving Colorado families money at the gas pump.

Shortly after Colorado took this important action, Colorado Governor Polis issued an Executive Order committing the state to widespread transportation sector electrification. A core element of this strategy is the directive for the Colorado Air Quality Control Commission (AQCC) to consider adoption of Zero Emission Vehicle (ZEV) standards — an action that has been adopted by ten other states across the country and has already received broad support from Colorado businesses and communities.[27,28] In May 2019, the AQCC unanimously approved to open a rulemaking to consider adoption of the ZEV program regulation. Electric vehicles are inherently cleaner than conventional gasoline vehicles and offer Colorado the opportunity to secure far deeper GHG reductions and consumer benefits in the longer term.

The nation's first ZEV program was adopted by California in 1990. Over the last 30 years, California

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[21] NCAR (October 30, 2017) Scientists Pinpoint Sources of Front Range Ozone. https://news.ucar.edu/129774/scientists-pinpoint-sources-front-range-ozone

[22] Denver Department of Environmental Health, How Neighborhood Planning Affects Health in Globeville and Elyria Swansea (September 2014). https://www.denvergov.org/content/denvergov/en/environmental-health/community-health/health-impact-assessment.html

[23] Rykowski (2018). The rollback will also result in significant pollution increases across the nation, including approximately 4.5 billion tons of additional cumulative $CO_2$ emissions between 2017-2050 and 200 million tons of additional, annual $CO_2$ emissions in 2050. Stagnant standards would also substantially increase harmful criteria emissions. Compared to the federal Tier 3 rule that implements tailpipe and evaporative emissions standards for new light-duty vehicles, the national emission increases attributable to the rollback in the 2030 calendar year would offset 24 percent of the VOC reductions, 13 percent of the NOx reductions, and 38 percent of the PM2.5 reductions that are expected from Tier 3.

[24] S. William Becker and Mary D. Becker, The Devastating Impacts of the Trump Proposal to Roll Back Greenhouse Gas Vehicle Emissions Standards: The Untold Story, (2018). http://blogs.edf.org/climate411/files/2019/05/FINALGHGREPORT.pdf

[25] Colorado Department of Public Health and Environment, Final Economic Impact Analysis; Proposed AQCC Regulation 20: Colorado Low Emission Automobile Regulation (November 15, 2018), Table 28, page 23.

[26] Rykowski (2018).

[27] Ceres (November 14, 2018) Colorado Businesses Support Advanced Clean Cars Standards, Press Release. https://www.ceres.org/news-center/press-releases/colorado-businesses-support-advanced-clean-cars-standards

[28] Bruce Finley (August 16, 2018) Colorado aims to cut greenhouse gas emissions with fuel efficiency push after federal standards freeze, The Denver Post. https://www.denverpost.com/2018/08/16/colorado-push-for-less-pollution-from-gas-powered-vehicles/

has modified the ZEV program to reflect the current state of advanced technologies, including full battery-electric, hydrogen fuel cell, and plug-in hybrid-electric vehicles. The ZEV program requires manufacturers to meet ZEV requirements each year, based on the total number of cars sold in the state by that manufacturer and ZEV credits earned based on technology and vehicle range. Since 2010, the ZEV program has helped put nearly 600,000 zero emission vehicles and plug-in hybrids on California roads.[29]

Under section 177 of the Clean Air Act, nine other states have since adopted a ZEV program, and together the 10 ZEV states (California, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont) represent more than 30 percent of the new car sales market in the United States.[30] These ZEV states also represent two-thirds of the new ZEV market as ZEV programs help to drive many of the other factors that lead to higher uptake of zero emission vehicles, including charging infrastructure, model availability and consumer awareness.[31]

Colorado's consideration of a state ZEV program also coincides with rapid growth in the electric vehicle (EV, including both BEVs and PHEVs) market. Manufacturers are making substantial investments in EV development and regularly introducing new models at the same time costs are briskly falling. Global EV sales surpassed 2 million vehicles in 2018[32] and are expected to reach 11 million units by 2020.[33] In the U.S., electric vehicle sales increased by nearly 30 percent from 2016 to 2017[34] and another 81 percent the following year.[35] This growth is being fueled by a sharp increase in model offers and production volume. The number of electrified models available in the U.S. increased from just one in 2010 to more than 40 in 2017,[36] and is projected to reach 55 by the end of 2019 and 81 by the end of 2022, with new types of vehicles becoming available, including sport-utility vehicles (SUVs), cross-overs and pick-up trucks.[37] These newer models also boast substantially greater battery range – more than 3.5 times the range of earlier models.[38]

**On a national average, it costs less than half as much to travel the same distance in an EV than in a conventional vehicle**

In addition to increased model availability and range, there has been a steady decrease in vehicle prices. According to manufacturers, by 2021 there will be at least five EV models available for under $30,000 (MSRP excluding tax incentives) with a range of up to 250 miles.[39] One of the factors driving down EV prices is the rapidly declining cost of batteries. A new analysis by the International Council on Clean Transportation (ICCT) projects that as battery prices continue to fall, plug-in electric vehicles and conventional vehicles will reach purchase cost parity between 2024-2028, depending on the range of the EV.[40] And parity for the total cost of ownership is one to two years earlier than initial cost parity, due to high fuel cost savings.[41] On a national average, it costs less than half as much to travel the same distance in an EV than in a conventional vehicle.[42]

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29 https://www.veloz.org/sales-dashboard/
30 California Air Resources Board webpage. https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about
31 Peter Slowik and Nic Lutsey (July 2018). The Continued Transition to Electric Vehicles in U.S. Cities, The International Council on Clean Transportation. https://www.theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf
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Against this dynamic landscape, the adoption of a ZEV program presents an important opportunity to further protect Coloradans' health and save Colorado consumers money, all while enhancing consumer ability to choose among a greater number of vehicles that will meet their needs. The remainder of this report discusses the methodology and results of our analysis of the specific costs and benefits of adopting a combined Colorado CLEAR and ZEV program.

# Analysis: Benefits of Adopting a ZEV Program in Colorado

This section describes our estimates of the costs and benefits of adopting a ZEV program as a complement to the CLEAR standards adopted in 2018. We first describe three different scenarios under which we evaluated the adoption of a ZEV program, including several additional sensitivities to capture how changing economic and environmental assumptions may affect the benefits of this program over time. Next, we describe key inputs and assumptions in our modeling, including the ZEV growth we project under baseline conditions, the mix of BEVs and PHEVs we anticipate in the fleet, and others. Finally, we present our results, identifying consumer economic savings (assuming both cash and loan purchases) and Colorado-wide economic impacts, as well as greenhouse gas and criteria emissions reductions and their associated health impacts.

## Modeling Scenarios in This Report

Our projections of the economic, environmental and health impacts of a combined Colorado CLEAR and ZEV program, which we collectively refer to as the Colorado Advanced Clean Car Program (ACCP), are based on the three scenarios summarized in Table 1.

### Table 1
### Colorado Light-Duty Vehicle Regulatory Scenarios

| SCENARIO | CRITERIA EMISSIONS | | GREENHOUSE GAS EMISSIONS | | ZEV ASSUMPTIONS |
|---|---|---|---|---|---|
| | TAILPIPE STANDARD | AVERAGING WITH HIGHER ZEV SALES | TAILPIPE STANDARD | AVERAGING WITH HIGHER ZEV SALES | |
| **BASELINE** | EPA TIER 3 | YES | EPA 2020 | YES | NO ZEV PROGRAM |
| **1** | CLEAR | NO | CLEAR | YES | CO ZEV |
| **2** | CLEAR | NO | CLEAR | NO | CO ZEV |
| **3** | CLEAR | NO | CLEAR | NO | CO ZEV + ZEV GROWTH MY 2026-2035 |

The baseline used for all the modeling runs in this report reflects the U.S. EPA Tier 3 light-duty vehicle criteria emissions standards.[43] For greenhouse gas (GHG) emissions, the baseline holds constant EPA's light-duty vehicle GHG standards for MY 2020, based on the Trump Administration proposal in August 2018 to freeze the GHG standards at MY 2020 levels.[44]

Automaker compliance with both the EPA Tier 3 criteria and EPA GHG standards is based on fleetwide averaging, i.e., EPA determines manufacturer compliance based on a sales-weighted average of the certification values of all the manufacturers' individual models, including ZEVs. In the baseline, we assume Colorado to be part of the national Tier 3 and GHG programs, and we assume that manufacturers will average the zero ZEV tailpipe emissions with gasoline vehicle emissions to achieve overall fleetwide compliance.[45]

The baseline does not reflect CLEAR, which was adopted in November 2018. However, the Tier 3 criteria emissions standards are essentially equivalent to the CLEAR criteria emissions standards adopted by Colorado beginning in MY 2022.[46] Though Colorado has already adopted CLEAR, we did not include it in the baseline because the stringency and associated emissions benefits of the CLEAR standards will change depending on how automakers respond to the adoption of a ZEV program. The CLEAR and ZEV programs are complementary components of a comprehensive package to address both GHG and criteria emissions. The programs allow the emissions from ZEVs to be averaged with gasoline vehicles to meet the CLEAR standards (effectively providing an incentive for the sale of ZEVs), and, accordingly, the CLEAR standards provide the bulk of the near-term GHG and criteria emissions benefits through 2025, with the ZEV program laying the foundation for larger long-term benefits post 2025. As a result, including CLEAR in the baseline could obscure these CLEAR/ZEV interactions and result in an inaccurate portrayal of the benefits of the combined program and its component parts. Conversely, our chosen baseline best illustrates the benefits Colorado will realize under a combined CLEAR and ZEV program. Finally, the baseline assumes no Colorado ZEV program.

Scenarios 1 and 2, which are equivalent with one exception discussed below, reflect the full ACCP, i.e. the Colorado ZEV program, the CLEAR tailpipe criteria and CLEAR GHG standards adopted by Colorado beginning in MY 2022. Both Scenarios 1 and 2 assume that gasoline vehicle criteria emissions will not increase over time due to averaging with higher ZEV sales. This assumption is made for several reasons: First, the absolute increase in ZEV sales due to the CO ZEV program is not projected to be large enough to affect automakers plans for criteria emissions compliance. Second, for criteria emissions, individual models are certified into a limited number of discrete "NMOG + NOx emissions bins" which inherently limits automaker flexibility to exploit averaging. Third, there are a number of emission standards, such as the particulate matter and evaporative emissions standards, that do not allow averaging, and, as a consequence, automakers cannot backslide on gasoline vehicle criteria emissions. Fourth, because criteria emissions control technologies and strategies are integrated with overall vehicle design and control algorithms, they are not easily removed and automakers would have limited incentive to do so. Finally, any potential

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[43] 79 Fed. Reg. 23414 (April 28, 2014).

[44] 83 Fed. Reg. 42986 (August 24, 2018). Note that the use of a MY 2020 EPA tailpipe GHG standard baseline is conservative as the Trump Administration also proposed to remove air conditioning refrigerant GHG credits for automakers, and to weaken the tailpipe standards for MY 2021 and later model years upward by about 14 grams per mile (which would increase the GHG savings in the scenarios analyzed in this report).

[45] Note that ZEVs are a small proportion of the current nationwide fleet, and EPA, in its January 2017 Final Determination, projected only about 3% EVs in its cost-effective compliance projections for the (pre-rollback) MY 2025 standards. So, at these levels, averaging has a small impact. Averaging has a larger impact as ZEV market share increases.

[46] Colorado Low Emission Automobile Regulation, Regulation Number 20, November 15, 2018, https://drive.google.com/file/d/1RPTsQgSNltEHnYtyXHuZ0KFoExPED1HB/view

cost savings from limiting technology in one portion of the national fleet would be at least partially offset by increased engineering time and vehicle testing requirements for certifying the Colorado fleet to a second set of standards, further disincentivizing manufacturers from even considering separate averaging for Colorado for criteria tailpipe emissions.

Scenario 1 (GHG averaging) assumes that automakers will seek to fully exploit averaging with respect to the CLEAR GHG standards, balancing additional ZEV sales with weaker gasoline vehicle GHG performance levels than would otherwise apply absent these ZEV sales. Manufacturers might elect to moderate gasoline vehicle GHG performance improvements for several reasons. Because the CLEAR GHG standards involve annual stringency increases, averaging may provide manufacturers with the most cost-effective ways to comply each year. In addition, GHG emissions compliance technology is generally more expensive than criteria emissions compliance technology, providing more of an economic incentive for automakers to consider averaging. Finally, there are no discrete "bins" for GHG emissions compliance, as individual models are simply certified at their unique GHG gram per mile test values, which allows more flexibility for GHG averaging by adjusting sales mix.

**A combination of regulatory and economic drivers will likely lead to sustained growth in ZEV sales after 2025**

Scenario 2 (no GHG averaging) assumes manufacturers will not use GHG averaging and will therefore maintain the gasoline vehicle GHG performance (and fleet sales mix) that would otherwise be required absent ZEV standards. Averaging is provided under existing programs in order to provide a regulatory incentive for automakers to sell ZEVs. As ZEVs improve their market competitiveness and the need for further GHG emissions reductions in conventional vehicles increases in importance, the need for and desirability of such an incentive diminishes. As a result, manufacturers may not need to use this incentive and, in the future, we anticipate regulators will reconsider whether it is included in the next phase of GHG standards and ZEV requirements. Moreover, even assuming manufacturers want to use some GHG averaging, gasoline vehicles in Colorado may not be affected because manufacturers can demonstrate compliance with the greenhouse gas standards across all ACCP states but must meet the CO ZEV standards within Colorado alone. While reality in Colorado will likely fall somewhere between Scenarios 1 and 2, these two scenarios bracket the potential impacts of GHG averaging with the additional ZEV sales under the CO ZEV program.[47]

Scenario 3 evaluates the benefits a ZEV program can have in positioning Colorado for more significant, post-2025 growth of ZEVs in the state. A combination of regulatory and economic drivers will likely lead to sustained growth in ZEV sales after 2025, though the degree to which Colorado can take advantage of this growth will likely depend on near-term investments in vehicle electrification and early action to introduce ZEVs into the fleet. Accordingly, Scenario 3 is equivalent to Scenario 2 through 2025, but illustrates the potential of the program to provide for long-term benefits. That scenario assumes that adoption of the ZEV program through 2025 will help position Colorado to experience overall ZEV market share growth by an absolute 3 percent per year for the ten years from MY 2026 through MY 2035, remaining constant after 2035. The 3 percent per year share growth applied in Scenario 3 was selected as a reasonable assumption based on manufacturer statements and investments regarding long-term commitments to ZEV development and deployment. California, which has had a ZEV program in place the longest, has the highest ZEV sales in the nation and also has ZEV sales that exceed its program requirements – both of which underscore the power of early investment in driving more significant future growth. Scenario 3 results in new ZEV market share increasing from about 7 percent in MY 2025 to 37 percent in MY 2035. There is no gasoline vehicle averaging with the higher ZEV sales in Scenario 3, either for criteria or GHG emissions compliance.

[47] Scenario 1 (relative to the baseline) in this report is very similar to the Colorado Clean Car Program (relative to the Potential Relaxed Scenario) in an earlier EDF report: Richard Rykowski, The Benefits of Protective Advanced Clean Car Standards in Colorado, (May 2018), Environmental Defense Fund. https://www.edf.org/sites/default/files/content/The_Benefits_of_Protective_Clean_Car_Standards_CO.pdf

[48] Dana Lowell and Alissa Huntington (May 2019) Electrical Vehicle Market Status: Manufacturer Commitments to Future Electric Mobility in the U.S. and Worldwide, MJ Bradley and Associates. www.mjbradley.com

We also performed two sensitivity cases that affect the economic and environmental impacts of the three regulatory scenarios.

- Appendix B – "High Fuel Price" – where future gasoline prices are from the 2019 Annual Energy Outlook's High Oil Price Case, and are about $1-2 higher than the Reference Case fuel prices used in the primary analysis
- Appendix C – "100% Renewables" – where all incremental electricity for the higher ZEV sales comes from renewables as opposed to the 75% renewables assumption in the primary analysis

## The Colorado ZEV Program and Projected ZEV Sales

The proposed Colorado ZEV program does not mandate that a manufacturer sell a certain number or percentage of ZEVs; rather, it requires that a manufacturer achieve a certain percentage of "ZEV credits" relative to its overall sales. In addition, there are constraints on the minimum percentage of credits that must be earned with battery electric vehicles (BEVs, where batteries are the only source of on-board energy) and on the maximum percentage of credits that may be earned with plug-in hybrid electric vehicles (PHEVs, which have both batteries and gasoline internal combustion engines).[49] There is also nothing in the program that will prevent manufacturers from selling light-duty trucks and SUVs. Is it up to manufacturers to determine which makes and models they want to electrify and they tend to be concentrated in the car and crossover sector.[50] Table 2 summarizes the credit requirements for the Colorado ZEV program beginning in MY 2023.

*Is it up to manufacturers to determine which makes and models they want to electrify and they tend to be concentrated in the car and crossover sector*

### Table 2
### Colorado ZEV Program Credit Requirements (% of Manufacturer Sales)

| MODEL YEAR | TOTAL ZEV CREDITS | MINIMUM BEV CREDITS | MAXIMUM PHEV CREDITS |
|---|---|---|---|
| **2023** | 17% | 12% | 5% |
| **2024** | 19.5% | 14% | 5.5% |
| **2025+** | 22% | 16% | 6% |

Individual ZEV designs earn different levels of credits based on "technology type" and range. Table 3 lists the number of credits earned by the three vehicle technology/range combinations included in the analyses in this report. There are other technology/range combinations eligible for ZEV credits as well, which, for simplicity, were not included in the analyses for this report.[51]

### Table 3
### Colorado ZEV Credits for Vehicle Designs Included in Modeling

| TECHNOLOGY | BATTERY RANGE | CREDITS PER VEHICLE |
|---|---|---|
| **PHEV** | 50 miles | 1.210 |
| **BEV** | 150 mies | 2.643 |
| **BEV** | 250 miles | 4.000 |

[49] The cap on PHEV credits only applies to "large" vehicle manufacturers and not to "intermediate" manufacturers whose sales fall below a sales threshold.

[50] Dana Lowell and Alissa Huntington (May 2019) Electrical Vehicle Market Status: Manufacturer Commitments to Future Electric Mobility in the U.S. and Worldwide, MJ Bradley and Associates. www.mjbradley.com

[51] For example, several automakers continue to develop fuel cell vehicle designs, which may be attractive for some larger light-duty vehicle applications. Fuel cell vehicles fueled with hydrogen will have zero tailpipe criteria and GHG emissions, and if the hydrogen fuel is produced from low or zero-GHG feedstocks and processes, such vehicles will have very low upstream criteria and GHG emissions as well. Accordingly, under the CO ZEV program, fuel cell vehicles fueled with renewable hydrogen would earn 4 credits per vehicle.

As is evident in Table 3, the credits vary significantly based on technology type and range. A BEV250 earns 3.3 times more credits than a PHEV50 and 1.5 times more credits than a BEV150.

Table 4 summarizes our total ZEV sales (BEV and PHEV) projections for each of the scenarios analyzed in this report. We based our projections of new light-duty vehicle sales in Colorado on national sales projections used by EPA in its analyses for the 2016 Proposed and 2017 Final Determinations. We assumed that the Colorado fraction of national light-duty sales was 1.72%, based on Colorado's share of nationwide population.[52] This led to new light-duty vehicle sales in Colorado of 271,000 in 2018, growing slowly to 308,000 in 2050.

## Table 4
## Projected ZEV Sales in Colorado Under Colorado Advanced Clean Car Program Scenarios

| MODEL YEAR | BASELINE | | SCENARIOS 1 AND 2 | | | | SCENARIO 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TOTAL | | TOTAL | | INCREMENTAL | | TOTAL | | INCREMENTAL | |
| | % | # | % | # | % | # | % | # | % | # |
| **2023** | 3.1 | 8,594 | 5.6 | 15,589 | 2.5 | 6,995 | 5.6 | 15,589 | 2.5 | 6,995 |
| **2024** | 3.8 | 10,491 | 6.4 | 18,069 | 2.7 | 7,578 | 6.4 | 18,069 | 2.7 | 7,578 |
| **2025** | 4.4 | 12,374 | 7.3 | 20,788 | 2.9 | 8,414 | 7.3 | 20,788 | 2.9 | 8,414 |
| **2030** | 4.4 | 12,681 | 7.3 | 21,307 | 2.9 | 8,626 | 22.3 | 65,055 | 17.9 | 52,374 |
| **2035+** | 4.4 | 13,460 | 7.3 | 22,615 | 2.9 | 9,155 | 37.3 | 115,487 | 32.9 | 102,027 |

* NOTE THAT SOME VALUES MAY NOT PRECISELY SUM DUE TO ROUNDING

In projecting Colorado ZEV sales for the baseline scenario, in the absence of a Colorado ZEV program, we relied on an analysis by Charles M. Shulock that was sponsored by the Natural Resources Defense Council.[53] Shulock used proprietary estimates of future nationwide ZEV sales by Alan Baum and Associates, in combination with a previous study by Navigant Consulting that apportioned future nationwide ZEV sales to individual states. We used these inputs to derive the ZEV percentage market share for the Colorado baseline scenario. As shown in Table 4, the baseline ZEV market share in Colorado with no ZEV program grows from 3.1 percent in MY 2023 to 4.4 percent in MY 2025 and later.

Scenarios 1 and 2 both reflect a Colorado ZEV program and are therefore assumed to have the same level of ZEV sales. Given the Colorado ZEV program requirements from Table 2 and the credits for various ZEV designs shown in Table 3, there are an infinite number of ways that individual manufacturers, and the overall new vehicle fleet, could comply with the ZEV program requirements. For simplicity, we narrowed the ZEV design choices to three: PHEVs with a 50-mile range (PHEV50), BEVs with a 150-mile range (BEV150), and BEVs with a 250-mile range (BEV250). We chose these vehicle designs because they provide three distinct electric-only ranges, they are aligned with current vehicle designs in the market, and they are consistent with the recent electric vehicle cost study that we rely on for vehicle cost estimates (see below).

[52] United States Census Bureau, Quick Facts website. https://www.census.gov/quickfacts/fact/table/US/PST045218
[53] Charles M. Shulock, Environmental and Climate Policy Consulting, Projection of ZEV Sales in Colorado With and Without Adoption of a ZEV Regulation (May 2019), prepared for the Natural Resources Defense Council. https://docs.wixstatic.com/ugd/6fe7f1_eeca19bd30f74933814fbec8f6f8d8ab.pdf

We made two additional assumptions in order to project overall ZEV sales under a Colorado ZEV program. First, we assumed that about 80 percent of total ZEVs sold in Colorado under a ZEV program would be BEVs and the remainder would be PHEVs. This split was chosen based on declining battery costs, lower fuel costs for BEVs, higher ZEV credits earned by BEVs, higher overall price of PHEVs, and recent manufacturer statements and investments regarding future product offerings. Second, based on the Shulock analysis, we assumed that BEV sales would be evenly split between BEVs with 150-mile range and BEVs with 250-mile range. The net effect of these assumptions is that the total ZEV sales projections for Scenarios 1, 2, and 3 in Table 4 are approximately 40% BEV250, 40% BEV150, and 20% PHEV50 (the breakdown for the baseline is slightly less BEV-heavy). Appendix A shows a more detailed breakdown of the various technology types for each scenario.

Based on these assumptions, we project that Scenarios 1 and 2 would yield total ZEV market share of 7.3% in MY 2025 and an incremental ZEV market share, relative to the baseline, of 2.9% (8,414 vehicles). The Colorado ZEV program requirements do not change after MY 2025, so these values are assumed to remain constant after MY 2025 for both scenarios, which is a conservative assumption as market trends suggest people will continue to buy a greater percent of ZEVs over time.

Scenario 3 assumes that adoption of the ZEV program through 2025 will help position Colorado to achieve growth in total ZEV sales by an absolute 3% per year for MY 2026-2035. Using the same assumptions discussed above, the total and incremental ZEV sales are equivalent to those for Scenarios 1 and 2 through MY 2025, but then continue to increase through 2035, as demand for ZEVs is expected to continue growing. Total ZEV market share would increase to 22.3% (65,055 vehicles) in MY 2030, and to 37.3% (115,487 vehicles) in MY 2035 and later. The incremental sales, relative to the baseline, would be 52,374 vehicles in 2030 and 102,027 vehicles in 2035 and later.

### Key Cost Inputs and Assumptions

This section projects the economic impacts of a combined CLEAR and ZEV program on individual Colorado car buyers as well as on the statewide fleet. The primary economic variables that would be affected by a Colorado ZEV program, and therefore drive consumer and state-wide economic projections, are vehicle up-front cost, fuel costs, insurance costs, and maintenance costs for both new gasoline vehicles and new ZEVs. In terms of magnitude, vehicle and fuel cost impacts are far more significant than changes in insurance and maintenance costs, and therefore we describe the former impacts in greater detail below.

### New ZEV Vehicle Cost

Historically, electric vehicles have cost more than comparable gasoline vehicles, due primarily to the additional cost associated with large battery packs. However, in recent years, there have been dramatic reductions in battery costs and this trend is expected to continue for the foreseeable future. In addition, economies of scale are critical in the automobile industry and as ZEV sales increase in the future, per-vehicle costs will further decline.

For our ZEV cost estimates, we rely on a recent study by the International Council on Clean Transportation (ICCT).[54] The study is based on the best battery pack and electric vehicle component data available through 2018. The ICCT authors reviewed several detailed technical studies of battery and overall electric vehicle cost that were published in 2017 and 2018, and

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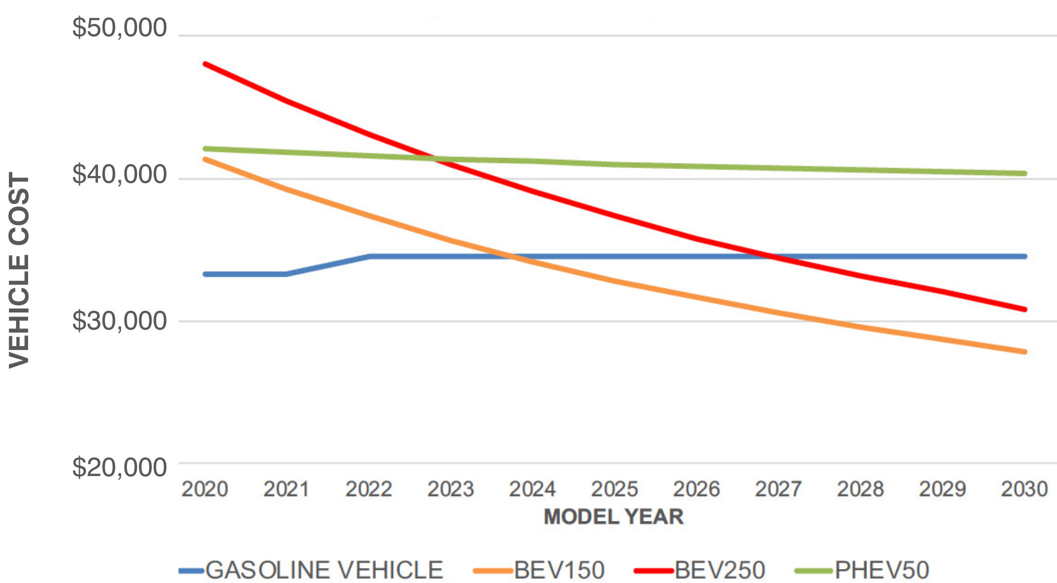
[54] Nic Lutsey and Michael Nicholas, Update on Electric Vehicle Costs in the United States Through 2030, The International Council on Clean Transportation, April 2, 2019. https://www.theicct.org/publications/update-US-2030-electric-vehicle-cost

supplemented these studies with statements by several automakers and a major survey of dozens of industry stakeholders. ICCT concluded that total battery pack costs were approximately $176 per kilowatt-hour (kWh) in 2018 and projected that there would be a 7% annual reduction in these costs, projecting battery pack costs of $104/kWh in 2025 and $72/kWh in 2030.

The ICCT report concludes that "electric vehicle parity is coming within 5-10 years…electric vehicle cost parity with conventional vehicles is likely to occur between 2024-2025 for shorter-range and 2026-2028 for longer-range electric vehicles."[55] And parity based on total cost of ownership could come 1 to 2 years sooner because of fuel cost savings. These trends have important ramifications for the overall economic impacts of a Colorado ZEV program.

Figure 1 uses the ICCT analysis to demonstrate the dramatic reduction in incremental vehicle up-front cost projections for three types of ZEVs – BEV150s, BEV250s, and PHEV50s – relative to the cost of conventional gasoline vehicles from MY 2020 to MY 2030 (for the absolute cost estimates of gasoline vehicles and ZEVs, divided into car, crossover, and sport utility vehicle categories, see Appendix A).

## Figure 1
## Electric Vehicle Cost Projections From International Council on Clean Transportation ($ Per Vehicle)




[55] Ibid, page 11.

Table 5 provides ICCT's incremental ZEV cost estimates for MY 2023, 2025, and 2030. While vehicle technology cost is the primary driver of the incremental costs in Table 5, these costs also include an additional $1300 for a home charger for BEV150s/250s and a $300 home charger for PHEV50s. These estimates do not account for currently available federal and state vehicle purchase tax credits.

## Table 5
## Projected Incremental Cost of New ZEVs in Colorado Relative to Gasoline Counterparts

| ZEV TYPE | MY 2023 | MY 2025 | MY 2030 |
|---|---|---|---|
| **BEV150** | $3,617 | $793 | $(4,226) |
| **BEV250** | $8,933 | $5,321 | $(1,224) |
| **PHEV50** | $8,327 | $7,941 | $7,287 |
| **AVERAGE ZEV** | | | |
| **SCENARIOS 1 AND 2** | $6,414 | $3,413 | $(1,966) |
| **SCENARIO 3** | $6,414 | $3,413 | $(933) |

* PARENTHESES MEAN THAT ZEV COST IS LOWER THAN ITS GASOLINE COUNTERPART

To place the ICCT ZEV cost projections in Table 5 in context, over the 5-year period from 2018 to 2023, the BEV150 cost premium is projected to decline by 75 percent and the BEV250 cost premium is projected to decline by 60 percent. In comparison, the PHEV50 incremental cost is projected to only decline by 16 percent, since batteries represent a much smaller component of the overall cost of a PHEV. By 2025, a BEV150 is projected to nearly reach cost parity with its conventional gasoline counterpart, and by 2030, both BEV150s and BEV250s are projected to be cheaper than comparable gasoline vehicles. PHEV50s remain considerably more expensive through 2030. The average incremental ZEV cost premium (including both BEVs and PHEVs) decreases from about $6,400 in 2023 to about $3,400 in 2025, and reverses to a ZEV cost advantage in MY 2030 of nearly $2,000 for Scenarios 1 and 2, and over $900 for Scenario 3.

Vehicle purchase income tax credits are a successful incentive adopted by both the federal government and Colorado to help spur the ZEV market

Vehicle purchase income tax credits are a successful incentive adopted by both the federal government and Colorado to help spur the ZEV market. The current maximum federal tax credit is $7,500 and the current maximum Colorado tax credit is $5,000.[56] We assume, in our primary analysis below, that there will be a $2,000 Colorado tax credit in MY 2025 but no such tax credit in MY 2030, consistent with state legislation recently signed into law.[57] We also show results below for a second tax credit case where the current maximum federal tax credit of $7,500 and the MY 2025 Colorado tax credit of $2,000 are both extended through MY 2030. These tax credits would even further improve the economic attractiveness to Coloradans who purchase new ZEVs.[58]

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[56] Under current law, the federal tax credit of $7,500 applies until individual manufacturers reach a cumulative sales threshold of 200,000 vehicles. Recently, Tesla became the first manufacturer to reach this threshold, and General Motors is expected to reach the threshold in the near future. The current Colorado tax credit of $5,000 begins to phase down after 2019 under existing law.

[57] Bill HB19-1159, Modify Innovative Motor Vehicle Income Tax Credits, signed May 31, 2019. https://leg.colorado.gov/bills/hb19-1159

[58] Note that a Colorado tax credit would not affect the statewide economic impacts summarized in a later section since that would simply be a transfer payment within the state, but a federal tax credit would provide additional economic benefits to Colorado to the degree that Coloradans would buy a higher proportion of eligible vehicles relative to the nationwide average.

### New Gasoline Vehicle Initial Cost

New gasoline vehicles will have incrementally higher initial costs under the Colorado ACCP, beginning in MY 2022 when the CLEAR GHG standards are first implemented, because the GHG standards become more protective each year through MY 2025 relative to the GHG rollback in the baseline. These costs are in line with the costs that would occur if the federal standards did not get rolled back. Table 6 shows the projected incremental new gasoline vehicle costs relative to the baseline.[59]

## Table 6
## Projected Incremental Cost of New Gasoline Vehicles in Colorado

| SCENARIO | MY 2022 | MY 2023 | MY 2024 | MY 2025+ |
|---|---|---|---|---|
| 1 | $273 | $410 | $546 | $683 |
| 2 and 3 | $398 | $598 | $797 | $996 |

We generated these projected gasoline vehicle cost increases from the latest publicly released version of the U.S. Environmental Protection Agency's Optimization Model for reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) that was used by the agency in its Proposed Determination and Final Determination actions in late 2016 and early 2017.[60] A major difference between this report and the previous, pre-rollback EPA analysis is that our baseline reflects the fact that the proposed federal rollback of the GHG emissions standards would lead to two "compliance pools," beginning in MY 2021: one that only needs to meet the much less stringent nationwide GHG standards, and a second "Advanced Clean Car Program" pool comprised of new vehicles that must meet the increasingly more protective standards adopted by states with clean car programs. The step-by-step details of how we used EPA's OMEGA Model to generate the incremental costs of the CLEAR program are described in Appendix A.

Under Scenario 1, the average annual incremental cost of new gasoline vehicles is projected to rise from $273 in MY 2022 to $683 in MY 2025 and later. For Scenarios 2 and 3, the projected incremental costs increase to $398 in MY 2022 and $996 in MY 2025 and later. The assumption around averaging between gasoline vehicles and ZEVs to meet the CLEAR GHG standards in Scenario 1 account for the relatively lower costs as compared to Scenarios 2 and 3, which do not assume such averaging.

### Fuel Costs

Fuel costs are an important factor in the total cost of owning and operating a car. Since electric powertrains are much more efficient at converting grid electricity to vehicle propulsion than are gasoline powertrains, electric vehicles typically provide significant monetary fuel savings to their owners relative to conventional gasoline vehicles.

[59] Our May 2018 analysis of the CLEAR rulemaking showed incremental new gasoline vehicle costs higher than those projected in Scenario 1. This is because Scenario 1 assumes full use of GHG averaging with ZEVs, resulting in a gasoline vehicle fleet with less technology and fewer associated costs.

[60] U.S. EPA, Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, U.S. EPA, EPA-420-R-16-020 (November 2016), and Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, U.S. EPA, EPA-420-R-17-001 (January 2017). Note that the Trump Administration issued a revised Final Determination on April 2, 2018, but EPA chose not to present any new gasoline vehicle cost estimates in the revised Final Determination.

Fuel costs are a function of three inputs: fuel consumption per mile, vehicle miles traveled, and fuel price. EPA's OMEGA model provides the average gasoline vehicle fuel consumption values to meet the relevant GHG emissions standards. We assumed that on-road, or real-world, gasoline vehicle fuel consumption values are similar to the values that EPA provides on new vehicle window stickers and at fueleconomy.gov, i.e., about 25% higher than the fuel consumption values necessary to meet GHG and fuel economy standards.

For ZEVs, kilowatt-hours per mile (kWh/mi) projections were taken from the same ICCT study of battery and electric vehicle costs cited above.[61] ICCT estimates that a 50% BEV150/50% BEV250 mix had an average electricity consumption rate of about 0.36 kWh/mi in 2018, and projects that this will drop slightly to 0.33 kWh/mi in 2030. ICCT estimates that PHEV50s, when operating on grid electricity, had an average rate of 0.38 kWh/mi in 2018, and that this too will drop to about 0.35 kWh/mi in 2030. ICCT also estimates that PHEV50s would operate 69 percent of the time on battery electricity, and the remainder of the time on gasoline with an average fuel economy of 47 mpg in 2018, rising to 56 mpg in 2030.

Vehicle miles traveled (VMT) is also a key assumption, and has been the subject of considerable research and analysis by experts at the EPA, Department of Transportation (DOT), and the Department of Energy (DOE). Our VMT estimates were taken from EPA analyses for the Proposed and Final Determinations in 2016 and 2017. For a more detailed description of VMT issues, see Appendix A.

Another key VMT assumption relates to the rebound effect, the assumption that owners of more efficient vehicles will drive them more, and vice versa. We use a rebound effect of 10 percent for new, more efficient gasoline vehicles – the same value EPA and DOT used for multiple rulemakings and technology assessments from 2009 through 2016.[62] This means that a new gasoline vehicle owner will increase VMT by 1 percent for each 10 percent decrease in fuel cost per mile.

Because their maximum range is less and refueling time is longer than that of gasoline vehicles, BEV150s are assumed to travel 93 percent of the annual VMT of a comparable gasoline vehicle, and BEV250s are assumed to drive 97 percent of gasoline vehicle VMT. This slightly lower VMT from BEVs is offset by slightly higher VMT from gasoline vehicles such that overall fleet VMT levels are equal. PHEV50s are assumed to travel the same annual mileage since they can operate on gasoline when needed.

Gasoline and electricity price projections were taken from the 2019 Annual Energy Outlook (AEO) published by the DOE Energy Information Administration.[63] Our primary analysis uses its "Reference Case" gasoline prices of $3.00 per gallon in 2020, slowly rising to $3.66 in 2050, while our High Fuel Price sensitivity uses AEO's High Oil Price gasoline price projections of $4.09 per gallon in 2020, rising to $5.57 in 2050 (see Appendix E for AEO's year-by-year gasoline prices and Appendix B for the detailed outputs of the High Fuel Price sensitivity). These gasoline prices are "at the pump" and include federal and state fuel taxes. When estimating the economic impact in Colorado, gasoline excise taxes are excluded. When estimating the economic impact on the purchaser of a new vehicle, gasoline excise taxes are included.

All of our analyses use AEO's Reference Case electricity (for transportation) prices of $0.119/kWh in 2018 and $0.124/kWh in 2050. We think these AEO transportation electricity prices are a reasonable proxy for average charging costs, with some consumers paying more for third-party charging and some paying less or even nothing as some work places and commercial establishments offer subsidized or free charging.

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[61] Nic Lutsey and Michael Nicholas, Update on Electric Vehicle Costs in the United States Through 2030, The International Council on Clean Transportation, April 2, 2019. https://www.theicct.org/publications/update-US-2030-electric-vehicle-cost

[62] The authors believe that 10% rebound is a very conservative assumption and that the actual rebound effect is less than 10% and may in fact be negligible. See Vehicle Fuel-Economy and Air-Pollution Standards: A Literature Review of the Rebound Effect, Analysis Group (June 28, 2018). http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/ag_fuel_economy_rebound_effect_june_2 018.pdf See also Comments of the California Air Resources Board on the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, October 26, 2018.

[63] Annual Energy Outlook 2019, U.S. Energy Information Administration, January 24, 2019. https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf

### Insurance Costs

Other things being equal, more expensive vehicles cost more to insure. We adopt the methodology used by EPA in its Proposed and Final Determinations in 2016 and 2017 where incremental insurance costs are 1.9 percent of the initial incremental vehicle cost in the first year and decrease each year consistent with the vehicle's residual value. Incremental lifetime insurance costs are included in the summary tables on overall economic impacts.

### Maintenance Costs

BEVs have very different maintenance requirements than gasoline vehicles—they do not need routine gasoline-related maintenance (e.g., oil changes, air filters, engine coolant, spark plugs), but they do need battery pack-related maintenance. PHEVs, on the other hand, need both gasoline and battery pack maintenance.

Table 7 describes the differential maintenance costs assumed in this study (other maintenance, such as tire care and replacement, will be the same with ZEVs and gasoline vehicles). With one exception, these values are based on the maintenance cost assumptions developed by EPA in its Proposed and (initial) Final Determinations in 2016 and 2017.[64] The one exception is that we reduced EPA's PHEV maintenance costs related to the gasoline powertrain by one-half to account for the fact that PHEV50s are expected to operate well over half of the time on electricity.

## Table 7
## Projected Differential Maintenance Costs for Gasoline Vehicles and ZEVs

| ITEM | FREQUENCY (MILES) | COST | | |
|---|---|---|---|---|
| | | GASOLINE | BEV | PHEV |
| **OIL CHANGE/FILTER** | 7,500 | $42 | -- | $21 |
| **AIR FILTER** | 30,000 | $31 | -- | $16 |
| **ENGINE COOLANT** | 100,000 | $64 | -- | $32 |
| **SPARK PLUGS** | 105,000 | $94 | -- | $47 |
| **BATTERY CHECK** | 15,000 | -- | $42 | $42 |
| **BATTERY COOLANT** | 105,000 | -- | $127 | $127 |
| **LIFETIME COST (3% DISCOUNT RATE)** | **--** | **$1,218** | **$546** | **$1,156** |

Over a vehicle's lifetime, and using a 3% discount rate for future expenditures, the net maintenance savings relative to a gasoline vehicle are $672 for BEVs and $62 for PHEV50s.

### Sales Taxes

More expensive vehicles entail higher sales taxes. When we project the economic impact on individual consumers, we used the Colorado state sales tax of 2.9 percent. Sales tax is not included in the overall economic impacts on the Colorado economy, since taxes are a transfer payment and do not affect overall societal cost.

[64] EPA and NHTSA, Draft Technical Support Document: Proposed Rulemaking for 2017-2025 Light-duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (November 2011), page 2-229.

### Discounting

In the model year analyses, all future costs and savings are discounted at a 3% annual rate back to the year when the new vehicle is introduced into the fleet.

## Economic Impacts on Individual Colorado Consumers

### Buyers of New ZEVs

Table 8 summarizes the projected incremental economic impacts on consumers who purchase MY 2025 and 2030 ZEVs, with cash, under the Colorado ACCP scenarios relative to the baseline. The first six rows of Table 8 summarize the projected incremental vehicle, insurance, fuel, and maintenance costs/savings that allow a computation of the net lifetime cost/savings impact, as well as a payback period for those consumers who purchase with cash, for the primary analysis case with AEO Reference Case fuel prices and a $2,000 Colorado tax credit for MY 2025 only.

Table 8 also summarizes the net lifetime costs/savings and payback periods for two additional cases: 1) the High Fuel Price case, which increases lifetime fuel savings by $5,000-$7,000 relative to the primary analysis across the various technology types and model years, and 2) an alternative tax credit case where we assume total tax credits of $9,500 for both BEVs and PHEVs, which effectively reduces ZEV purchase costs by $7,500 in MY 2025 (because the $2,000 Colorado tax credit is already included in the primary analysis for MY 2025) and $9,500 in MY 2030 relative to the primary analysis.

### Table 8

### Key Consumer Cost (Savings) Metrics for MY 2025/2030 ZEVs Purchase with Cash Under Colorado Advanced Clean Car Program

| METRIC | MY 2025 | | | MY 2030 | | |
|---|---|---|---|---|---|---|
| | BEV150 | BEV250 | PHEV50 | BEV150 | BEV250 | PHEV50 |
| **VEHICLE**** | $(1,184) | $3,476 | $6,171 | $(4,349) | $(1,260) | $7,498 |
| **INSURANCE** | $182 | $1,222 | $1,823 | $(970) | $(281) | $1,673 |
| **FUEL** | $(6,895) | $(6,901) | $(5,417) | $(7,194) | $(7,557) | $(6,132) |
| **MAINTENANCE** | $(672) | $(672) | $(63) | $(672) | $(672) | $(63) |
| **NET LIFETIME** | **$(8,568)** | **$(2,876)** | **$2,514** | **(13,185)** | **$(9,770)** | **$2,976** |
| **PAYBACK** | IMMEDIATE | 5 YEARS | NA | IMMEDIATE | IMMEDIATE | NA |
| **HIGH FUEL PRICE SENSITIVITY** | | | | | | |
| **NET LIFETIME** | **(14,325)** | **$(8,879)** | **$(2,256)** | **$(19,030)** | **$(15,867)** | **$(1,974)** |
| **PAYBACK** | IMMEDIATE | 3 YEARS | 8 YEARS | IMMEDIATE | IMMEDIATE | 9 YEARS |
| **TAX CREDITS OF $9,500 IN BOTH MY 2025 AND MY 2030** | | | | | | |
| **NET LIFETIME** | $(16,068) | $(10,376) | $(4,986) | $(22,685) | $(19,270) | $(6,524) |
| **PAYBACK** | IMMEDIATE | IMMEDIATE | IMMEDIATE | IMMEDIATE | IMMEDIATE | IMMEDIATE |

*PARENTHESES INDICATE A SAVINGS, NOT A COST, COMPARED TO THE BASELINE SCENARIO AND THE VALUES REFLECT A 3% ANNUAL DISCOUNT RATE
**THESE VEHICLE COSTS INCLUDE SALES TAXES, THE COST OF A HOME CHARGER, AND REFLECT A $2,000 COLORADO TAX CREDIT FOR MY 2025

The results in Table 8 vary across vehicle type and model year.

- MY 2025 BEV150s are nearly $1,200 less expensive to purchase than comparable MY 2025 gasoline vehicles, as the $2,000 tax credit more than offsets a slightly higher non-tax credit incremental vehicle cost. These vehicles therefore would have an immediate consumer payback under the primary analysis. They would save nearly $7,000 in lifetime fuel costs and yield a net lifetime savings of $8,600. The high fuel price and higher tax credit cases would each substantially increase the net lifetime savings.
- MY 2030 BEV150s are economically favorable as they have crossed the cost parity point with gasoline vehicles, providing immediate payback even with no tax credits, making them cheaper to purchase, insure, fuel, and maintain. MY 2030 BEV150s are projected to offer lifetime net savings of over $13,000 in the primary analysis. Either higher fuel prices or higher tax credits could raise the lifetime savings to approximately $20,000.
- MY 2025 BEV250s, with a $2,000 tax credit, are projected to cost about $3,500 more to purchase than a MY2025 gasoline vehicle and require over $1,200 more in lifetime insurance. However, these vehicles will save $7,600 in lower lifetime fuel and maintenance expenditures and therefore yield a net lifetime savings of $2,900 in the primary analysis. Payback takes 5 years. Higher fuel prices would reduce payback to 3 years, and higher tax credits would yield immediate payback.
- MY 2030 BEV250s are also projected to be economically attractive as they too have crossed the cost parity point with gasoline vehicles, allowing immediate payback even in the absence of any tax credits. Consumers save money across the board, and the total net lifetime consumer savings are projected to be $9,800, without tax credits. Either higher fuel prices or tax credits would raise total savings to between $15,000 and $20,000.
- MY 2025 PHEV50s, with a $2,000 tax credit, are projected to cost over $6,000 more than gasoline vehicle counterparts, as well as a lifetime incremental insurance cost of over $1,800. Lifetime fuel savings is over $5,400, but this is insufficient to offset the higher vehicle and insurance costs. MY 2025 PHEV50s have a net lifetime consumer cost of about $2,500 and, therefore, do not achieve payback under the primary analysis. However, higher fuel prices would yield net lifetime savings of over $2,200 and a payback period of 8 years. An additional $7,500 tax credit in MY 2025 would yield immediate payback and increase net lifetime savings to $5,000.
- MY 2030 PHEV50s are more costly in the primary analysis than MY 2025 PHEV50s due to the lack of any tax credits. They have an incremental vehicle cost of $7,500 and a higher insurance cost of nearly $1,700. They accrue fuel and maintenance savings of about $6,100, yielding a net lifetime cost of nearly $3,000. However, higher fuel prices would yield a net lifetime savings of about $2,000 with a payback period of 9 years, and higher tax credits would yield immediate payback and a net lifetime savings of about $6,500.

Table 9 shows the monthly balance sheets for MY 2025 and 2030 BEVs (a 50/50 mix of BEV150s and BEV250s) and PHEV50s purchased with a 6-year loan, at an interest rate of 4.25 percent.[65]

[65] The average length of an auto loan is nearly 6 years. Bloomberg, U.S. Average Auto Loan Length Balloons to All-Time High (July 5, 2017). https://www.bloomberg.com/news/articles/2017-07-05/u-s-average-auto-loan-length-balloons-to-all-time-high
Nearly 70 percent of auto loans are 5 years or longer. Consumer Financial Protection Bureau, Growth in Longer-Term Auto Loans, Quarterly Consumer Credit Trends (November 2017).
https://files.consumerfinance.gov/f/documents/cfpb_consumer-credit-trends_longer-term-auto-loans_2017Q2.pdf
The average interest rate for a 5+ year loan is 4.25 percent. EPA, Proposed Determination (2017).

## Table 9

## Consumer Monthly Loan Cash Flow Impacts for MY 2025/2030 ZEVs Under Colorado Advanced Clean Car Program

| | MY 2025 | | MY 2030 | |
|---|---|---|---|---|
| | BEVS | PHEV50 | BEVS | PHEV50 |
| INCREMENTAL MONTHLY PAYMENT** + INSURANCE COST | $(17) | $69 | $(48) | $128 |
| INCREMENTAL MONTHLY FUEL + MAINTENANCE SAVINGS | $(77) | $(58) | $(83) | $(63) |
| NET MONTHLY COST OR (SAVINGS) | $(94) | $11 | $(131) | $65 |
| HIGH FUEL PRICE SENSITIVITY | | | | |
| NET MONTHLY COST OR (SAVINGS) | $(160) | $(39) | $(199) | $14 |
| TAX CREDITS OF $9,500 IN BOTH MY 2025 AND MY 2030 | | | | |
| NET MONTHLY COST OR (SAVINGS) | $(357) | $(253) | $(465) | $(269) |

*PARENTHESES INDICATE A SAVINGS, NOT A COST, AND THE VALUES REFLECT A 3% ANNUAL DISCOUNT RATE

** THE MONTHLY PAYMENT REFLECTS A $2,000 COLORADO TAX CREDIT FOR MY 2025

Consumers who purchase MY 2025 BEVs with a 6-year loan are projected to realize an immediate positive cash flow of $94 per month, due to savings in both monthly payments and monthly fuel/maintenance. Five years later, the cash flow savings for MY 2030 BEV purchasers is projected to improve to $131 per month. Higher fuel prices or higher tax credits would substantially improve the monthly cash flow.

Purchasers of PHEV50s with a 6-year loan are projected to have a negative cash flow of $11 in MY 2025 and $65 in MY 2030, as the higher monthly payments and insurance costs exceed the monthly fuel and maintenance savings. Under higher fuel prices, MY 2025 PHEV50 owners would reverse to a positive cash flow (aided by the $2,000 vehicle tax credit), but MY 2030 PHEV50 owners would still have a small negative cash flow impact of $14 per month. A $9,500 tax credit would allow a MY 2025 PHEV50 owner to realize a positive monthly cash flow of $253, increasing to $269 for a MY 2030 PHEV50.

Tables 8 and 9 illustrate that BEVs are projected to be much more economically attractive than PHEV50s in the 2025-2030 timeframe, because PHEVs retain a gasoline engine and BEVs benefit, to a much greater degree, from the expectation that battery costs will continue to rapidly decline. As discussed above, manufacturers would receive more credits under the Colorado ZEV program for selling BEVs than for selling PHEVs. Also, consumers particularly concerned about electric vehicle range will continue to have access to advanced gasoline vehicles, as well as the potential availability of even longer range (i.e., beyond 250 miles) BEVs in the future. Since the ZEV program does not mandate any PHEVs, it is possible that these multiple factors will move the future ZEV market exclusively toward BEVs. Nevertheless, PHEVs do represent a partial compliance option for automakers for some applications. While there may be some demand from consumers who do not have easy access to charging or want a PHEV for other reasons, it is impossible to predict how the future market will evolve. While the most economic pathway would be to assume no PHEVs, we conservatively project that PHEVs will account for about 20 percent of total ZEV sales in Colorado under all ZEV scenarios. Given the much more attractive BEV price projections and much greater ZEV program credits for BEVs, the authors believe that our PHEV sales projections are likely high and therefore conservative.

Figure 2 converts the data for net lifetime costs/savings from Table 8 above for BEV150s, BEV250s, and PHEV50s to a single value that represents the projected net lifetime savings for the average ZEV purchased in Colorado in 2025 and 2030. Based on our assumed total (baseline plus incremental sales) ZEV model mix shares of 40% BEV150, 40% BEV250, and 20% PHEV50, the PHEV share of incremental ZEV sales under the ZEV program ranges from 7 to 19 percent across the three scenarios.

## Figure 2
## Buyers of New ZEVs in 2025 and 2030 Will Realize Net Lifetime Savings ($ Per Vehicle)

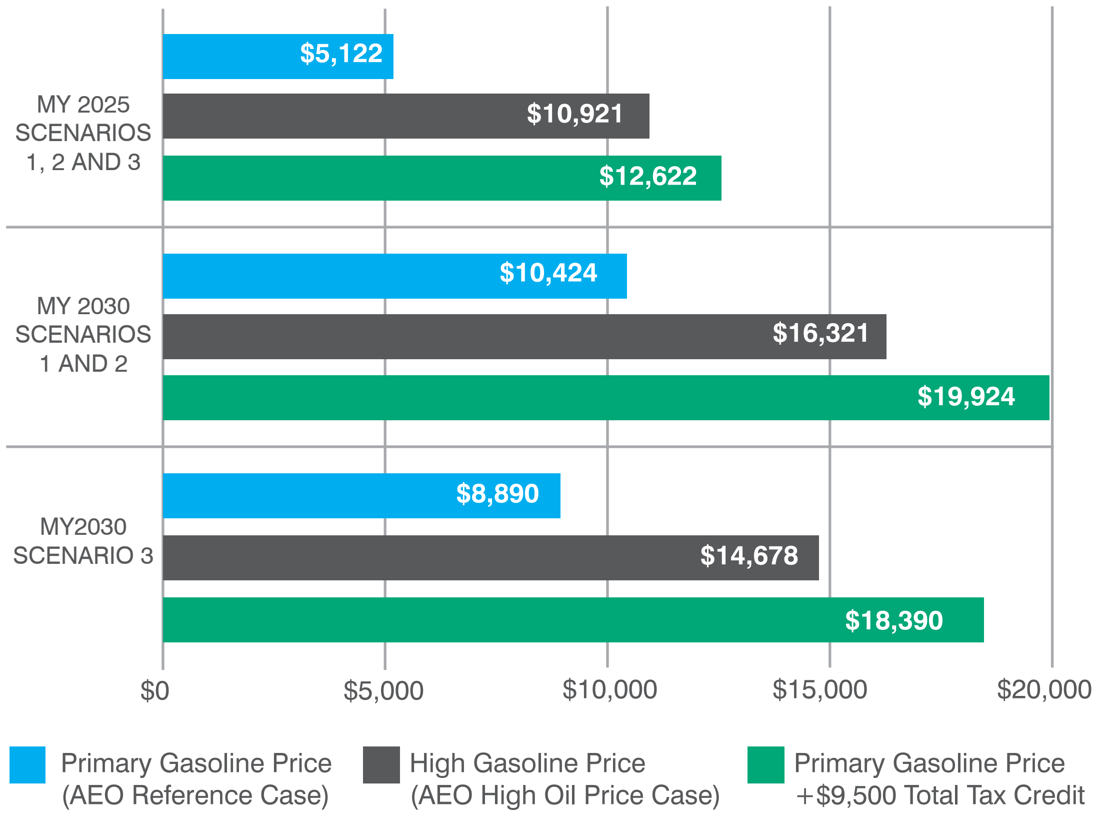


Figure 2 shows that, on average, new ZEVs bought in MY 2025 and 2030 are projected to yield net lifetime savings for their owners relative to the average vehicles in the baseline. In the primary analysis for MY 2025, the net lifetime savings per vehicle will be over $5,000 under all scenarios as lifetime fuel savings more than offset the higher average cost of purchasing a new ZEV. The net lifetime savings for a MY 2030 ZEV increases to about $10,000 (a little more under Scenarios 1 and 2, and a little less under Scenario 3, as PHEVs account for a greater fraction of the incremental ZEV sales under Scenario 3) in the primary analysis as the average new ZEV is projected to be a little less expensive to purchase, relative to the baseline gasoline vehicle, and this savings adds to the substantial fuel savings. With higher gasoline prices, the net lifetime savings increase to nearly $11,000 in MY 2025 and to about $15,000 in MY 2030. The combination of the primary gasoline price and higher tax credits yields net lifetime savings of nearly $13,000 in MY 2025 and almost $20,000 in MY 2030.

### Buyers of New Gasoline Vehicles

Based on the above economic assumptions and inputs, Table 10 summarizes the projected incremental economic impacts of the Colorado ACCP on individual consumers who buy, with cash, a new gasoline vehicle in MY 2025 or MY 2030 for both the primary analysis and the High Fuel Price sensitivity.

Under Scenario 1 for the primary analysis, an average MY 2025 gasoline vehicle is projected to cost nearly $900 more to purchase and insure. These upfront gasoline vehicle costs of a combined ACCP with averaging are lower than those associated with CLEAR alone. This is because the inclusion of ZEVs in the combined program allows manufacturers to moderate gasoline vehicles emissions performance. If the consumer owns the vehicle over its full lifetime, they will save nearly $2,800 in lower gasoline expenditures leading to a net lifetime consumer savings of over $1,900. Of course, many consumers do not keep their vehicles for the full vehicle lifetime. But, the payback period for Scenario 1 is just 3.5 years, which means that the vehicle owner has reached the break-even point where the cumulative fuel savings has offset the higher upfront investment at that time, and continued ownership after 3.5 years will yield net savings.

Under Scenarios 2 and 3, the impacts under the primary analysis are larger: the combined average MY 2025 vehicle cost and insurance would increase by nearly $1,300. The upfront gasoline vehicle costs of a combined ACCP program without averaging are similar to those of the existing CLEAR program alone. This is because, in these scenarios, manufacturers do not moderate gasoline vehicle emissions performance due to greater ZEV sales. Fuel savings would increase to nearly $3,800, and therefore the net lifetime consumer savings would increase to over $2,500. Because of the higher upfront costs, the payback period increases slightly to 3.8 years.

## Table 10
## Key Consumer Cost (Savings) Metrics for MY 2025 Gasoline Vehicle Purchased With Cash Under Colorado Advanced Clean Car Program ($ Per Vehicle)

| METRIC | SCENARIO 1 | SCENARIOS 2 AND 3 |
|---|---|---|
| **VEHICLE**** | $703 | $1,025 |
| **INSURANCE** | $161 | $235 |
| **FUEL** | $(2,782) | $(3,772) |
| **MAINTENANCE** | $0 | $0 |
| **NET LIFETIME** | $(1,918) | $(2,512) |
| **PAYBACK** | 3.5 YEARS | 3.8 YEARS |
| | HIGH FUEL PRICE SENSITIVITY | |
| **NET LIFETIME** | $(3,335) | $(4,434) |
| **PAYBACK** | 2.2 YEARS | 2.4 YEARS |

*PARENTHESES INDICATE A SAVINGS, NOT A COST, AND THE VALUES REFLECT A 3% ANNUAL DISCOUNT RATE
**THESE VEHICLE COSTS INCLUDE SALES TAXES AND ARE SLIGHTLY HIGHER THAN IN TABLE 6

The only change due to the High Fuel Price sensitivity is that fuel savings are $1,400-1,900 higher due to the higher assumed fuel prices. This increases the net lifetime savings to over $3,300 under Scenario 1 (with a payback of 2.2 years) and to over $4,400 for Scenarios 2 and 3 (with a payback period of 2.4 years).

The results for MY 2030 are essentially the same as the results shown in Table 8 for MY 2025, as the only variable that changes is that gasoline prices are projected to be very slightly higher over the lifetime of a MY 2030 vehicle, which would very slightly improve the net consumer savings and payback period.

While the cash/payback period approach is one way to summarize the economic impacts on individual consumers, most new vehicle purchases today are made with loans (in this respect, leases are also more similar to a loan purchase than a cash purchase). Since the payback periods in Table 10 of 2-4 years are well below the average length of automobile loans today (in 2017, the length of the average car loan was 69.3 months and about two-thirds of auto loans were 5 years or longer)[66], the typical consumer who buys with a loan would immediately benefit from day one with an improved overall cash flow.

Table 11 shows that the typical consumer who buys a new gasoline vehicle with a 6-year loan, at an interest rate of 4.25 percent, would immediately realize monthly fuel savings $7 to $9 more than the increase in monthly loan payments (due to the more expensive vehicle) and insurance costs, so would have an immediate positive cash flow under the primary analysis. Under higher fuel prices, the positive monthly cash flow would increase to $18-23 per month. Again, the results for buying a MY 2030 vehicle under either the primary analysis or the high fuel price sensitivity would be similar.

### Table 11

### Monthly Loan Payments and Fuel Savings for MY 2025 Gasoline Vehicle Under Colorado Advanced Clean Car Program

| | SCENARIO 1 | SCENARIO 2 AND 3 |
|---|---|---|
| INCREMENTAL MONTHLY PAYMENT + INSURANCE COST | $12 | $18 |
| INCREMENTAL MONTHLY FUEL COST OR (SAVINGS) | $(20) | $(27) |
| NET MONTHLY COST OR (SAVINGS) | $(7) | $(9) |
| HIGH FUEL PRICE SENSITIVITY | | |
| NET MONTHLY COST OR (SAVINGS) | $(18) | $(23) |

*PARENTHESES INDICATE A SAVINGS, NOT A COST, AND THE VALUES REFLECT A 3% ANNUAL DISCOUNT RATE

## Aggregate Economic Impacts on the Overall Colorado Fleet

In this section we project the aggregate statewide impacts of the Colorado Advanced Clean Car Program (ACCP) over the period 2025 through 2050 relative to the baseline scenario for both the primary analysis and the High Fuel Price sensitivity. Unlike the previous sections which analyzed the economic impacts on individual consumers over the lifetimes of gasoline or ZEV vehicles purchased in MY 2025 or MY 2030, this is a "calendar analysis" which projects the statewide economic impacts that will occur in specific calendar years in the future, i.e., it accounts for the expenditures and savings in the actual years in which they are realized. It also combines the incremental impacts of both new gasoline and new ZEV vehicles that would be required under the Colorado ACCP. We assumed that 60 percent of new vehicles would be purchased on credit (a 6-year loan at 4.25% interest), 30 percent would be leased (3 years), and the remaining 10 percent would be purchased with cash.

[66] U.S. Average Auto Loan Length Balloons to All-Time High, Bloomberg Businessweek, July 5, 2017. https://www.bloomberg.com/news/articles/2017-07-05/u-s-average-auto-loan-length-balloons-to-all-time-high
Growth in Longer-Term Auto Loans, Consumer Financial Protection Bureau, November 2017. https://files.consumerfinance.gov/f/documents/cfpb_consumer-credit-trends_longer-term-auto-loans_2017Q2.pdf

Table 12 shows the projected statewide economic impacts under each of the three scenarios for both the primary analysis (with AEO Reference Case gasoline price projections) and the High Fuel Price sensitivity (using the AEO High Oil Price gasoline price projections). Under the High Fuel Price sensitivity, the Vehicle and Maintenance and Insurance columns are the same, so for simplicity we only show the Total column (the reader can "back out" the Fuel values under the High Fuel Price sensitivity by subtracting Vehicle and Maintenance and Insurance values from the Total for the High Fuel Price sensitivity).

## Table 12

## Projected Annual Statewide Economic Impacts Under Colorado Advanced Clean Car Program ($ Millions)

| CALENDAR YEAR | VEHICLE | FUEL | MAINTENANCE AND INSURANCE | TOTAL (PRIMARY) | TOTAL (HIGH FUEL PRICE) |
|---|---|---|---|---|---|
| | | | SCENARIO 1 | | |
| **2025** | $181 | $(209) | $14 | $(15) | $(168) |
| **2030** | $203 | $(575) | $25 | $(347) | $(730) |
| **2040** | $202 | $(1,052) | $42 | $(809) | $(1,465) |
| **2050** | $227 | $(1,294) | $50 | $(1,018) | $(1,838) |
| | | | SCENARIO 2 | | |
| **2025** | $254 | $(234) | $20 | $40 | $(131) |
| **2030** | $295 | $(705) | $38 | $(372) | $(835) |
| **2040** | $304 | $(1,335) | $64 | $(967) | $(1,786) |
| **2050** | $341 | $(1,649) | $78 | $(1,230) | $(2,261) |
| | | | SCENARIO 3 | | |
| **2025** | $254 | $(234) | $20 | $40 | $(131) |
| **2030** | $275 | $(754) | $29 | $(449) | $(1,009) |
| **2040** | $123 | $(1,722) | $(5) | $(1,604) | $(3,014) |
| **2050** | $138 | $(2,308) | $(33) | $(2,204) | $(4,123) |

*PARENTHESES INDICATE A SAVINGS, NOT A COST

As shown in Table 12, the net economic impact in Scenario 1 under both the primary analysis and the High Fuel Price sensitivity are positive beginning in 2025, and grow significantly over time. In Scenarios 2 and 3 the higher vehicle costs slightly outweigh the fuel savings in 2025 under the primary analysis but turn to savings in 2030 and grow significantly thereafter. In the primary analysis, the statewide benefits are more than $300 million annually in 2030, grow to between $800 million and $1.6 billion in 2040, and as high as $2.2 billion each year in 2050. The benefits are greater under higher fuel prices, of course, with aggregate annual benefits starting at $130 million in 2025 and reaching more than $4 billion in 2050 under the post-2025 ZEV growth Scenario 3. Clearly the dominant statewide economic impact is fuel savings. Under the primary analysis, while higher vehicle costs either outweigh or just offset fuel savings in 2025, by 2030 fuel savings are 2-3 times greater than incremental vehicle costs, and by 2050 fuel savings are 5 to 16 times the incremental vehicle costs. The ratio of fuel savings to vehicle costs are even greater with higher fuel prices.

Under Scenarios 1 and 2, annual incremental vehicle costs are fairly constant. Absolute vehicle costs are higher under Scenario 2 than under Scenario 1, since we assume no GHG averaging under Scenario 2, which requires new gasoline vehicles to have more technology to meet the GHG standards.

Incremental vehicle costs under Scenario 3 are equal to those under Scenario 2 in 2025, but decrease beginning in 2030 due to lower ZEV costs over time. Post-2025 fuel savings are significantly higher under Scenario 3 due to the much higher ZEV sales.

## Greenhouse Gas and Criteria Emissions Impacts

Should Colorado adopt a ZEV program to complement the CLEAR standards, the combined program has the potential to offer the state GHG emissions reductions of up to 3.2 million tons in 2030 and 7.6 million tons in 2040, depending on the ZEV scenario. The state would also see a significant reduction in health-harming criteria pollution emissions.

In order to estimate the impacts of the three Colorado ZEV scenarios on greenhouse gas and criteria emissions, we estimated the upstream and direct emissions from conventional and ZEV vehicles in Colorado. We used many of the input factors and methodology contained in EPA's Inventory, Costs and Benefits Tool (ICBT) model. We scaled vehicle sales to those in Colorado, as described above in the section on economic impacts, as well as some upstream emissions factors for natural gas and gasoline.

### Conventional Vehicles

Our analysis used CO2 tailpipe emission rates for cars and light trucks as measured over the EPA test cycles from EPA's ICBT model.[67] Onroad CO2 emissions are estimated to be 25 percent higher than the values measured over the EPA test cycles due to differences in driving patterns, fuel and environmental factors (ambient temperature, wind, road conditions, etc.). We assume a rebound effect of 10 percent consistent with the 2016 and 2017 EPA analyses for the light-duty GHG emissions standards. If the rebound effect is indeed lower, the benefits would all be slightly higher. Vehicular emission factors for criteria pollutants and the two other GHGs were also taken from EPA's analysis for the Proposed and Final Determination.

We based our criteria emissions factors on Colorado's CLEAR standards. The CLEAR program sets standards for the emission of non-methane organic gases plus nitrogen oxides (NMOG+NOx), carbon monoxide (CO), formaldehyde and fine particulate matter (PM) from cars and light trucks. EPA has established very similar NMOG+NOx and PM standards under their Tier 3 program and currently automakers comply with both sets of standards with the same fleet. Therefore, we assume that the CLEAR and the EPA Tier 3 standards for NMOG+NOx and PM are equivalent.

We used upstream gasoline emissions estimates developed by NHTSA in its 2018 proposal, which are based on DOE's GREET model.[68] We modified NHTSA's assumptions concerning the fractions of crude oil production, crude oil transportation, gasoline refining, and gasoline distribution, which occurred domestically to reflect the situation existing in Colorado.

Energy Analysts International (EAI) recently found that 28 percent of the gasoline consumed in Colorado is produced by the Suncor refinery in the Denver area.[69] The remainder is imported from Kansas, Texas, and Wyoming, primarily by pipeline. The availability of inexpensive pipeline transportation makes the Colorado market very competitive. The cost of gasoline production for each refiner depends on a large number of factors, such as crude oil source and quality, the capacity of gasoline producing units, available markets for non-gasoline products, and more. Projecting how each refiner would respond to a reduction in Colorado gasoline demand is beyond the scope of this study. Therefore, we have projected that each refiner's share of the Colorado market would remain constant as gasoline consumption declines. Thus, we assume 28 percent of the upstream refinery emissions in our estimate of criteria pollutant emissions would occur in Colorado. We used total upstream emissions factors for all GHG emissions.

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[67] EPA, Optimization Model for reducing Emissions of Greenhouse Gases from Automobiles (OMEGA), v1.4.56, "OMEGA pre-processors, Technology and Benefit-Cost Analysis files and OMEGA runs used in the Proposed Determination analysis, Technology and Benefit-Cost Analysis Files." https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases

[68] DOT (July 2018), Preliminary Regulatory Impact Analysis, The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model \ Year 2021 –2026 Passenger Cars and Light Trucks, Page 1067.

[69] Energy Analysts International, Denver Metro/North Fuel Supply Impacts and Compliance Costs for Refiners and Consumers, March 27, 2019.

### ZEV Vehicles

Our analysis also estimates tailpipe and upstream GHG and criteria emissions for ZEVs. BEVs have zero criteria tailpipe emissions, as do PHEVs while operating on electricity. While operating on gasoline, we assume PHEVs to have criteria emissions factors consistent with those developed for conventional vehicles explained above.

To determine GHG emissions from ZEVs, we began with ICCT's estimates of electricity usage by BEVs and PHEVs.[70] Based on these estimates,[71] and assuming a 50/50 BEV150/BEV250 sales mix, we used an average electricity usage for BEVs of 0.36 kW-hr/mi in 2018 and 0.33 kW-hr/mi in 2030. We also used ICCT's estimates that PHEV50 electricity usage averaged 0.38 kW-hr/mi in 2018 and by 2030 that average electricity usage will decrease to 0.35 kW-hr/mi. We assumed that electricity usage between 2018 and 2030 changed linearly between the above estimates, remaining constant after 2030.

Department of Energy data shows Colorado produces more energy than the state consumes, so we assumed that additional electrical energy needed to power ZEVs would be generated in state.[72] We used data provided by Western Resource Advocates (WRA) on the current and projected future electricity production levels and CO2 emissions for individual power plants in Colorado.[73] In 2018, 46 percent of Colorado's electricity was generated from coal, 30 percent by natural gas, and 24 percent by renewables, including hydroelectric. But that mix is changing rapidly. Coal as a source of electrical power in Colorado is decreasing, especially in the Front Range, while use of natural gas and renewables are both on the rise. To assess how Colorado may meet the incremental energy demand associated with increased ZEVs[74], we evaluated the rate of increase in both natural gas and renewables usage and found that roughly one fourth of the increase in power generation came from natural gas and three fourths from renewables. Accordingly, we assumed that 25 percent of incremental energy demand associated with ZEVs in Colorado would be met by natural gas and 75 percent would come from renewables. We maintained this projection for 2040, though it is possible that the portion of incremental electricity from renewable sources used to power ZEVs may grow even higher. Appendix C includes a sensitivity analysis where 100 percent of the added electrical power demand to fuel ZEVs comes from renewable sources. As compared with our primary analysis, this change in the source of ZEV power would not affect any of the economic impacts, but would notably improve the emissions and health impacts under Scenario 3.

We obtained emission rates for natural gas fired power plants from EPA's AP-42 Emission Factor document.[75] We obtained estimates of emissions associated with producing and processing natural gas from DOE's GREET model. We assumed power line losses are 6.5 percent of delivered electricity per EPA's 2016 and 2017 Proposed and Final Determinations. We assumed that emissions from renewable sources were zero, which reduced the natural gas emission rates by 75 percent when averaged with those from renewable sources. For upstream emissions factors for gasoline and electricity see Appendix A.

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[70] Nic Lutsey and Michael Nicholas (April 2019). Update on Electric Vehicle Costs in the United States Through 2030, The International Council on Clean Transportation. https://www.theicct.org/publications/update-US-2030-electric-vehicle-cost

[71] Lutsey determined that the split of cars, crossover, and SUVs was 41%, 26%, and 22%, respectively. These percentages do not include the 11% of vehicles that EPA and NHTSA assume are not likely to have BEV counterparts.

[72] U.S. Energy Information Administration, Colorado, State Profile and Energy Estimates. https://www.eia.gov/state/?sid=CO (accessed May 4, 2019).

[73] Stacy Tellinghuisen and Gwen Farnsworth, Anticipated Mix of New Electric Generating Resources in Colorado, Western Resource Advocates (June 2019), attached as Exhibit 1 to this report

[74] We base our analysis on the incremental electricity needed to fuel the additional ZEVs consistent with the methodology used by the U.S. Environmental Protection Agency in its 2012 rulemaking that established the MY 2017-2025 light-duty vehicle GHG emissions standards. See 77 Federal Register 62821 (October 15, 2012).

[75] EPA, Emissions Factors, AP-42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, Section 1.4: Natural Gas Combustion, Supplement D (July 1998). https://www3.epa.gov/ttn/chief/ap42/ch01/index.html
Emission rates for the GHGs were taken from Table 1.4-2, which is generic to all natural gas fired units. These emission rates were: 120,000 for CO2, 2.3 for methane and 0.644 for N2O, all in pounds per million standard cubic feet.

### Impacts of Colorado ACCP on Greenhouse Gas and Criteria Emissions

Our baseline scenario assumes that the Trump Administration will rescind the current 2021-2025 GHG standards, holding the standards constant beginning in 2020. This would increase CO2 emissions from light-duty vehicles by 27 percent in 2025.[76] Table 13 below shows the vehicle and upstream GHG emissions attributable to vehicle use in Colorado under the baseline scenario. It also shows estimated emissions under the three scenarios. Vehicle tailpipes are responsible for the majority of the lifecycle GHG emissions.

## Table 13
## Vehicle GHG Emissions in Colorado Under the Baseline and Advanced Clean Car Program (Million Metric Tons CO2e Per Year)

| CALENDAR YEAR | VEHICLE | UPSTREAM ELECTRICITY | UPSTREAM GASOLINE | TOTAL |
|---|---|---|---|---|
| | | **BASELINE** | | |
| **2030** | 16.3 | 0.06 | 5.1 | 21.4 |
| **2040** | 16.7 | 0.09 | 5.2 | 22 |
| **2050** | 18.5 | 0.10 | 5.7 | 24.3 |
| | | **SCENARIO 1** | | |
| **2030** | 14.6 | 0.10 | 4.5 | 19.2 |
| **2040** | 13.8 | 0.15 | 4.3 | 18.3 |
| **2050** | 15 | 0.18 | 4.7 | 19.9 |
| | | **SCENARIO 2** | | |
| **2030** | 14.2 | 0.10 | 4.4 | 18.7 |
| **2040** | 13.1 | 0.15 | 4.1 | 17.3 |
| **2050** | 14.1 | 0.18 | 4.4 | 18.7 |
| | | **SCENARIO 3** | | |
| **2030** | 13.8 | 0.17 | 4.3 | 18.3 |
| **2040** | 10.5 | 0.62 | 3.3 | 14.4 |
| **2050** | 10.2 | 0.88 | 3.2 | 14.3 |

Table 14 summarizes the annual GHG emissions reductions potential associated with the three Colorado ACCP scenarios, relative to the baseline where standards are held at 2020 levels. Should Colorado adopt a ZEV program to compliment the CLEAR standards, the state stands to reduce GHG emissions (carbon dioxide equivalent (CO2e)) by a total of 3.2 million tons annually in 2030 and nearly 7.6 million tons each year in 2040, under Scenario 3. That would be equivalent to taking more than 600,000 cars off of Colorado's roads in 2030 and removing nearly 1.6 million cars in 2040.[77]

Even under Scenario 1, Colorado could reduce GHG emissions by more than 2 million tons annually in 2030 and nearly 4 million tons per year in 2040 – and that assumes ZEV sales would plateau off in 2025, which is unlikely.

As mentioned above, these GHG emission reductions are achieved with a net cost savings, making the cost per ton of reductions negative. Our analysis uses EPA's CO-Benefits Risk Assessment (COBRA) model to calculate the economic value of the GHG reductions. Our analysis estimates that the greenhouse gas reductions from a Colorado ACCP program could generate $47-52 million dollars annually in 2025 and $317-712 million dollars annually in 2050, in reduced climate damage, depending on the scenario.[78]

[77] EPA, Greenhouse Gas Equivalencies Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

[78] NYU's Institute for Policy Integrity (IPI) has separately monetized the benefits of Scenario 3 using a methodology similar to the one we employed, though using the social cost of CO2, CH4, and NO2 as opposed to converting these emissions to CO2e and monetizing based only on the social cost of CO2. Peter H. Howard and Jason A. Schwartz, Expert Report of Dr. Peter H. Howard, Ph.D. and Jason A. Schwartz, J.D., (July 2019). Both EDF and IPI estimates show the program will deliver billions of dollars in climate benefits.

## Table 14

## GHG Emissions Reductions in Colorado Under Advanced Clean Car Program (Million Metric Tons CO2e Per Year) and Associated Monetized Value ($ Millions Per Year)

| CALENDAR YEAR | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 |
|---|---|---|---|
| **2025** | 0.9 | 1.0 | 1.0 |
| **2030** | 2.2 | 2.7 | 3.2 |
| **2035** | 3.2 | 4.0 | 5.6 |
| **2040** | 3.8 | 4.8 | 7.6 |
| **2045** | 4.1 | 5.3 | 9.0 |
| **2050** | 4.5 | 5.7 | 10.0 |
| MONETIZED VALUE ($ MILLIONS PER YEAR) | | | |
| **2025** | $47 | $52 | $52 |
| **2030** | $131 | $159 | $186 |
| **2035** | $206 | $257 | $362 |
| **2040** | $267 | $337 | $542 |
| **2045** | $295 | $374 | $642 |
| **2050** | $317 | $403 | $712 |

To illustrate the impacts a combined CLEAR and ZEV program would have on criteria emissions in Colorado, we show NOx emissions from all passenger vehicles in Colorado for the baseline and each of the three scenarios in Table 15 below. As above, we show the individual contributions of vehicles, power plants and gasoline production on NOx emissions separately. Vehicles are responsible for the majority of NOx emissions but upstream gasoline production is also responsible for a significant portion. NOx gases react to form smog and acid rain as well as being central to the formation of fine particles (PM2.5) and ground level ozone, both of which are associated with adverse health effects. Similar data for volatile organic compounds (VOC), fine particulates (PM2.5) and sulfur oxides (SOx) emissions can be found in Appendix A.

## Table 15

## Passenger Vehicle NOx Emissions in Colorado Under Baseline and Advanced Clean Car Program (Metric Tons Per Year)

| CALENDAR YEAR | VEHICLE | UPSTREAM ELECTRICITY | UPSTREAM GASOLINE | TOTAL |
|---|---|---|---|---|
| | | BASELINE | | |
| **2030** | 4,424 | 62 | 1,839 | 6,324 |
| **2040** | 3,438 | 88 | 1,888 | 5,415 |
| **2050** | 3,308 | 102 | 2,084 | 5,494 |
| | | SCENARIO 1 | | |
| **2030** | 4,375 | 97 | 1,644 | 6,117 |
| **2040** | 3,335 | 149 | 1,558 | 5,042 |
| **2050** | 3,180 | 174 | 1,692 | 5,047 |
| | | SCENARIO 2 | | |
| **2030** | 4,376 | 97 | 1,603 | 6,076 |
| **2040** | 3,336 | 149 | 1,472 | 4,957 |
| **2050** | 3,182 | 174 | 1,588 | 4,944 |
| | | SCENARIO 3 | | |
| **2030** | 4,322 | 170 | 1,557 | 6,049 |
| **2040** | 2,870 | 604 | 1,184 | 4,658 |
| **2050** | 2,343 | 859 | 1,154 | 4,356 |

The adoption of a combined CLEAR and ZEV program in Colorado would result in significant criteria emissions reductions under any scenario. Table 16 summarizes the criteria emissions reductions of NOx, VOC, PM2.5 and SOx under the three scenarios. Under Scenario 1, the state could reduce NOx emissions by 207 tons per year in 2030 and under Scenario 3 that estimate goes up to 276 tons per year in 2030. These reductions are on the same order as an inspection and maintenance program adopted for the Denver metro area as part of its ozone action plan to meet federal health based air quality standards.  By 2040, a Colorado ACCP could reduce NOx emissions by roughly 373 to 757 tons per year, depending on the scenario. Volatile organic compounds (VOCs), another precursor to ozone, could fall by up to 1,200 tons annually by 2040 and PM2.5 and sulfur dioxides (SO2) would also be significantly reduced under an ACCP.

## Table 16
## Criteria Emissions Reductions in Colorado Under Advanced Clean Car Program (Metric Tons Per Year)

| CALENDAR YEAR | NOx | VOC | $PM_{2.5}$ | $SO_x$ |
|---|---|---|---|---|
| | | SCENARIO 1 | | |
| **2030** | 207 | 225 | 15 | 121 |
| **2040** | 373 | 404 | 27 | 204 |
| **2050** | 448 | 485 | 33 | 242 |
| | | SCENARIO 2 | | |
| **2030** | 248 | 263 | 18 | 146 |
| **2040** | 458 | 483 | 33 | 258 |
| **2050** | 551 | 583 | 40 | 308 |
| | | SCENARIO 3 | | |
| **2030** | 276 | 356 | 23 | 173 |
| **2040** | 757 | 1,163 | 71 | 427 |
| **2050** | 1,139 | 1,735 | 105 | 563 |

Because the net cost of adopting the Colorado ACCP is negative (the lifetime consumer fuel savings exceed the incremental vehicle technology costs), the cost per ton of achieving these criteria emissions reductions are also negative.

While we did not attempt to quantify the potential impact, it is also likely that increased sales of electric vehicles could provide an additional criteria emissions benefit. As gasoline vehicles age they can have excessively high criteria emissions over time due to hardware failure or poor maintenance. Therefore, a relatively small number of early-model gasoline vehicles can contribute a significant proportion of total fleet emissions. The emissions factors we used from EPA include some deterioration in emissions with age, but likely not to the full extent occurring in the real world. On the other hand, tailpipe emissions from electric vehicles are inherently zero, regardless of hardware failure or maintenance. So, to the degree that electric vehicles are displacing older gasoline vehicles, there should be an additional criteria emissions benefit that is not quantified here.

Finally, for our baseline and scenarios we based future fleet growth on AEO 2018 projections, which are quite modest. If ZEV sales growth turns out to be higher than projected, then the emissions reductions would be greater.

### Health Impacts

Our analysis uses EPA's CO-Benefits Risk Assessment (COBRA) model to project changes in human health as a result of changes in criteria emissions levels in Colorado. COBRA is a tool that can help estimate how the changes in air pollution from a clean energy policy, such as a Colorado ACCP, affect human health at the state level, and then help calculate the economic value of the health benefits associated with the policy.[79] We used COBRA's built in baseline emission inventories for 2025, and input changes in emissions (tons per year) for 2050. The health impacts addressed by

[79] EPA website, CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool. https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool#3 (accessed May 22, 2019).

COBRA are predominantly related to PM2.5 levels. Because ambient PM2.5 levels are not expected to decrease dramatically between 2025 and 2050, based on existing emission controls, we assumed that absolute changes in emissions in 2050 would produce similar health impacts as the same emissions reductions in 2025.

We input the changes in NOx, VOC, PM2.5 and SOx emissions shown above to the COBRA model at a state level. The predicted improvements in annual health effects in Colorado in 2050 under Scenario 3 are shown in Table 17 below. A Colorado ACCP would result in up to 10 saved lives per year by 2050 and up to 670 lost work days avoided. The health impacts reflected in COBRA are solely due to changes in estimated ambient PM2.5 levels, as opposed to ozone. There are often several studies considered for each health impact resulting in a range of incidence reduction. The projected health improvements in 2025, 2030, and 2040 under Control Scenario 3 can be found in Appendix D, as well as for 2025-2050 for Control Scenarios 1 and 2.

## Table 17
## Annual Health Improvements in 2050 Under Scenario 3

| HEALTH ENDPOINT | REDUCTION IN INCIDENCE |
|---|---|
| MORTALITY | 4.5 - 10.1 |
| INFANT MORTALITY | 0.010 |
| NONFATAL HEART ATTACKS (LOW ESTIMATE) | 0.5 - 4.7 |
| HOSPITAL ADMITS, ALL RESPIRATORY | 1.2 |
| HOSPITAL ADMITS, CARDIOVASCULAR (EXCEPT HEART ATTACKS) | 1.37 |
| ACUTE BRONCHITIS | 8.3 |
| UPPER RESPIRATORY SYMPTOMS | 151.3 |
| LOWER RESPIRATORY SYMPTOMS | 106.0 |
| EMERGENCY ROOM VISITS, ASTHMA | 2.3 |
| MINOR RESTRICTED ACTIVITY DAYS | 3,953 |
| WORK LOSS DAYS | 670.9 |
| ASTHMA EXACERBATION | 156.7 |

We also used COBRA to estimate the range of total monetized value of the projected health improvements associated with each of the three scenarios. The results in Table 18 show a public health benefit of $2-6 million annually in 2025 from ambient PM-related health benefits and up to $100 million annually in 2050. The majority of the value of the health impact comes from reduced mortality.

## Table 18

## Monetized Value of Ambient PM-Related Health Benefits in Colorado from Advanced Clean Car Program ($ Millions Per Year)

| CALENDAR YEAR | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 |
|---|---|---|---|
| **2025** | $64-67 | $15-18 | $15-18 |
| **2030** | $7-15 | $8-18 | $10-23 |
| **2040** | $12-27 | $14-32 | $31-70 |
| **2050** | $14-32 | $17-39 | $45-102 |

### Net Economic and Pollution Impacts

To evaluate the net economic and pollution benefits of a Colorado ACCP, we combine the vehicle-related economic savings with the monetized ambient PM-related health benefits plus the monetized benefits of GHG emission reductions from EPA's COBRA model. The vehicle-related savings include the fuel consumption and maintenance savings, less the cost of additional gasoline and ZEV technology costs, including insurance. As mentioned above, the monetized health impacts only include those related to ambient PM. Benefits related to ozone and air toxics (i.e., cancer) are not included.

Table 19 presents the net economic and pollution benefits under each of the three scenarios and both fuel price cases. All three scenarios produce net annual economic and pollution benefits to Colorado as early as 2025. Under the primary analysis, a Colorado ACCP would result in net annual economic and pollution benefits of up to $67 million in 2025 and these benefits would progressively increase to between $1.3 and $3 billion in 2050. The net economic and pollution benefits are greater under higher fuel prices, totaling over $200 million each year in 2025 and growing to between $2 billion and nearly $5 billion annually by 2050.

## Table 19

## Advanced Clean Car Program Yields Net Economic and Pollution Benefits to Colorado ($ Million Per Year )

| CALENDAR YEAR | SCENARIO 1 | SCENARIO 2 | SCENARIO 3 |
|---|---|---|---|
| **2025** | $64-67 | $15-18 | $15-18 |
| **2030** | $484-492 | $539-550 | $646-658 |
| **2040** | $1,088-1,103 | $1,319-1,337 | $2,177-2,216 |
| **2050** | $1,349-1,366 | $1,650-1,672 | $2,961-3,018 |
| | HIGH FUEL PRICE | | |
| **2025** | $217-220 | $185-188 | $185-188 |
| **2030** | $867-876 | $1,002-1,012 | $1,205-1,218 |
| **2040** | $1,744-1,759 | $2,138-2,156 | $3,587-3,626 |
| **2050** | $2,169-2,187 | $2,681-2,703 | $4,880-4,937 |