

Appendix 1: Technical Support Document

An analysis of Minnesota's proposal to adopt California's Low Emissions Vehicle and Zero-Emission Vehicle standards

This technical support document supplements the Minnesota Pollution Control Agency's (MPCA) Statement of Need and Reasonableness (SONAR) In the Matter of Proposed Revisions of Minnesota Rule Chapters 7023, Clean Cars Minnesota; Revisor ID No. 04626.

Contents

Contents	2
Introduction	4
1. Analysis overview and main inputs	4
A. Background on the proposed rule	5
B. Framework of the analysis	7
C. Vehicle sales inputs	8
i. EV sales projections in the Reference scenario	9
ii. EV sales projections in the Clean Cars scenario	13
D. Annual mileage inputs	16
2. Emissions benefits	17
A. Overview	17
B. Emissions background data and inputs	19
i. Tailpipe emissions rates	19
ii. Fuel economy and upstream emissions rates	22
C. Emissions benefit results	25
i. Greenhouse gas benefits	25
ii. Projected greenhouse gas benefits beyond 2034	27
iii. Emissions benefits of other air pollutants	27
iv. Sensitivity analyses	30
3. Costs and benefits to Minnesota consumers	35
A. LEV standard consumer impact analysis	35
i. Estimated per-vehicle technology costs for the LEV standard	37
ii. LEV standard per-vehicle cumulative costs and benefits over vehicle lifetimes	39
iii. LEV standard fuel savings in Minnesota	43
iv. Net consumer costs and benefits of the LEV standard	47
B. ZEV standard consumer impact analysis	50
i. EV sales estimates	50
ii. Vehicle technology costs	51
iii. Fuel savings	55
iv. Maintenance and repair savings	58
v. ZEV standard cumulative costs and savings in Minnesota	60
C. LEV and ZEV standards impact on state tax revenue	70

4. Health and equity analysis	72
A. Health benefits analysis	73
i. Methodology	73
ii. Results	74
B. Equity analysis	77
i. Areas of concern for environmental justice	79
ii. Traffic density	79
iii. Disproportionate impacts	82
iv. Increasing benefits over time	82
v. Sensitive land uses	83
5. Economic slowdown sensitivity analysis	86
A. Emissions benefits results	89
B. Costs and benefits to Minnesota consumers	89
i. LEV standard consumer impacts in an economic slowdown	89
ii. ZEV standard consumer impacts in an economic slowdown	92
iii. Health and equity impacts in an economic slowdown	95
6. Establishing an initial ZEV credit bank	96

Introduction

This technical support document (TSD) presents results and details about the methods, inputs, assumptions, and sensitivities for the regulatory analysis (section 7) conducted for the Minnesota Pollution Control Agency's (MPCA) Statement of Need and Reasonableness (SONAR) for the proposed adoption of California's Low Emission Vehicle (LEV) and Zero Emission Vehicle (ZEV) vehicle standards into Minnesota Rules. The TSD provides the detailed information behind the analysis that examines the direct and indirect costs and benefits of the proposed rule.

The MPCA considered the impacts of the rules in three general areas: emissions impacts of greenhouse gases (GHGs) and other air pollutants; economic impacts for Minnesota consumers and producers; and health, climate, and disproportionate environmental impacts in Minnesota (see SONAR sections 7 and 8 for information on health, climate, and disproportionate environmental impacts). These areas are not separate areas of analysis, but rather interact and depend on one another. Since the primary purpose of the proposed rule is to reduce vehicle tailpipe emissions and increase the number of vehicles with zero tailpipe emissions, its most direct benefit is a reduction in emissions from vehicle operation on roadways. This benefit leads to a secondary co-benefit of improved public health outcomes, since vehicle pollutants, even at low and moderate levels, directly harm human health.

This TSD contains six parts:

- 1. Analysis overview and main inputs:** Describes the overall framework of the cost-benefit analysis and the MPCA's approach used to determine the assumptions and inputs needed, including historic and projected vehicle sales estimates and characteristics of vehicle usage in Minnesota.
- 2. Emissions benefits:** Estimates the air pollution emissions that would be avoided as a result of adopting the proposed rule.
- 3. Costs and benefits to Minnesota consumers:** Covers direct and indirect economic costs and benefits, including those related to vehicle purchase, fuel and maintenance, and costs to state agencies.
- 4. Health and equity analysis:** Analyzes the potential health benefits resulting from the emissions benefits and whether some groups of Minnesotans will be more affected than others.
- 5. Sensitivity analyses to address potential economic slowdown:** The COVID-19 pandemic could have long-term impacts on the U.S. and Minnesota economies, which could affect future vehicle sales and specifically EV sales. This section provides analysis of how future economic slowdowns could affect every component of this analysis, including emissions benefits, costs and benefits to Minnesota consumers, establishment of initial ZEV credit banks, and health and equity implications.
- 6. Establishment of an initial ZEV credit bank:** Provides analysis of the MPCA's proposed mechanism to establish an initial ZEV credit bank to aid in compliance once the proposed rule goes into effect. Analyses of alternative early action mechanisms are also included.

Given the variety of economic and societal factors at play in the scope of this analysis, the methodology described demonstrates the practical extent to which the MPCA determined reasonable assumptions and inputs for future scenarios.

1. Analysis overview and main inputs

As part of the Clean Cars Minnesota rulemaking, MPCA is proposing the adoption of LEV and ZEV standards. In its analysis of how LEV and ZEV emissions standards would impact Minnesota, the MPCA considered the following:

- Impacts on emissions of GHGs and other pollutants,
- Economic costs and benefits to Minnesota consumers,
- Costs to vehicle manufacturers and dealers to comply with the rules,
- Costs to state agencies from implementing and enforcing the rules,
- Impacts on the climate and the health of Minnesotans, and
- Equity implications of the rules.

Additionally, the MPCA analyzed methods for establishing an initial ZEV credit bank. The analysis begins with model year (MY) 2025 because this is the earliest possible year the rules could be in effect.¹

This section outlines key concepts of the proposed rule as well as the general framework and key inputs to the analysis.

A. Background on the proposed rule

The MPCA is proposing to adopt the ZEV standard and the LEV standard together. Until spring of 2020, the LEV standard was identical to the federal standards. However, on April 30, 2020, the federal government published the final Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule, effective June 29, 2020, which weakened the federal GHG emissions standards for light-duty vehicles. One of the purposes of the proposed Clean Cars Minnesota rule is to maintain the more stringent GHG emissions standard in Minnesota in light of this federal action. The LEV and federal standards are the same for non-methane organic gases (NMOG) and nitrogen oxides (NO_x), and the federal government has not changed those standards. The LEV particulate matter (PM) standard is currently the same as the federal standards, but begins to become more stringent after MY 2025 until MY 2028. The LEV and federal standards for medium-duty vehicles are harmonized, so medium-duty vehicles are not included in this analysis.

The proposed LEV emissions standards apply to the following vehicle types:

- Passenger car: vehicles designed mostly to transport 12 people or less.
- Light-duty truck: vehicles with a gross vehicle weight of under 8,500 pounds.
- Medium-duty vehicle: vehicles with a gross vehicle weight of between 8,501 and 14,000 pounds.
- Medium-duty passenger vehicle: medium-duty vehicles with a gross vehicle weight of less than 10,000 pounds and is designed mostly to transport people.

The TSD sometimes refers to “light-duty vehicles” (LDV) which is a category that combines both “passenger cars” and “light-duty trucks.” LEV sets emissions limits for these vehicle categories for GHGs, as well as other pollutants, including NMOG, NO_x, and PM. NMOG and NO_x are combined into one standard together so that manufacturers can determine the balance of emission control technologies that works best for their vehicles.

New cars and light-duty trucks sold in Minnesota are currently subject to the federal emission standards. Until spring 2020, the federal standards and LEV standards were equivalent. The LEV standard and 2020 SAFE Rule have identical tailpipe emissions standards for PM and NMOG + NO_x through MY 2025.

¹There are many variables that may impact when the proposed rules would go into effect if they are adopted. These variables include rulemaking timeline and the resolution of the litigation over California’s waiver under section 209 of the CAA. This analysis assumes the earliest date by which the proposed rules could be in effect. Section 177 of the CAA provides that states must adopt the new standards at least two years prior to their implementation. Therefore, if MPCA adopts the proposed rules in early 2021, they would not be applicable for MY 2023, which begins on January 1, 2022, nor for MY 2024, but will be applicable to MY 2025, which begins January 1, 2024.

Starting in MY 2025, the LEV standards begin to phase in a more stringent standard for emissions of PM. However, the 2020 SAFE rule is significantly less stringent for GHG tailpipe emission standards, compared to the LEV standard. Under the 2020 SAFE rule, the federal GHG emissions standards get more stringent by 1.5% annually through MY 2026 compared with the LEV standard, which get more stringent by 5% annually through MY 2025.

The proposed rule requires automobile manufacturers deliver for sale in Minnesota only passenger cars, light-duty trucks, medium-duty vehicles, and medium-duty passenger vehicles that are certified by California as meeting the LEV standards. Manufacturers also need to meet average emissions requirements for the entire fleet of vehicles they deliver for sale in Minnesota. There are separate fleet-wide emission standards for passenger cars, light-duty trucks, medium-duty vehicles, and medium-duty passenger vehicles. The proposed rule for GHGs and NMOG + NO_x provide flexibility for manufacturers by using a vehicle footprint-based calculation for determining the manufacturer's fleet-wide average. Under this system, the fleet-wide average requirement for a manufacturer who sells a higher percentage of larger trucks or cars would be less stringent than if they sold a higher proportion of smaller vehicles. EVs delivered for sale as required by the ZEV standard are incorporated into this fleet average. A vehicle manufacturer whose fleet produces less emissions than their fleet-wide average requirement for a model year earns credits, while a manufacturer whose fleet produces more emissions than their fleet-wide average requirement has a deficit it must fill with credits either from its bank or by purchasing credits from other manufacturers. The LEV standard provides compliance flexibilities including banking and trading of credits across model years and trading of credits between manufacturers. Additionally, manufacturers have the option of demonstrating compliance with the LEV standard based on deliveries for sale in each state individually or by averaging across California and all the other states that have adopted the LEV standard (collectively referred to as "section 177 states") together. The PM standard requires manufacturers to annually phase in increasing percentages of lower-emitting vehicles into their fleet.

The ZEV standard would require a certain percentage of the passenger cars and light-duty trucks that each automobile manufacturer delivers for sale in Minnesota annually to be vehicles with zero tailpipe emissions, including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs),² and hydrogen-fueled vehicles. These vehicles are collectively considered "zero emission vehicles" (ZEVs). BEVs and PHEVs are often collectively referred to as "electric vehicles" (EVs). Credit requirements vary depending on the size of the manufacturer. The number of vehicles that the credit percentage ZEV requirement is applied to for the given model year is based on the three-year average of the manufacturer's volume of passenger cars and light-duty trucks produced and delivered for sale in Minnesota in the prior second, third, and fourth model year. For example, 2025 model year ZEV requirements would be based on Minnesota production volume average of passenger cars and light-duty trucks for 2021 to 2023 model years. The production volume for calculating a manufacturer's ZEV credits includes only its sales of light-duty passenger cars and trucks, not medium-duty vehicles. Large volume manufacturers³ must meet a portion of their credit requirements with credits from the delivery

² PHEVs are called "transitional zero emission vehicles" or "TZEVs" in the regulatory language, although TZEV is not a commonly used term. For the purposes of this SONAR, the terms TZEV and PHEV are synonymous, however PHEV will be used for consistency.

³ California Code of Regulations Title 13 § 1900 (b)(10), "Large volume manufacturer" means "any 2000 and subsequent model year manufacturer that is not a small volume manufacturer, or an independent low volume manufacturer, or an intermediate volume manufacturer."

for sale of BEVs, while intermediate volume manufacturers⁴ can meet their requirements from any mix of BEV or TZEV credits. Small volume manufacturers⁵ have no regulatory obligations under the ZEV standard.

B. Framework of the analysis

The MPCA's general approach to estimate the costs and benefits of the proposed rule was to consider two future scenarios: one in which the proposed rule is adopted, referred to as the "Clean Cars scenario," and one in which they are not—a business-as-usual, or "Reference" scenario. The difference in estimated emissions and economic outcomes in each scenario yields the costs and benefits of adopting and implementing the standards.

The two scenarios were considered over the same 10-year time frame, MYs 2025-2034. The first model year considered is MY 2025 because it is the first model year in which the proposed rules could be implemented in Minnesota, pending resolution of the California-EPA waiver dispute under section 209 of the Clean Air Act.

The Reference Scenario assumes all new passenger cars, light-duty trucks, and medium-duty passenger vehicles sold would comply with the GHG emission standards as published in the final "The Safer Affordable Fuel-Efficient (SAFE) Vehicle Rule for Model Years 2021-2026 Passenger Cars and Light Trucks" (85 FR 24174). The final SAFE rule was jointly published by the U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration's (NHTSA) on April 30, 2020 and went into effect June 29, 2020. The rule amends the federal GHG standards for MYs 2021-2026 light-duty vehicles to make them less stringent than they were previously. The SAFE rule does not change the emissions standards for other air pollutants. Therefore, the federal standards and LEV standards will remain the same for non-GHG pollutants.

Colorado is the most recent state to have adopted the LEV and ZEV standards, having done so in 2017 and 2018 respectively. The MPCA often referred to and relied on the regulatory analysis done by the Colorado Department of Public Health and Environment (CDPHE) on their rules to inform and shape our own. CDPHE analysts shared their cost-benefit analysis tools and data sources with the MPCA. MPCA staff then rebuilt Colorado's spreadsheet analysis tools for Minnesota, using inputs and data that reflected Minnesota-specific characteristics and conditions related to passenger and light-duty vehicles. Additionally, the MPCA put together a variety of our own spreadsheet tools in which various inputs could be adjusted with ease, in order to be able to easily compare outputs of estimated costs and benefits.

The following sections of this TSD describe the inputs the MPCA used in its analysis. Some inputs were held constant throughout the analysis, like vehicles sales totals, annual vehicle miles traveled, and vehicle size. Some inputs required adjustments to see how the resulting estimates changed, such as projected EV sales and car production share (the percentage of passenger vehicles sold that are smaller cars versus larger trucks or SUVs). EV compliance estimates were made using the California Air Resources Board (CARB) ZEV Regulatory Calculator, a spreadsheet tool that estimates the number of EVs

⁴ *California Code of Regulations Title 13 § 1900 (b)(9)*, "Intermediate volume manufacturer" means "...any 2018 and subsequent model year manufacturer with California sales between 4,501 and 20,000 new light- and medium-duty vehicles based on the average number of vehicles sold for the three previous consecutive model years for which a manufacturer seeks certification..."

⁵ *California Code of Regulations Title 13 § 1900 (b)(22)*, "Small volume manufacturer" means "with respect to the 2001 and subsequent model-years, a manufacturer with California sales less than 4,500 new passenger cars, light-duty trucks, medium-duty vehicles, heavy-duty vehicles and heavy-duty engines based on the average number of vehicles sold for the three previous consecutive model years for which a manufacturer seeks certification as a small volume manufacturer..."

needed to be sold to comply with the ZEV standard in a given state.⁶

C. Vehicle sales inputs

Before any emissions or economic impacts could be evaluated, the MPCA needed to establish how many new vehicles sold in any given year would be impacted by the proposed rule. Assumptions about future sales of internal combustion engine (ICE) and electric vehicles formed the basis of all the analysis that follows, including emissions and economic cost and benefit estimates. Historic and future sales were the first inputs we needed to establish in order to begin analysis in any of these areas. They were also an important input for determining EV sales necessary to comply with the proposed ZEV standard, since future ZEV credits are determined using manufacturers' historic sales volume of light-duty passenger vehicles (including EVs).

The MPCA used light-duty vehicle registration data provided by Alliance for Automotive Innovation (Auto Innovators), which they derived from Minnesota Department of Public Safety (DPS) vehicle registration data, to consider past and current trends in light-duty vehicle sales. Auto Innovators provided the MPCA with a set of Minnesota vehicle registration data that had already been cleaned and sorted to give the number of new registrations in the state from 2013-2018 by model year, power train (electric, gas, hybrid, and plug-in hybrid electric), and body style (car, pickup, SUV and van), and later provided 2019 sales total when it became available. The MPCA used Auto Innovators' 2013-2018 totals to consider historic trends in car production share (the percentage of LDV sales that are cars, versus larger passenger vehicles). The MPCA used DPS registration data to determine the approximate market share percentages of each manufacturer in Minnesota, since the Auto Innovators data did not give totals by manufacturer. Each vehicle manufacturer's market share was used to estimate the number of EV sales needed for compliance with the proposed ZEV standard, since compliance requirements are based on a manufacturer's size and sales volume. The MPCA used projected annual sales growth rates of new light-duty vehicle sales from the Minnesota Department of Transportation's (MnDOT) report, "Pathways to Decarbonizing Transportation in Minnesota"⁷ (Pathways report), to project Auto Innovators' vehicle totals, starting with MY 2019, through MY 2034.

The MPCA used the same estimates of the total number of light-duty vehicles sold for both the Reference scenario and the Clean Cars scenario. Buyer response to shifts in different factors related to vehicle cost such as up-front costs and fuel economy is difficult, if not impossible, to predict. According to EPA's Technical Assessment Report, "It is difficult, if not impossible, to separate the effects of the standards on vehicle sales and other characteristics from the impacts of macroeconomic forces on the auto market".⁸ Similarly, during the MPCA's request for comments (RFC) period, Consumer Reports submitted a comment stating:

New (and used) car sales are mostly influenced by macroeconomic factors, such as the state and nation's gross domestic product, employment rates, inflation, and oil and gasoline prices, and not by governmental regulation. Greenhouse gas (GHG) vehicle standards are unlikely to affect the number of new cars sold in Minnesota. Figure [1], below, which is based on data from the U.S. Department of Energy as presented by the

⁶Information about the ZEV Regulatory Compliance Calculator, developed by the California Air Resources Board, can be found at <https://ww2.arb.ca.gov/resources/documents/zev-regulatory-calculator>.

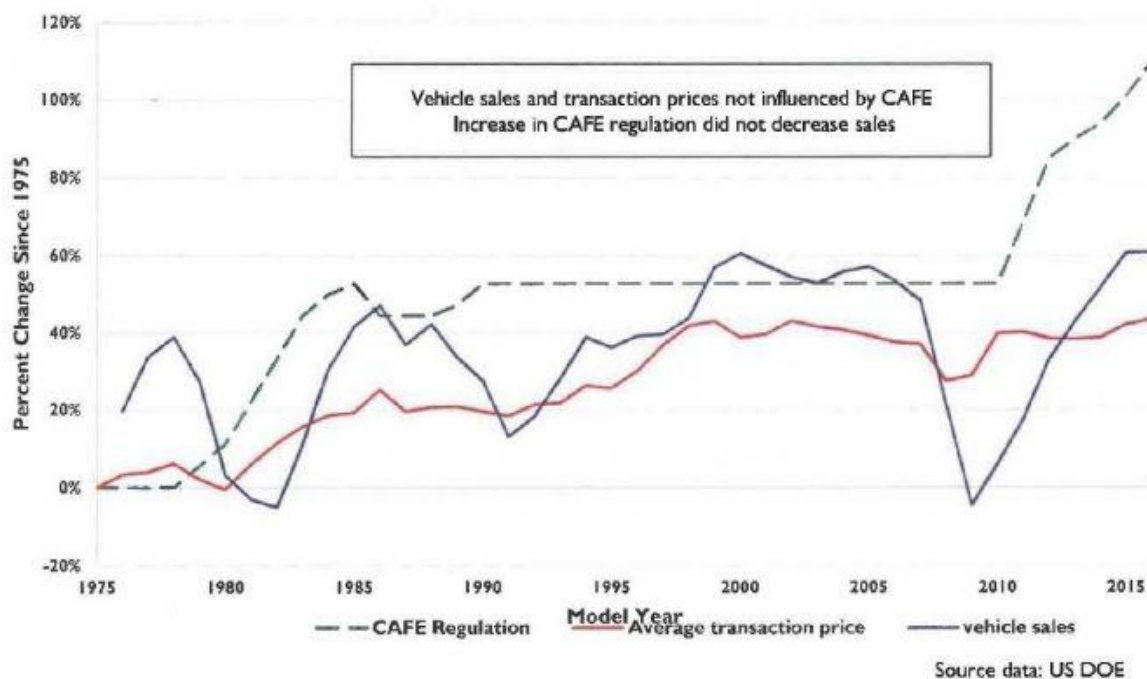
⁷ Pathways to Decarbonizing Transportation in Minnesota, Pathways to Decarbonizing Transportation in Minnesota (2019). Retrieved from <https://www.dot.state.mn.us/sustainability/docs/pathways-report-2019.pdf>

⁸ Draft Technical Assessment Report: Mid-Term Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025 (July, 2016) at 6-1.

Aluminum Association, shows the relationship over time between CAFE standards, the price of a new vehicles and the number of vehicles sold.⁹ As shown in this graph, an increase in vehicle price does not translate into lower sales. Periods of higher vehicle sales occur when prices are rising or flat, and such sales can decrease when prices drop. This means that vehicle sales are primarily influenced by macroeconomic factors, not the price of the vehicles. Similarly, changes in miles per gallon (MPG) requirements do not show any relationship to the number of cars sold. There are multiple times when the MPG requirement climb steeply and new cars sales climb with it. There are periods when the MPG requirements are flat, and new car sales decline sharply. Likewise, regulations such as the LEV Standard are very unlikely to affect new vehicle sales in Minnesota.

Figure 1: Historical U.S. vehicle prices and sales have no correlation

Historical data from the U.S. Department of Energy shows that tightening vehicle emissions standards and increasing vehicle purchase prices do not seem to have a meaningful impact on vehicle sales.



Since there is no clear evidence linking vehicle emissions standards to changes in purchasing rates of vehicles, the MPCA maintained the same vehicle sales rates for both the Clean Cars and Reference scenarios.

i. EV sales projections in the Reference scenario

To evaluate the costs and benefits of the proposed rule, the MPCA needed to first consider what EV sales could be expected without the ZEV standard in place. There are many projections of EV sales that

⁹ News Release, Automotive Aluminum Industry Statement on Today's EPA Determination on Emissions Regs, DRIVE ALUMINUM (August 2, 2018), <https://www.drivealuminum.org/news-releases/automotive-aluminum-industry-statement-on-todays-epa-determination-on-emissions-regs/>.

vary widely. To account for this uncertainty and understand the range of possibilities and implications, the MPCA looked at several scenarios that range from conservative low EV sales estimates to more optimistic projections of higher EV sales. This set of possible EV sales futures provide reasonable bounds on the possibilities for future EV sales. While we think that considering a range of business-as-usual scenarios is informative, for the analyses of emissions benefits and costs and benefits to Minnesota consumers, we used the most conservative estimate of EV sales future as the Reference scenario.

For the low scenario, the MPCA used past EV sales from the years of 2015 through 2019 to linearly project future sales.¹⁰ This scenario would result in the additional sale of 555 BEVs and 146 PHEVs each model year from 2020 on. As a conservative estimate of future EV sales in Minnesota, which is lower than other Minnesota EV sales projections, this linear projection defines a lower bound of future Minnesota EV sales. EV sales in our linear projections make up slightly less than 6% of total LDV sales in MY 2034 (see Figure 2).

For high scenarios, or more generous estimations of business-as-usual EV sales, the MPCA first considered the U.S. Energy Information Administration (EIA) 2019 Annual Energy Outlook (AEO)¹¹ Reference case EV sales projections for the West North Central region of the U.S.¹² EIA 2019 sales estimates projected that EVs would make up about 10.5% of all light-duty vehicle sales in MY 2034. These estimates were considered particularly optimistic because they exceeded EV sales projection in other regions of the U.S., such as the Mid-Atlantic, Pacific, and New England regions, where the ZEV standard has already been adopted. EIA 2019 estimates exceed the sales totals that would be needed to comply with a ZEV standard in Minnesota. Thus, if the business-as-usual future were to unfold as EIA 2019 estimates predict, manufacturers would be over-complying with what the proposed ZEV standard would require even without the standard in place. If EIA 2019 sales projections were to occur, the ZEV standard would have no emissions or economic benefit or cost, but would serve as a backstop to ensure a minimum level of EV deliveries to Minnesota.

The MPCA heard from several parties that the EIA 2019 sales projections are unreasonably optimistic. For example, comments submitted by the Union of Concerned Scientists (UCS) recommended "...that the agency use projections based on historical EV sales in Minnesota. UCS does not recommend that the agency use Energy Information Administration's Annual Energy Outlook (AEO) 2019 regional vehicle sales projections as they do not accurately reflect vehicle availability in Minnesota as well as important national policy shifts. The AEO projections fail to account for state-level ZEV availability factors..."¹³ The MPCA heard similar comments from the Alliance for Automotive Innovation, which stated, "the EIA-based projections are concerning, as they predict sales of nearly 6,000 BEVs in 2019, when in fact Minnesota has had sales of only just over 2,000 for BEVs and under 3,000 for BEVs and PHEVs combined

¹⁰ 2013-2018 sales: Alliance of Automobile Manufacturers (2019). Advanced Technology Vehicles Sales Dashboard. Data compiled by the Alliance of Automobile Manufacturers using information provided by IHS Markit (2011-2018) and Hedges & Co. (2019) Data last updated 8/20/2019. <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>. (Alliance of Automobile Manufacturers merged with the Association of Global Automakers in early 2020 to form the Alliance for Automotive Innovation). 2019 totals were provided by the Alliance for Automotive Innovation (Auto Innovators), since the complete 2019 sales data was unavailable on the Advanced Technology Vehicle Sales Dashboard.

¹¹ <https://www.eia.gov/outlooks/aeo/>

¹² EIA's West North Central Region is comprised of Minnesota along with Iowa, Kansas, Missouri, Nebraska, North Dakota, and South Dakota.

¹³ UCS comment on proposed early action credit mechanism, received January 17, 2020, at page 2.

in 2019.”¹⁴

Given this feedback, the MPCA did not use EIA 2019 sales projections for our cost and benefit estimates, and relied primarily on the low scenario linear EV sales projections. We did, however, consider the 2019 EIA projections in our analysis for establishing an early-action ZEV credit bank, in order to consider the wide range of possible EV sales outcomes before and after the start of ZEV implementation.

On January 29, 2020, EIA released its 2020 Annual Energy Outlook,¹⁵ which projected significantly lower EV sales in the West North Central region of the U.S. than it had in 2019.

¹⁶ The EIA 2020 EV sales projections are very close to the MPCA’s linear EV sales growth projections (see Figure 2), slightly exceeding the linear growth trajectory for most of the years of our analysis. Thus, the MPCA decided it was reasonable to continue to use the linear projection for the Reference scenario in this analysis. EIA’s 2020 business-as-usual EV sales projections, like the MPCA’s linear business-as-usual EV sales projections, are lower than what the MPCA projects would be necessary for ZEV compliance for most of the MY 2025-2034 time frame.

One final possible future business-as-usual Minnesota EV sales scenario was based on recent EV sales in Minnesota, but instead of projecting linear growth, the MPCA fit a quadratic growth curve (essentially, exponential growth) through the sales data. For this projection, we used EV sales (BEVs and PHEVs) in Minnesota from the Auto Innovators for 2013-2019¹⁷ and as was the case for the linear sales growth projections, fitted separate growth curves for BEVs and PHEVs to project future sales of each. The quadratic growth curve had a better fit to the recent sales data than the linear growths for BEVs. This is to say that, while we cannot necessarily expect quadratic growth in BEVs and PHEVs to continue into the future, the quadratic growth curve, at least for BEVs, is a better representation of the recent past growth in Minnesota than a linear growth pattern.

Figure 2 compares the different Minnesota future EV sales projections: MPCA’s linear projections, EIA’s 2019 and 2020 projections, and MPCA’s quadratic projections, along with ZEV standard compliance estimates.

¹⁴ Alliance for Automotive Innovation comment on proposed early action credit mechanism, received January 21, 2020, at page 3.

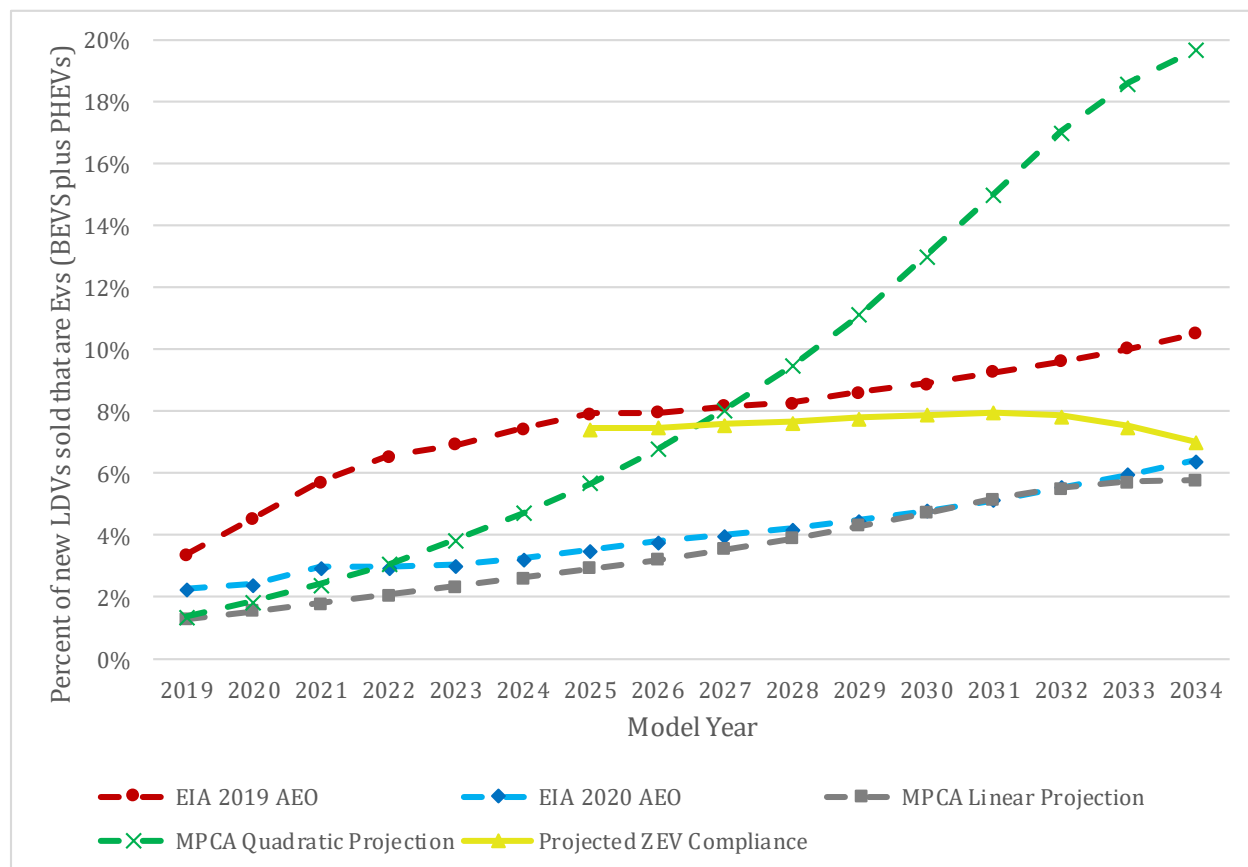
¹⁵ Available at: <https://www.eia.gov/outlooks/aeo/>.

¹⁶ Annual Energy Outlook 2020, Table 38. Light-Duty Vehicle Sales by Technology Type, available at <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=48-AEO2020®ion=1-4&cases=ref2020&start=2018&end=2050&f=A&linechart=ref2020-d112119a.4-48-AEO2020.1-4&map=ref2020-d112119a.5-48-AEO2020.1-4&sourcekey=0>.

¹⁷ 2013-2018 totals: Alliance of Automobile Manufacturers (2019). Advanced Technology Vehicles Sales Dashboard. Data compiled by the Alliance of Automobile Manufacturers using information provided by IHS Markit (2011-2018) and Hedges & Co. (2019) Data last updated 8/20/2019. <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>. Additional information for Minnesota 2019 BEVs and PHEVs sales provided through personal communication with Alliance of Automobile Manufacturers, 5/21/2020. 2019 totals were provided by the Alliance for Automotive Innovation (Auto Innovators), since the complete 2019 sales data was unavailable on the Advanced Technology Vehicle Sales Dashboard.

Figure 2: EV sales (as percentage of total LDV sales) projections: EIA 2019, EIA 2020, linear sales growth, quadratic sales growth, and requirements for ZEV standard compliance.

EIA's EV sales projections published in 2019, shown in red, were much higher than those published in 2020 (blue). MPCA's linear EV sales projections (grey) are more closely aligned with EIA's more recent 2020 projections. Both MPCA's linear and EIA's 2020 business-as-usual EV sales projections fall below what is needed for compliance with the ZEV standard (yellow). However, EIA's 2019 business-as-usual EV projections exceed what is needed for ZEV standard compliance over the entire time frame and MPCA's quadratic sales projections (green) exceed what is needed for ZEV standard compliance for all but the first two projected years of the standard.



The MPCA cannot say for certain which of these future scenarios is more likely in Minnesota if no ZEV standard is implemented, but considering all of them provides a range of potential futures. To err on the side of being conservative, the MPCA chose the linear growth as the Reference scenario and thus the difference between linear growth and the ZEV compliance projection described in the next section as the projected burden on vehicle manufacturers to comply with the ZEV standard. Given the uncertainty of projecting future EV sales, the proposed ZEV standard would provide a backstop, or regulatory floor, for the number of EVs delivered for sale in Minnesota, ensuring at least the minimum number of EVs required for compliance are sold in Minnesota.

Table 1 shows the projected EV sales under the linear growth projection. These sales estimates are used throughout this analysis for the Reference scenario.

Table 1: Minnesota light-duty vehicle sales and Reference scenario linear EV growth projections

Model year	Light-duty vehicle sales	Projected BEV sales	Projected PHEV sales	Total	Percent of total LDVs that are EVs
2025	253,385	5,611	1,799	7,410	2.92%
2026	251,104	6,166	1,945	8,111	3.23%
2027	247,840	6,721	2,091	8,811	3.56%
2028	243,379	7,276	2,236	9,512	3.91%
2029	237,538	7,830	2,382	10,213	4.30%
2030	230,649	8,385	2,528	10,913	4.73%
2031	224,883	8,940	2,674	11,614	5.16%
2032	222,634	9,495	2,820	12,314	5.53%
2033	226,641	10,050	2,965	13,015	5.74%
2034	237,067	10,604	3,111	13,716	5.79%

LDV sales are based on Minnesota 2019 sales with future sales based on MnDOT Pathways report projections. Projected BEV and PHEV Reference scenario deliveries are based on linear extrapolations of Minnesota EV sales in 2015-2019.

Due to potential long-term economic impacts of the COVID-19 pandemic, which could impact future sales of LDVs and EVs in Minnesota, the MPCA also conducted a sensitivity analysis with alternative projections for LDV and EV sales in Minnesota based on AEO's Low Economic Growth Scenario. This sensitivity analysis is addressed in Section 5 of this TSD.

ii. EV sales projections in the Clean Cars scenario

The ZEV standard is a credit-based percentage requirement intended to balance EV sales with the types of EVs being produced; it does not specify an EV sales volume target. Under the ZEV standard, EVs delivered for sale earn a manufacturer credits based on the vehicle technology (BEV vs. PHEV) and the distance it can travel on a full battery. BEVs typically earn more credits than PHEVs because vehicles that can travel further on a full battery earn a manufacturer more credits, and in general, BEVs can travel further than PHEVs on a single charge. Manufacturers have some flexibility, based on the amount of their sales within the state, to determine what mix of BEVs and PHEVs they want to produce and make available for sale to receive credits.

The flexibilities built into the proposed ZEV standard mean that it is not possible to know with certainty the exact number of BEVs or PHEVs a manufacturer might choose to deliver for sale in a state in order to comply. To help answer the question of how many EV sales could result from the regulation, and to show the effects that these flexibilities have on the overall number of EVs produced and delivered for sale in a state with the ZEV standard, staff at the California Air Resources Board (CARB) developed a ZEV Compliance Calculator and made it available for download on their website. The 2017 ZEV Compliance Calculator Tool is an Excel spreadsheet tool that estimates the minimum number of EVs that manufacturers might need to sell in order to comply with the rule, based on certain inputs and how quickly EV technology develops.¹⁸ The tool is not a market forecast of what actual total sales may be, or are likely to be, in any given model year, rather it is a regulatory compliance projection using the best

¹⁸ See California Air Resources Board, *ZEV Regulatory Calculator* (2019), <https://ww2.arb.ca.gov/resources/documents/zev-regulatory-calculator>.

available information on EV technology and production.

The MPCA used California's ZEV Compliance Calculator,¹⁹ updated with Minnesota-specific data, to create a ZEV Calculator of its own to estimate BEV and PHEV sales needed to comply with the proposed ZEV standard. Outputs from the Minnesota's ZEV Calculator are listed in Table 3. We needed to estimate how many EV sales might occur from the proposed ZEV standard so we could compare Minnesota's current and projected business-as-usual EV sales to what would be needed for compliance with the ZEV standard. The estimate provided a sense for how much manufacturers may or may not need to increase their EV sales between adoption and implementation of the rule in order to comply.

The California ZEV calculator off of which Minnesota's was based includes several scenarios for achieving the minimum level of compliance necessary to meet the ZEV standards based on assumptions about EV technology development and trends. MPCA used California's mid-range technology advancement scenario for our analysis. Staff at CARB and CDPHE recommended the mid-range technology advancement scenario as the most reasonable and balanced. This scenario assumed 5% annual growth in electric range for BEVs starting from 192.5 miles per charge in MY 2018. For PHEVs, the range reaches 55 miles per charge starting at MY 2023. These ranges are in label range which can be converted to UDDS²⁰ test cycle range by dividing by 0.7. ZEV credits are calculated based on UDDS test cycle range.

This analysis also assumes that by MY 2025, the majority of Large Volume Manufacturers (LVMs) and Intermediate Volume Manufacturers (IVMs) would focus on BEV technology rather than PHEV technology since BEVs earn more credits than PHEVs. Both LVMs and IVMs are likely to focus on BEV sales for compliance with the ZEV standard because, as many sources predict, battery costs are expected to go down significantly in the coming years.²¹ Moreover, forecasts predict that BEVs would reach price parity with ICE vehicles – around MYs 2027 or 2028.²² The Minnesota ZEV compliance scenario presented here estimates vehicle manufacturers may deliver to Minnesota a mix of EVs including around 62% BEV and 38% PHEV in order to meet the MY 2025 ZEV program requirements. Because EV battery technology is likely to improve as time goes by and battery costs are likely to decline, we expect that manufacturers will generally gradually shift their focus from PHEVs to BEVs to meet ZEV program requirements. Manufacturers may also be motivated to shift away from PHEVs to BEVs due to the fact that BEVs generally earn more ZEV credits toward compliance than PHEVs. By MY 2034, the projected EV vehicle mix in the Minnesota ZEV compliance scenario will be around 76% BEVs and 24% PHEVs. The key assumptions underlying this scenario in Minnesota are listed in Table 2.

¹⁹ Information about the ZEV Regulatory Compliance Calculator, developed by the California Air Resources Board, can be found at <https://ww2.arb.ca.gov/resources/documents/zev-regulatory-calculator>.

²⁰ UDDS stands for Urban Dynamometer Driving Schedule. It refers to the US EPA's mandated dynamometer test on fuel economy that represents city driving conditions and is used for light duty vehicle testing.

²¹ 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://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf. APCD PHS EX D.

²² *Id.*

Table 2: Key Minnesota-specific assumptions for Minnesota ZEV compliance calculator

Assumption	Value(s)	Rationale
BEVs range (miles)	192.5 for MY 2018 with 5% annual growth thereafter	These are what California and other states chose for their mid-range scenarios and are reasonable given current expectations of growth of EV technology.
PHEVs range (miles)	21 for MY 2018 with 5% annual growth thereafter	
% of large volume manufacturers making only BEVs	60% for MY 2025 with 2 percentage points annual growth thereafter ²³	Based on California's and other states' assumptions and informed by recent and likely future sales of BEVs and PHEVs in Minnesota.
% of intermediate volume manufacturers making only PHEVs	40% for MY 2025 with 2 percentage points annual decline thereafter ²⁴	
Total LDV Minnesota market share of large volume manufacturers	89%	Based on Minnesota new vehicle sales data in 2019 provided by the Auto Innovators.
Total LDV Minnesota market share of intermediate volume manufacturers	11%	

These are the key assumptions that led to our projections for ZEV credit requirements under the proposed ZEV standard. These assumptions also are used to estimate how many early action credits would be accrued in Minnesota, as described in section 4.

ZEV compliance calculator estimates indicate that the ZEV standard would require manufacturers to deliver for sale in Minnesota approximately 18,800 EVs in MY 2025. For comparison, there were approximately 3,200 new EVs sold in Minnesota in 2019, 2,900 in 2018, and 1,400 in 2017.²⁵ Table 3 shows the projected EV sales estimated by the Minnesota ZEV Compliance Calculator. These sales estimates are used throughout this analysis for the Clean Cars scenario.

²³ It is generally believed that as EV battery technology improves and battery costs decline, BEVs will become more popular relative to PHEVs and manufacturers will shift their focus away from PHEVs and towards ZEVs. This is why the MPCA has chosen to slightly increase each year the percentage of LVMs solely making BEVs.

²⁴ Again, due to expected changes in EV battery technology and costs, we expect that as time goes by IVMs will also generally shift their focus away from PHEVs and towards BEVs.

²⁵ Alliance of Automobile Manufacturers (2019). Advanced Technology Vehicles Sales Dashboard. Data compiled by the Alliance of Automobile Manufacturers using information provided by HIS Markit (2011-2018) and Hedges & Co. (2019) Data last updated 8/20/2019. Retrieved 2/3/2020 from <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>. Additional information for Minnesota 2019 BEVs and PHEVs sales provided by Alliance for Automotive Innovation, 5/21/2020. In early 2020, the Alliance of Automotive Manufacturers merged with the Association of Global Automakers to form the Alliance for Automotive Innovation.

Table 3: Minnesota light-duty vehicle sales and Clean Cars compliance scenario

Model year	Light-duty vehicle sales	BEVs	PHEVs	Total EVs	Percent of total LDVs that are EVs
2025	253,385	11,714	7,139	18,852	7.44%
2026	251,104	11,804	6,777	18,581	7.40%
2027	247,840	11,865	6,401	18,266	7.37%
2028	243,379	11,893	6,012	17,904	7.36%
2029	237,538	11,879	5,607	17,486	7.36%
2030	230,649	11,811	5,187	16,998	7.37%
2031	224,883	11,682	4,752	16,434	7.31%
2032	222,634	11,489	4,309	15,798	7.10%
2033	226,641	11,269	3,874	15,143	6.68%
2034	237,067	11,106	3,475	14,581	6.15%

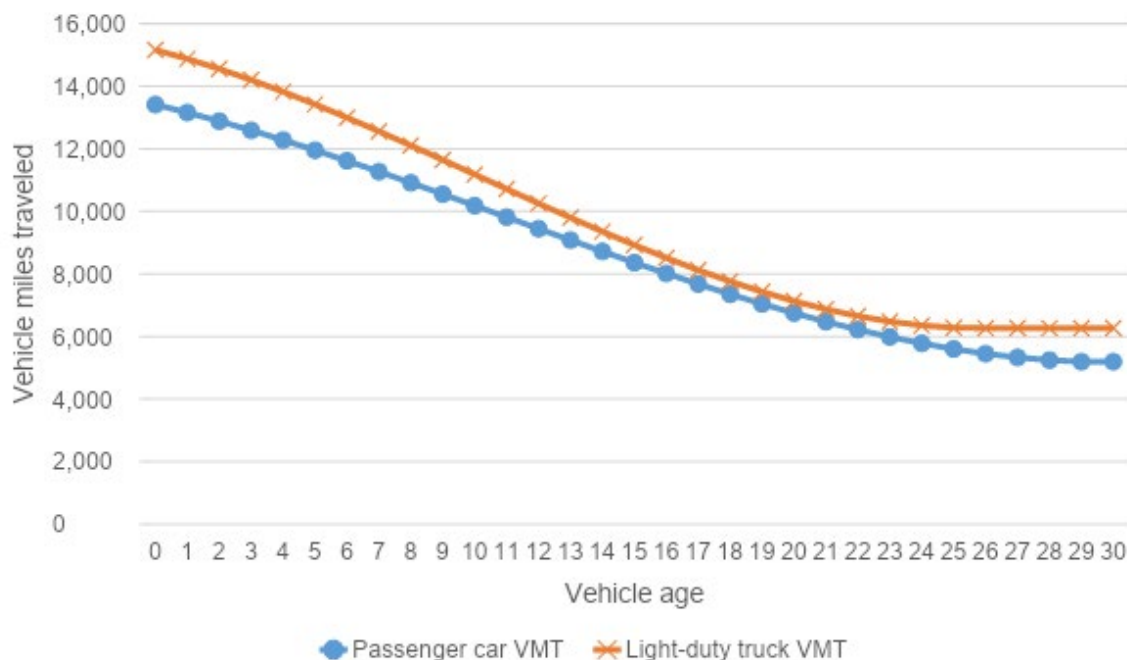
The MPCA used the Minnesota ZEV Compliance Calculator to project the number of BEVs and PHEVs in each MY 2025-2034 that would be required to comply with the standard. Because the ZEV standard plateaus in MY 2025, projections of BEVs and PHEVs required for compliance in subsequent model years are based on projected fluctuations in Minnesota light-duty vehicle sales. These compliance projections are used throughout this document in our estimation of emissions and consumer impacts of the ZEV standard.

D. Annual mileage inputs

To estimate emissions and fuel savings on an annual basis, the MPCA used data from the EPA 2014b Motor Vehicle Emissions Simulator (MOVES) to estimate annual vehicle miles traveled (VMT) for new vehicles sold. MOVES provides default VMT values for passenger cars and light-duty trucks based on their age, shown in Figure 3. We used the same VMT values in both the Reference and Clean Cars scenario. In both scenarios, the MPCA assumed that PHEVs would power 75% of their mileage with electricity, and 25% with gas. Colorado used this same assumption in their analysis. In the absence of any data to suggest an alternative for Minnesota, the MPCA determined it reasonable to use Colorado's assumption.

Figure 3: EPA MOVES model vehicle miles traveled default Minnesota values, by vehicle age and class

EPA data from its Motor Vehicle Emissions Simulator (MOVES) assumes that as vehicles age they travel fewer miles each year. It also assumes that larger vehicles, like trucks and SUVs, generally drive more miles annually than smaller cars.



2. Emissions benefits

This section provides an overview of the results, methodology, data and inputs used to estimate emissions impacts of the proposed rules.

A. Overview

The basic approach to calculating the emissions benefits of the proposed rule was to estimate the emissions from light-duty vehicles that would occur in the Reference scenario and the Clean Cars scenario, between MYs 2025 and 2034, and to subtract to find the difference. For both scenarios, the MPCA estimates strict compliance with the applicable standards and does not consider any potential over-compliance with the standards.

If the MPCA does not adopt the proposed rule and maintains the federal standards in the state, Minnesota will be subject to the final changes to the federal GHG emissions standards as published in the Federal Register on April 30, 2020. Therefore, in the Reference scenario, the analysis assumes all new light-duty vehicles sold will comply with the final federal SAFE rule, which rolls back the previous GHG standards for MYs 2021 to 2026 and makes them less stringent. The SAFE rule requires an approximate 1.5% annual reduction in tailpipe CO₂ emissions through MY 2026. In contrast, the LEV rule, which is equivalent to the former federal standards, requires an approximate 5% annual reduction in tailpipe CO₂ emissions through MY 2025.

We considered the Reference and Clean Cars scenarios over the same ten-year period, starting with MY 2025, the year in which the proposed rule would be most likely to take effect. For all remaining years of analysis we apply the standards from the last year for which they've been set (MY 2026 standards for all remaining years in the Reference scenario, MY 2025 standards in the Clean Cars scenario), which

effectively flatlines emissions rates through those years. On average, emissions standards for LEV-certified passenger cars and light-duty trucks are about 12% and 16% lower, respectively, in the Clean Cars scenario than in the Reference scenario.

The analysis considers the differences in tailpipe emissions in each scenario, as well as the differences in upstream emissions that occur from extraction, transportation, and consumption of fuels used for electricity generation (for electric vehicles) and the extraction, transportation, and energy use from the production of gasoline.

The primary air pollutants the MPCA included in the analysis are those specifically regulated by the LEV rule: GHGs, NMOG + NO_x, and PM. Greenhouse gases included in the rule are carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄). Since N₂O, CH₄, and NMOG + NO_x emission standards are the same under the SAFE and LEV rules, the MPCA only considered upstream emissions impacts of those pollutants. The LEV standard, in addition to CO₂, sets a more stringent emissions limit for PM. Whenever necessary, emissions of N₂O and methane were converted to carbon dioxide equivalents (CO₂-e) using global warming potential multipliers used in the LEV standard: of 298 and 25, respectively.

Since tailpipe emissions standards are established separately for passenger cars and light-duty trucks, our analysis considers the emissions differences between these vehicle types in the Reference and Clean Cars scenarios. For each pollutant, the MPCA determined a tailpipe and upstream emissions rate expressed in grams emitted per mile for each model year, vehicle type (passenger cars and light-duty trucks), and scenario. The MPCA then multiplied these per-mile emissions rates by annual VMT and the total number of vehicles sold in a model year and summed across model years to yield the total emissions (tailpipe and upstream) from all new vehicles sold after MY 2025 in each scenario. We then calculated the difference to determine the emissions benefit.

Since the SAFE and LEV GHG standards are enforced as a fleet average requirement for vehicle manufacturers, tailpipe GHG emissions benefits from additional EVs required under the ZEV standard are not included in tailpipe emissions benefit estimates. This is because EVs are allowed to be included when calculating a manufacturer's fleet-wide average. As a manufacturer produces more EVs, the fleet-average system effectively allows internal combustion engine vehicles produced by a manufacturer to emit a little more, on average, meaning more EVs produced does not necessarily mean a greater tailpipe GHG benefit.

In contrast, PM standards are enforced on a per-vehicle basis, meaning that every vehicle produced must not exceed a particular emission level. As a result, more EVs produced under the ZEV mandate would have an additional emissions benefit, which our analysis considers. Additionally, LEV PM emissions rates, though they begin at the same level as the federal standards in MY 2025, become increasingly more stringent each model year thereafter through 2028. In MYs 2028-2034, PM emissions rates in the Clean Cars scenario are one-third of those in the Reference scenario.

Since LEV and federal NMOG + NO_x emissions standards are equivalent, NMOG + NO_x emissions rates are equal for vehicles in both scenarios. Since these pollutants are emitted at the same rate in each scenario, all estimated emissions reductions of these pollutants are a result of reduced upstream emissions from fuel production.

The MPCA estimated emission impacts at two different scales:

- Tailpipe emissions: direct emissions from the vehicle itself.
- Well-to-wheel emissions: Tailpipe emissions plus upstream emissions from electricity and gasoline production, including extraction, transportation, and refining.

B. Emissions background data and inputs

This section (B) describes the data, inputs, and methods used to estimate the emissions benefits reported in section (C).

i. Tailpipe emissions rates

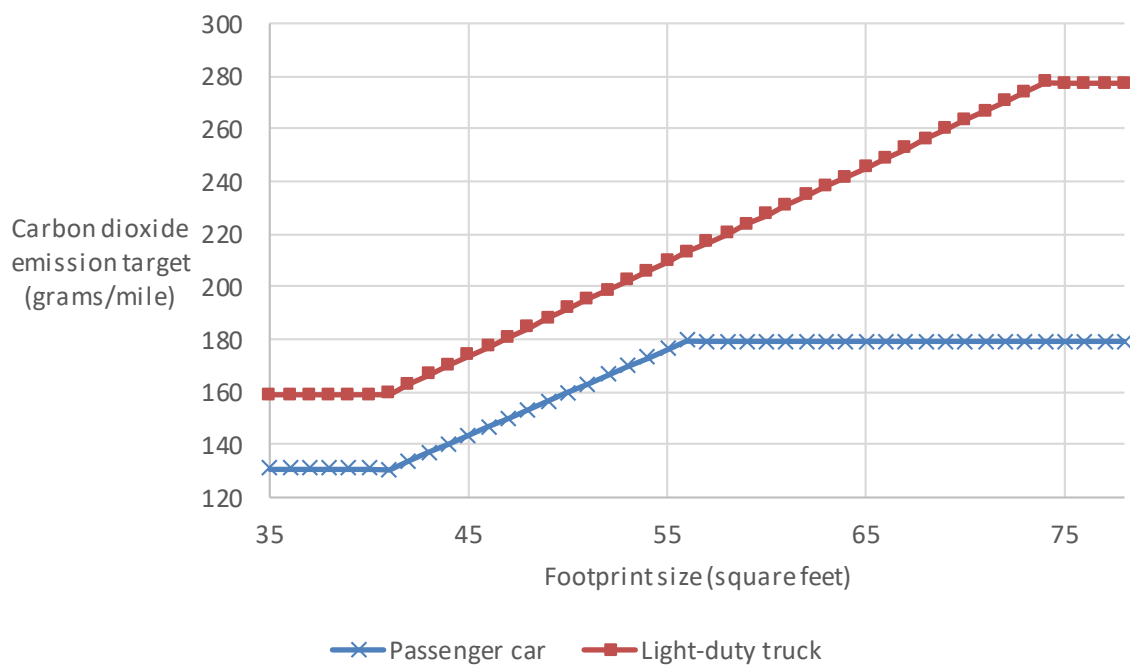
This section (i) describes emissions from the vehicle itself.

CO₂ emission rates

A vehicle's CO₂ emissions limit, as set by the LEV standards, is determined by the size of its footprint—the area between the points where its four tires touch the ground. Figure 4 shows MY 2025 LEV standards to illustrate the relationship between footprint size and emissions limit. The standards allow larger vehicles to emit more per mile than smaller vehicles.

Figure 4: LEV MY 2025 fleet average CO₂ emissions requirements

The LEV standard allows larger vehicles to emit more CO₂ per mile than smaller ones.



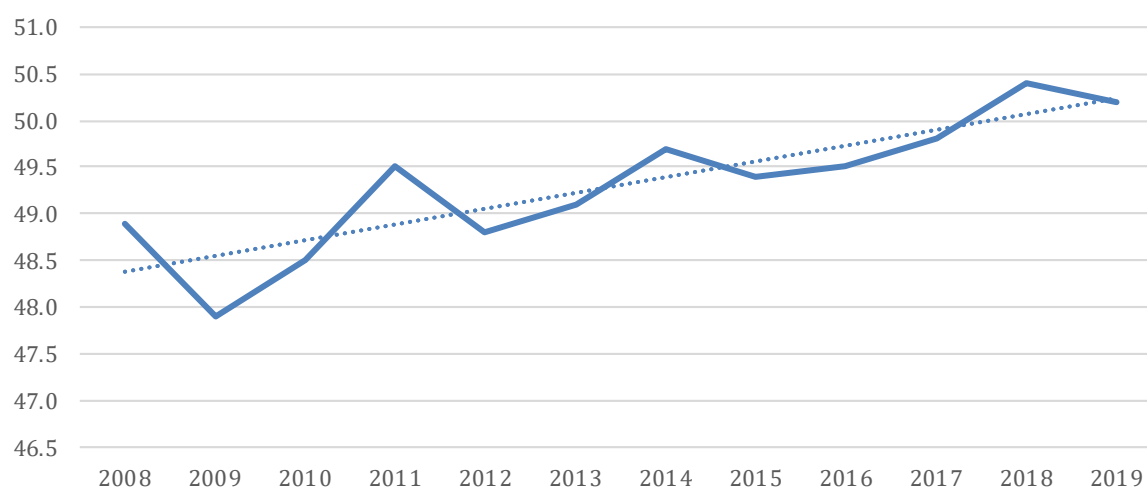
The MPCA used each model year's footprint-emission-rate relationship as exemplified in Figure 4 to determine an average CO₂ emission rate for passenger cars and light-duty trucks based on an average footprint size. We assumed an average footprint size for each vehicle type using U.S. EPA trend data²⁶ on light-duty vehicle sales. The average footprint size of all new LDVs sold over the last eleven model years has hovered between 47.9 and 50.4 square feet, and has increased, on average, by about 0.2% annually (Figure 5). Preliminary EPA estimates for MY 2019 passenger car and light-duty truck average footprint sizes are 46.7 and 53.6 square feet, respectively. These values were projected through MY 2034 at a 0.2% annual growth rate. This growth rate is consistent with the current general U.S. trend of

²⁶ EPA 2018 Vehicle Trends Report data, T.3.5, <https://www.epa.gov/automotive-trends/download-data-automotive-trends-report>

larger light-duty vehicles making up increasing percentages of all light-duty vehicle sales. We assumed average footprint sizes of new light-duty vehicle sales to be the same in the Reference and Clean Cars scenario.

Figure 5: Average U.S. new vehicle footprint size with “best-fit” line

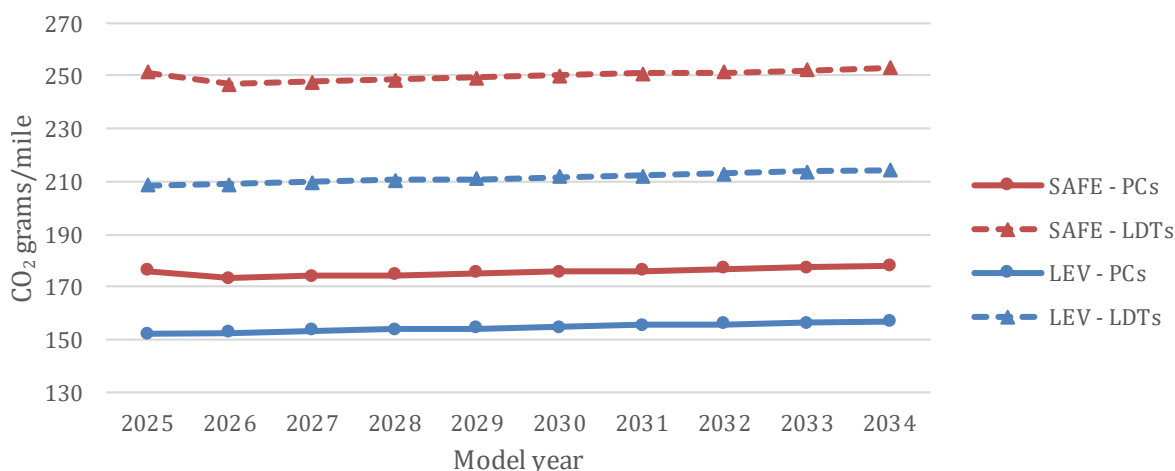
A vehicle’s “footprint” (the area between the points where its wheels touch the ground) determines its CO₂ emission limit. Vehicles with larger footprints are allowed to emit more CO₂ per mile. The average footprint size of light-duty passenger vehicles has been increasing over time.



As discussed in section 2(A), emissions rates in the Reference scenario plateau after MY 2026 and those in the Clean Cars scenario plateau after MY 2025. The underlying assumption of an increasing average footprint size for both vehicle types therefore resulted in a very slight increase in emissions rates in both scenarios after the model years in which they plateau (Figure 6). Across all model years, passenger car CO₂ emissions rates in the Clean Cars scenario were, on average, 12% lower than those in the Reference scenario; light-duty trucks emissions rates were 16% lower.

Figure 6: CO₂ emission rates by ICE vehicle type and scenario

Proposed federal SAFE standards for CO₂ emissions (red) plateau after MY 2026, while LEV standards (blue) plateau after MY 2025. The MPCA’s assumed emission rates increase very slightly over time because of the assumption that the average vehicle size (footprint) would increase slightly over time. Larger vehicles are allowed to emit more per mile.



This analysis assumes manufacturers would comply exactly with their sales-weighted fleet-average emissions standard and does not take into account the number or percentage of individual vehicle models produced that may over-comply with their applicable CO₂ emissions limits. Additionally, since manufacturers are allowed to include EVs, which have no tailpipe emissions, when calculating their fleet-wide average, the fleet-average system effectively allows internal combustion engine vehicles to emit slightly more, on average, as more EVs are produced. This means more EVs produced under a ZEV rule does not necessarily mean a greater CO₂ benefit. Therefore we did not include any additional CO₂ benefits from increased EV sales. While in practice, manufacturers may not comply exactly with the standards and may even over-comply, the MPCA determined it was not practical to attempt to estimate over-compliance and that estimating the emissions benefits of exact compliance provides a reasonable, but conservative estimate of benefits.

Particulate matter

In contrast to CO₂ tailpipe emissions standards, PM standards are enforced on a per-vehicle basis, rather than as a fleet-average. As a result, more EVs produced under a ZEV rule would have an additional emissions benefit, which we considered in our analysis.

Tailpipe PM emissions rates in the Reference scenario were held at 0.03 grams/mile for all model years, since this is the federal particulate emissions standard. Comparatively, LEV particulate emissions standards require manufacturers to certify 100% of their fleet to the same 0.03 grams/mile in MY 2024, but from MYs 2025 to 2028, require manufacturers to certify increasing percentages of their light-duty fleet to 0.01 grams/mile. In the analysis, we treated the LEV PM standards like a fleet-average standard for MYs 2024-2027, while the phase-in is taking place. In MY 2028, LEV requires 100% of a manufacturer's fleet to meet the 0.01 grams/mile standard.²⁷ PM emissions benefits for model year vehicles 2028-2034 were therefore evaluated on a per-vehicle basis, rather than as a fleet-average. Tailpipe particulate emissions rates inputs for the Clean Cars scenario are listed in Table 4, which were based on LEV's required fleet percentages certified to the 0.03 and 0.01 grams/mile standard.

Table 4: PM emission rates

²⁷ California LEV Regulations, section 1961.2(a)(2)(A), "Particulate Standards for Passenger Cars, Light-Duty Trucks, and Medium-Duty Passenger Vehicles".

Model year	Reference scenario	Clean Cars scenario
2025	0.03	0.025
2026	0.03	0.02
2027	0.03	0.015
2028+	0.03	0.01

Federal PM emission standards remain at 3 milligrams per mile, while LEV standards become more stringent over time.

We assumed that 88% and 89% of PM emissions from passenger cars and light-duty trucks, respectively, would be particulate matter with a diameter of 2.5 micrometers or less (PM_{2.5}) in size, in order to determine a PM_{2.5} reduction estimate for the health and equity analysis in Section 4. These percentages are consistent with what is used in the EPA MOVES model.

NMOG + NO_x

The MPCA held the NMOG + NO_x tailpipe emission rates for passenger cars and light-duty trucks equal in the Reference and Clean Cars scenarios because the federal and LEV standards for those pollutants are the same and the federal standards for those pollutants were not changed in the final SAFE rule.²⁸ Therefore, there are no estimated reductions of these pollutants from vehicle tailpipe emissions between the Reference scenario and the Clean Cars scenario. All estimated emissions benefits of these pollutants reported in this analysis are from reductions in upstream emissions.

ii. Fuel economy and upstream emissions rates

This section (ii) describes emissions from the extraction, transportation, and production of both liquid fuels and fuels used in electricity generation.

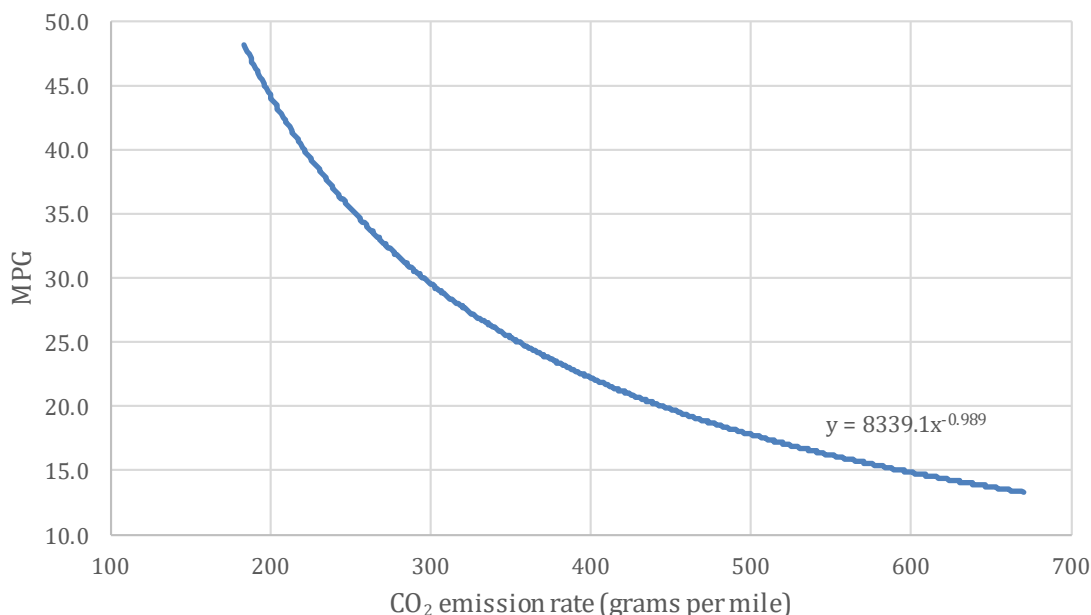
Upstream emissions from ICE vehicles' gasoline usage are dependent on a vehicle's fuel economy (miles per gallon). GHG emissions standards typically result in improvements in fuel economy because that is the primary way to reduce GHG emissions from ICE vehicles. The following equation, which is also shown on the graph in Figure 7, was used to estimate fuel economy based on CO₂ emissions rates:

$$mpg = 8,339.1 \times (CO_2 \text{ grams emitted per mile})^{-0.989}$$

Figure 7: CO₂ tailpipe emission rate conversion to mpg

As CO₂ emission standards become more stringent (move to the left on the x-axis), fuel economy improves (miles per gallon gets higher).

²⁸ California LEV Regulations, section 1961.2(b)(1)(A), "Fleet Average NMOG + NOX Requirements for Passenger Cars, Light-Duty Trucks, and Medium-Duty Passenger Vehicles".



This equation was derived using EPA data on real-world CO₂ grams emitted per mile and its relationship with real-world fuel economy.²⁹ The fuel economy estimate that resulted from converting the CO₂ emission rate to miles per gallon (MPG) was used to estimate fuel savings in Section 3 of this analysis about the costs and benefits to Minnesota consumers.

The MPCA used data from Argonne National Laboratory’s Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool 2018 to calculate upstream emissions rates from electricity generation and gasoline production.³⁰ AFLEET is a module of Argonne’s Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model. Upstream emissions rates for ICE vehicles are dependent on a vehicle’s fuel usage and its fuel economy (miles per gallon). The more fuel efficient a vehicle, the less fuel it uses. The less fuel is used, the less gasoline production is required, meaning lower emissions upstream. Similarly, upstream electricity generation emission rates for EVs were based on mile per kWh of charge.

The MPCA used AFLEET gasoline assumptions to estimate upstream emissions from ICE vehicles. AFLEET assumes a 10% ethanol blend for gasoline; therefore, when this analysis refers to “gasoline” it means a 10% ethanol-gasoline blend (E10). The MPCA assumed the gasoline blend would be the same in the Reference and Clean Cars scenarios since the proposed rule does not affect biofuels standards. The MPCA also held the 10% blend constant for each year of the analysis based on existing regulations.

AFLEET’s upstream emission data from gasoline production activities (e.g. extraction, transportation, refining, etc. of materials) is given in grams emitted per million British thermal units (mmBtu) of gasoline produced.³¹ Since our analysis was dependent on a gram/mile emission rate, we used the standard conversion of 112,194 Btu per gallon of gasoline and a vehicle’s fuel economy to convert AFLEET’s

²⁹ EPA 2018 Vehicle Trends Report data, T.3.1, <https://www.epa.gov/automotive-trends/download-data-automotive-trends-report>

³⁰ The AFLEET 2018 spreadsheet tool can be downloaded at <https://greet.es.anl.gov/afleet-tool>.

³¹ A British thermal unit is a measure of the heat content of fuels or energy sources. One Btu is the amount of heat, or energy, needed to increase the temperature of a pound of water by one degree Fahrenheit.

upstream emission rates from grams/mmBtu to a gram per mile equivalent.

Similarly, AFLEET upstream electricity generation emission data is given as grams emitted per million British thermal units (mmBtu) of electricity used, and includes the range of activities involved in electricity generation (extraction, transportation, and burning of fuels). Using the standard conversion of 3,412.1 Btu per kWh, we converted AFLEET's upstream electricity generation emission rates from grams/mmBtu to a gram per mile equivalent. The MPCA assumed an average of 3.4 miles/kWh for electric vehicles.³²

To estimate future emissions from electricity generation in Minnesota, the MPCA relied on projections and modeling conducted for two earlier evaluations: Minnesota Environmental Quality Board's Climate Strategies and Economic Opportunities (CSEO) analysis and MPCA's evaluation of U.S. EPA's Clean Power Plan in Minnesota. The MPCA's projected average electricity generation mix is shown in Table 5; each year's row gives the percentage of electricity assumed to be generated from each source. Since MPCA's evaluation of the Clean Power Plan was only completed through 2030, the 2030 mix was used for all subsequent years.

The historic and forecasted emissions in CSEO reflected electricity generation and planning in 2013. To evaluate the impacts of the Clean Power Plan, the CSEO analysis was revised to include proposed generation projects in Minnesota. Future projections of air emissions from Minnesota electric generation under the Clean Power Plan was completed in 2016, and included Xcel Energy's plans for coal plant closures in their 2015 integrated resource plan.³³

Table 5: Projected Minnesota electricity generation mix

Model year	Residual oil	Natural gas	Coal	Nuclear power	Biomass	Others (wind, solar, hydro, etc.)
2025	0.3%	13.3%	31.3%	20.9%	2.5%	31.7%
2026	0.2%	13.8%	29.4%	21.3%	2.4%	32.9%
2027	0.2%	20.1%	24.0%	20.4%	2.2%	33.1%
2028	0.2%	19.0%	23.9%	20.7%	2.2%	34.0%
2029	0.2%	21.1%	22.8%	19.7%	1.7%	34.5%
2030	0.2%	20.8%	22.4%	19.7%	1.7%	35.1%
2031	0.2%	20.8%	22.4%	19.7%	1.7%	35.1%
2032	0.2%	20.8%	22.4%	19.7%	1.7%	35.1%
2033	0.2%	20.8%	22.4%	19.7%	1.7%	35.1%
2034	0.2%	20.8%	22.4%	19.7%	1.7%	35.1%

MPCA estimated that over time a greater proportion of electricity will be generated from renewables (Other) and natural gas, while proportions from all other sources would decline. Since renewables emit less than other sources, emissions from electricity generation to power an electric vehicle will decrease over time.

³² Based on data from the US Department of Energy Alternative Fuel Data Center, <https://afdc.energy.gov/>

³³ CSEO documentation: <https://www.eqb.state.mn.us/sites/default/files/documents/CCS%20Appendix%20with%20policy%20details%20and%20results.pdf>

C. Emissions benefit results

The following sections describe the estimated emissions impacts of the proposed rules. The results also include several sensitivity analyses that help describe the range of impacts that might result from the proposed rules. This section (C) describes the results of the MPCA's emissions analysis. The previous section (B) describes the data and inputs used to develop the emissions estimates.

i. Greenhouse gas benefits

The MPCA estimates the first 10 model years of implementation of the proposed rule would result in a GHG emissions reduction of 8.4 million tons total, well-to-wheel, measured in carbon dioxide equivalents (CO₂e), of which 7.1 million tons would be reduced from vehicle tailpipes.

The Next Generation Energy Act (NGEA), passed by the Minnesota Legislature in 2007, set interim and long-term goals for the reduction of GHG emissions in the state. NGEA established a goal for 2050 of an 80% reduction in GHG emissions from 2005 emission levels. To compare to sectors as identified in MPCA's GHG emissions inventory and to the NGEA goals, we must look just at tailpipe emissions.³⁴ The proposed rule is estimated to result in a reduction of 1.2 million tons of tailpipe GHG emissions in the year 2034, which equates to a 2.7% reduction from 2005 transportation GHG emission levels, and a 3.5% reduction from 2005 levels of surface transportation emissions.

While the LEV standard is a GHG emissions standard, not a fuel economy standard, the primary method for reducing GHG emissions from vehicles is to improve fuel economy. The MPCA estimates that the proposed rules would also result in a total upstream GHG emissions reduction of 1.3 million tons over the 10 years leading up to 2034 from a reduction in upstream liquid fuel extraction, transportation, and production, even after considering the upstream emissions from electricity generation to power additional EVs. The reduced upstream emissions from liquid fuels would be the result of decreased fuel demand caused by the increased fuel economy of average LEV-certified vehicles compared to average federally-certified vehicles. The MPCA also estimated emissions associated with electricity generation used to power EVs and the extraction, processing, and transportation of the fuel used for that generation. Since the emissions from gasoline and electricity extraction and production may not necessarily occur in Minnesota, these emissions benefits cannot be compared to the NGEA goals or the MPCA's GHG emissions inventory. The MPCA considered these emissions separately from vehicle tailpipe emissions, which we can reasonably assume would mostly occur in Minnesota and can thus be compared with the MPCA's GHG inventory and the NGEA goals. However, GHGs are a global pollutant – emissions anywhere have the same impact everywhere. For that reason, it is important to consider upstream GHG benefits as well as local GHG benefits.

Emissions benefits of the proposed rules accumulate over time, since each year old vehicles with higher emissions are replaced by either lower-emitting LEV-certified ICE vehicles, BEVs, or PHEVs. Each year's emissions benefit, therefore, is greater than the previous year's, until about the mid-2040s (see section 2(C)(iii)). Figure 8 and Table 6 show how estimated well-to-wheel GHG emissions benefits grow over time. The MPCA's analysis estimates that by 2034 annual well-to-wheel net GHG emissions benefits would be 1.4 million tons.

³⁴ MPCA's GHG inventory captures emissions where they are produced. So emissions from the power sector are attributed to the power sector, no matter the end use of the electricity. Emissions from the production of gasoline are attributed to the point at which they occur.

Figure 8: GHG emissions costs and benefits from the proposed rules over time (with average electricity generation mix)

CO₂e emissions benefits from the proposed rules accumulate over time, since each year old vehicles are replaced by lower-emitting, more fuel-efficient LEV-certified ICE vehicles, BEVs, or PHEVs. Even with an estimated increase in GHG emissions from electricity generation for additional EVs required by the rules, emissions benefits from tailpipes and a reduction in gasoline production vastly exceed emissions costs. The net cumulative well-to-wheel CO₂e emissions benefit of the rules is estimated to be 8.4 million tons reduced over the first 10 years of implementation.

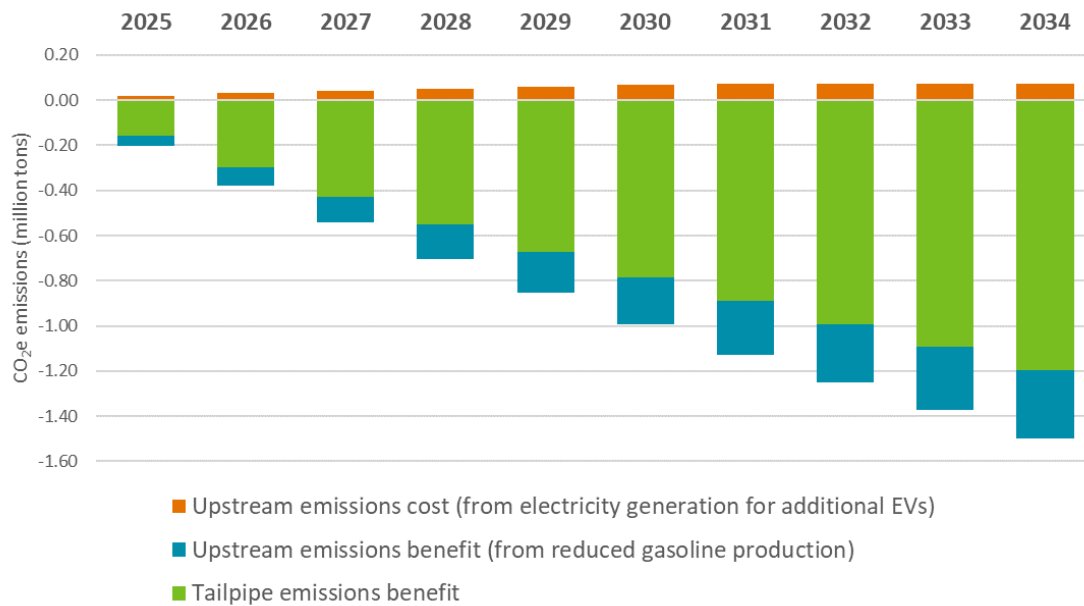


Table 6: GHG emissions costs and benefits from the proposed rules over time (with average electricity generation mix) in million tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	-0.16	-0.30	-0.43	-0.55	-0.67	-0.79	-0.89	-0.99	-1.09	-1.20
Upstream emissions benefit (from reduced gasoline production)	-0.04	-0.08	-0.12	-0.15	-0.18	-0.21	-0.24	-0.26	-0.28	-0.30
Upstream emissions cost (from electricity generation for additional EVs)	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.07	0.08	0.07

ii. Projected greenhouse gas benefits beyond 2034

GHG emissions benefit estimates from the proposed rule begin in MY 2025, the first model year the proposed rule could potentially be implemented, and grow each subsequent year as each year more of the older, higher-polluting vehicles are replaced with LEV-certified ICE vehicles, BEVs, and PHEVs, and the vehicles sold in previous years since implementation began continue to emit at a lower rate than they would without the standards in place. Estimated annual emissions benefits for MYs 2025-2034, when plotted on a graph, perfectly fit a negative quadratic curve (a downward-opening u-shaped curve). Using the equation of the quadratic curve in which they fit, we projected GHG emissions benefits beyond 2034 up to the maximum annual benefit. The model year in which the maximum annual tailpipe emissions benefit occurs is 2052. This result is consistent with when we would expect complete fleet turnover to occur: there would be about 25-30 years of implementation before all passenger vehicles operating on the roads would be either LEV-certified or an EV.

Maximum annual projected tailpipe GHG reductions beyond 2034 are estimated to be 2.0 million tons annually, equating to a 5.9% reduction from 2005 surface transportation emissions.

While the MPCA focused our analysis on the first 10 years of implementation of the proposed rules, it is important to note the fact that estimated annual GHG emissions benefits are still increasing at the 2034 model-year mark.

iii. Emissions benefits of other air pollutants

The federal and LEV NMOG + NO_x tailpipe emission standards are equivalent; the SAFE rule does not change the federal passenger car and light-duty truck emissions standards for non-GHG pollutants. Therefore, our analysis assumes equal NMOG + NO_x tailpipe emissions rates in the Clean Cars scenario and the Reference scenario. However, LEV PM standards become more stringent than federal PM standards starting in MY 2025 and grow increasingly stringent until MY 2028. Our analysis also considers upstream NMOG + NO_x and PM emissions from electricity generation and fuel production.

As with GHGs, emissions benefits of NMOG + NO_x and PM from the proposed rules grow over time, since each year old vehicles with higher emissions are replaced by either lower-emitting LEV-certified ICE vehicles, BEVs, or PHEVs. MPCA's analysis indicates that implementation of the proposed rules

together would result in an annual well-to-wheel emission reduction of 998 tons of NMOG + NO_x and 637 tons of PM in 2034. These well-to-wheel emissions reductions equate to 6,059 tons of NMOG + NO_x and 3,245 tons of PM reduced over the first 10 years of the rule. Over the first 10 years, our analysis estimates the proposed rules would reduce PM tailpipe emissions by 3,032 tons. These results are presented in Figures 9 and 10 and Tables 7 and 8. It is particularly important to consider tailpipe emission reductions because of the immediate exposure that these emissions have to human populations.

Figure 9: NMOG + NO_x emissions costs and benefits from the proposed rules over time (with average electricity generation mix)

NMOG + NO_x emissions benefits from the proposed rules accumulate over time, since each year old vehicles are replaced by more fuel-efficient LEV-certified ICE vehicles, BEVs, or PHEVs. Even with an estimated increase in NMOG + NO_x emissions from electricity generation for additional EVs required by the rules, emissions benefits from a reduction in gasoline production vastly exceed emissions costs. The net cumulative well-to-wheel NMOG + NO_x emissions benefit of the rules is estimated to be 6,059 tons reduced over the first 10 years of implementation.

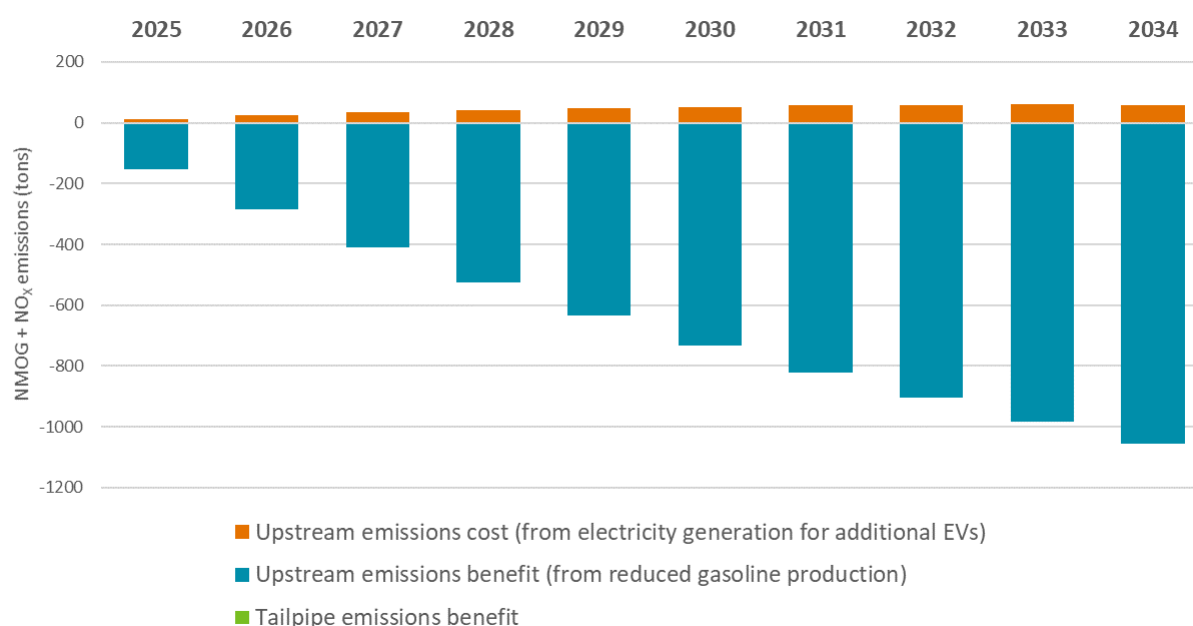


Table 7: NMOG + NO_x emissions costs and benefits from the proposed rules over time (with average electricity generation mix) in tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upstream emissions benefit (from reduced gasoline production)	-153.2	-284.7	-409.4	-526.3	-634.6	-733.4	-823.1	-905.0	-981.9	-1056.9

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Upstream emissions cost (from electricity generation for additional EVs)	13.3	24.3	34.0	41.6	48.3	52.9	56.8	59.1	59.8	59.0

Figure 10: PM emissions costs and benefits from the proposed rules over time (with average electricity generation mix)

PM emissions benefits from the proposed rules accumulate over time, since each year old vehicles with higher emissions are replaced by either lower-emitting LEV-certified ICE vehicles, BEVs, or PHEVs. Even with an estimated increase in PM emissions from electricity generation for additional EVs required by the rules, emissions benefits from tailpipe emissions and a reduction in gasoline production vastly exceed those emissions costs. The net cumulative well-to-wheel PM emissions benefit of the rules is estimated to be 3,245 tons reduced over the first 10 years of implementation.

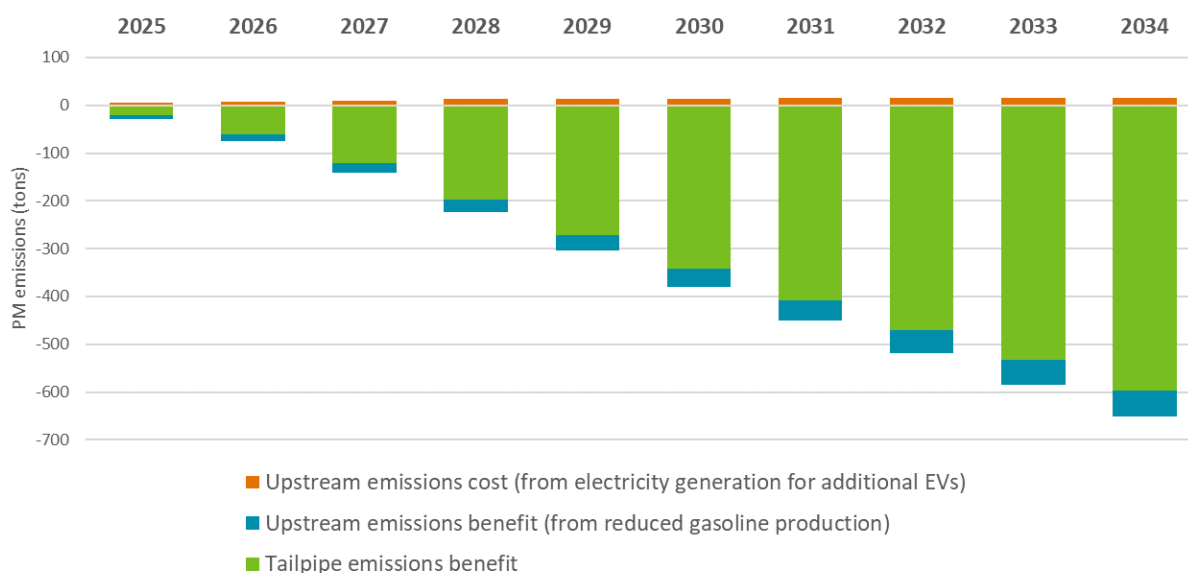


Table 8: PM emissions costs and benefits from the proposed rules over time (with average electricity generation mix) in tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	-20.6	-60.9	-120.1	-198.7	-273.3	-343.6	-409.8	-472.9	-534.8	-597.7
Upstream emissions benefit (from reduced gasoline production)	-8.0	-14.9	-21.4	-27.5	-33.1	-38.3	-43.0	-47.3	-51.3	-55.2

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Upstream emissions cost (from electricity generation for additional EVs)	4.6	8.4	10.3	12.9	13.1	14.3	15.4	16.0	16.2	16.0

More stringent GHG emissions standards typically result in improvements in fuel economy, which means less fuel is used by a vehicle, and less frequent refueling frequent. Volatile organic compounds (VOCs) are emitted during the refueling process. While the MPCA did not quantify the emission benefits from reduced refueling, there would be additional emissions and health benefits associated with less frequent refueling and less exposure to emissions at gas stations.

iv. Sensitivity analyses

This section (iv) describes additional analyses that the MPCA conducted by adjusting certain inputs into the analysis to understand how emissions benefits might change under different future scenarios.

Sensitivity: proportion of passenger cars versus light-duty trucks

In both the Reference and Clean Cars scenarios, our analysis assumes the make-up of annual new vehicle sales to be 25% passenger cars and 75% light-duty trucks for all future model years. Auto Alliance vehicle sales data, covering MYs 2014-2018, provided to the MPCA showed an annually decreasing car production share. The car production share is the percentage of new light-duty vehicle sales that are cars versus light-duty trucks. Car production share started at 40% in MY 2014 and ended at about 21% in MY 2018. The MPCA held a 25%/75% split constant for all future model years instead of continuing a downward trend. This decision was made because while the Auto Alliance data covered just four model years of data, national EPA data³⁵ going back to 1975 showed periods of both increasing and decreasing car production shares. This data suggests it is difficult to predict with any degree of certainty what the car production share will be each model year compared to the last, especially over the next 14 years. It is not reasonable to assume the dramatic annual decrease car production share in the Auto Alliance data would continue, especially since it would result in a car production share of about 0% in 2024.

However, during the Request for Comments period, MPCA heard comments that the actual current percentage of total sales that are passenger cars could be as low as 20%, with 80% light-duty trucks sales.³⁶ The MPCA therefore conducted a sensitivity analysis to understand how emissions benefit would change based on different levels of car and light-duty truck production shares. A 20% car production share results in an additional 0.2 tons of tailpipe GHG emissions benefit over the first ten years of implementation, which increases the GHG 10-year emissions benefit by about 3%. The reason for the increased GHG emissions benefit is that the difference between emissions from a LEV-certified light-duty truck and a federally certified light-duty truck is greater than the difference between emissions from a LEV-certified passenger car compared to a federally certified passenger car. Passenger car CO₂

³⁵ EPA 2018 Vehicle Trends Report data, T.3.1, <https://www.epa.gov/automotive-trends/download-data-automotive-trends-report>

³⁶ Comment by MADA made during the RFC period, at page 3 (December 6, 2019)

emissions rates in the Clean Cars scenario are 12% lower than those in the Reference scenario and light-duty trucks emissions rates are 16% lower, so there is a greater reduction achieved for every LEV-certified light-duty truck sold than a LEV-certified passenger car. Assuming a 25%/75% split for all future model years, therefore, may provide a conservative estimate of GHG emissions benefits.

Sensitivity: Marginal fuel mix

In both the Reference and Clean Cars scenarios, the MPCA estimated upstream and well-to-wheel emissions impacts of electricity generation to fuel EVs based on the average mix of electricity generation sources in Minnesota. Table 5 in section 2(B)(ii) gives the projected annual average mixes of oil, natural gas, coal, nuclear, biomass, and renewables used in the analysis.

An alternative method for evaluating power sector emissions related to the adoption of EVs is to use the marginal fuel mix. The “marginal fuel” refers to the energy source that is brought on to the grid at any moment to power additional demand for electricity. In Minnesota, currently the marginal fuel is most often coal and natural gas, and occasionally wind. To consider the worst-case upstream emissions impacts, one in which the emissions from EVs are attributed to those from the marginal fuel rather than the average mix, the MPCA analyzed a scenario assuming 50% of the electricity for EVs might come from coal and 50% from natural gas. There are not existing projections for future marginal fuels, so this assumption was based on data from the Minnesota Department of Commerce on MISO marginal fuels in 2017 and excludes wind energy in order to represent a worst-case scenario.

Using this fuel mix, the accumulated 10-year GHG upstream emissions benefit is reduced by 53%, from 1.3 million tons to 0.6 million tons. This reduces the 10-year GHG well-to-wheel emissions benefit from 8.4 to 7.7 million tons, and the 2034 GHG well-to-wheel benefit from 1.4 to 1.3 million tons (Figure 11 and Table 9). **Despite this reduction in benefit, the analysis shows a net upstream GHG benefit of the proposed rule because the increased emissions from electricity generation do not exceed the reduction in emissions from reduced liquid fuel production.** Similarly, upstream NMOG+NO_x and PM benefits would still be positive when using the worst-case fuel mix, but are reduced by 7% and 3%, respectively (Figures 12 and 13 and Tables 10 and 11).

These estimates represent a worst-case upstream emissions scenario for several reasons: the electricity grid is expected to get cleaner over time, which means that the marginal fuel will likely be cleaner over time as well; excluding wind most likely underestimates its influence as a marginal fuel; and it is likely that, because of population, a majority of EV sales would occur in the Twin Cities metropolitan area, which is largely in Xcel Energy’s service territory, which generally has a cleaner marginal mix than the rest of the state.

Figure 11: GHG emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix)

Using a worst-case marginal fuel mix (instead of an average) of 50% coal and 50% natural gas to estimate the upstream emissions costs from electricity generation for additional EVs required by the rules reduces the overall 10-year well-to-wheel GHG emissions benefit from 8.4 to 7.7 million tons. Despite this reduction in benefit, emissions from electricity generation do not exceed the tailpipe and gasoline production GHG emissions benefits.

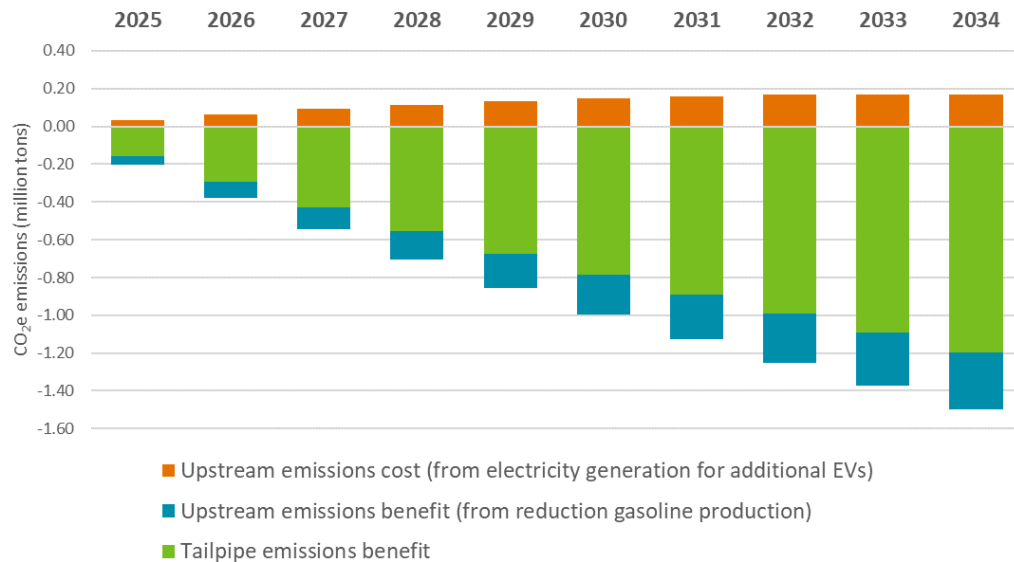


Table 9: GHG emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix) in million tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	-0.16	-0.30	-0.43	-0.55	-0.67	-0.79	-0.89	-0.99	-1.09	-1.20
Upstream emissions benefit (from reduced gasoline production)	-0.04	-0.08	-0.12	-0.15	-0.18	-0.21	-0.24	-0.26	-0.28	-0.30
Upstream emissions cost (from electricity generation for additional EVs)	0.03	0.06	0.09	0.12	0.13	0.15	0.16	0.17	0.17	0.17

Figure 12: NMOG + NO_x emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix)

Using a worst-case marginal fuel mix (instead of an average) of 50% coal and 50% natural gas to estimate the upstream emissions costs from electricity generation reduces the overall 10-year well-to-wheel NMOG + NO_x emissions benefit from 6,059 to 5,618 tons. Despite this reduction in benefit, emissions from electricity generation do not exceed emissions benefits from reduced gasoline production.

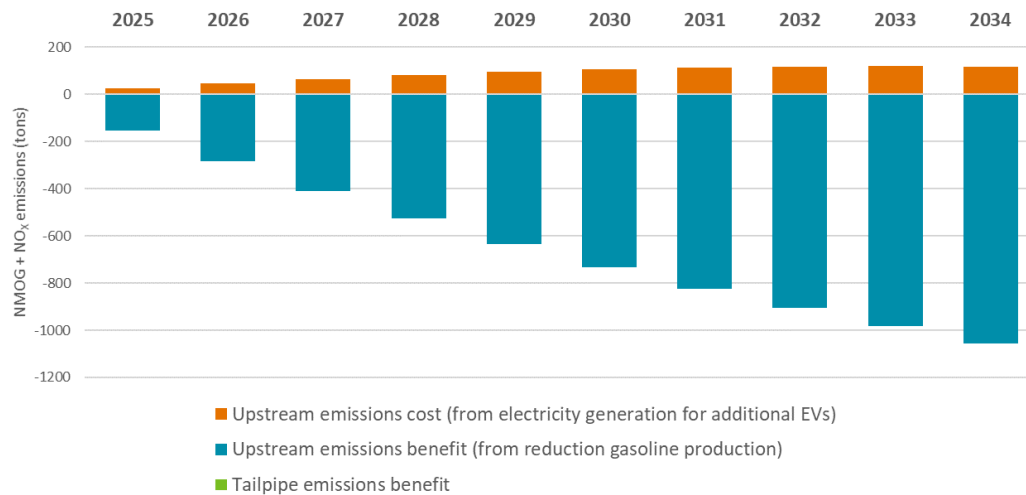


Table 10: NMOG + NO_x emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix) in tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upstream emissions benefit (from reduced gasoline production)	-153.2	-284.7	-409.4	-526.3	-634.6	-733.4	-823.1	-905.0	-981.9	-1056.9
Upstream emissions cost (from electricity generation for additional EVs)	24.3	46.1	65.3	81.8	95.5	106.4	114.1	118.7	120.1	118.6

Figure 13: PM emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix)

Using a worst-case marginal fuel mix (instead of an average) of 50% coal and 50% natural gas to estimate the upstream emissions costs from electricity generation reduces the overall 10-year well-to-wheel PM emissions benefit from 3,245 to 3,238 tons.

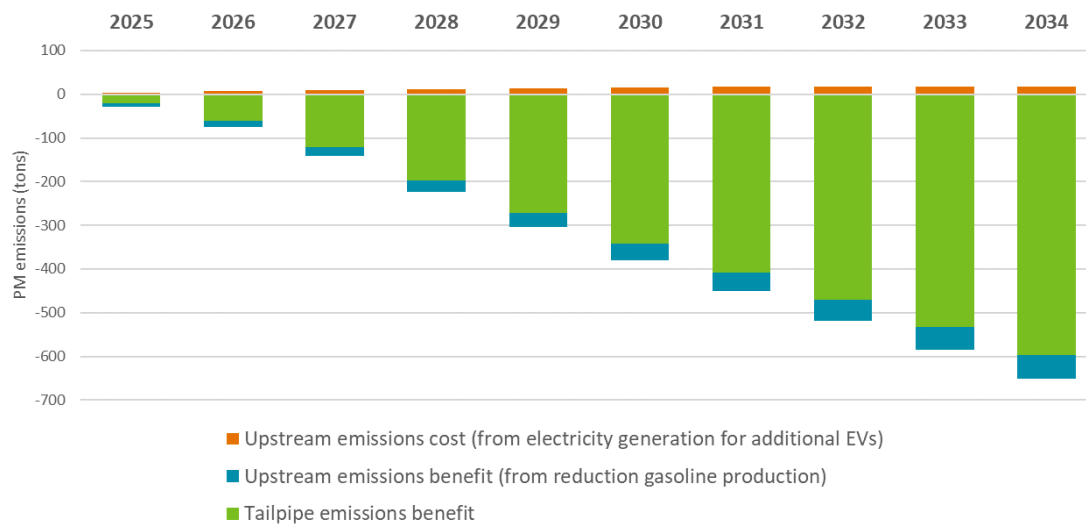


Table 11: PM emissions costs and benefits from the proposed rules over time (with marginal electricity generation mix) in tons

Model year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Tailpipe emissions benefit	-20.6	-60.9	-120.1	-198.7	-273.3	-343.6	-409.8	-472.9	-534.8	-597.7
Upstream emissions benefit (from reduced gasoline production)	-8.0	-14.9	-21.4	-27.5	-33.1	-38.3	-43.0	-47.3	-51.3	-55.2
Upstream emissions cost (from electricity generation for additional EVs)	3.6	6.9	9.8	12.3	14.4	16.0	17.2	17.8	18.1	17.8

3. Costs and benefits to Minnesota consumers

Adoption of the proposed rule would result in economic impacts to Minnesota consumers. Individuals purchase new vehicles as do a wide variety of organizations, including businesses, non-profit organizations, and all levels of government. All of these groups would experience essentially the same per-vehicle costs and benefits.

The MPCA analyzed the economic impacts of the proposed LEV and ZEV standards separately. Each would have economic impacts on new vehicle purchasers. The mechanisms for these impacts would be different for the LEV standard compared to the ZEV standard. Hence, this analysis first evaluates the likely costs and benefits of the LEV standard for purchasers and then considers the likely additional costs and benefits of ZEV standard. In other words, the Reference scenario for the LEV standard analysis is a future Minnesota without the LEV standard and with the anticipated federal standards instead, while the Reference scenario for the ZEV standard analysis is a future Minnesota with a LEV standard already in place.

A. LEV standard consumer impact analysis

As with the emissions analysis, this economic analysis assesses the costs and benefits of the proposed LEV standard (Clean Cars Minnesota scenario) compared with the costs and benefits of the federal SAFE rule. As described above in Section 2, the final SAFE rule reduces the stringency of federal GHG emissions standards for MYs 2021 through 2026.

The analysis of consumer costs and benefits from adoption of the LEV standard was conducted based on analysis underlying the EPA's January 2017 Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation and the proposed SAFE rule as published in August 2018. This data was the best available when the MPCA was developing our analysis. On April 30, 2020, EPA and NHTSA published in the Federal Register their final SAFE rule and related regulatory analysis. The MPCA examined our existing analysis against data provided in the final SAFE rule Final Regulatory Impact Analysis and found that the conclusions of that review to be very close to the conclusions of our existing analysis. In fact, the comparison indicated that the conclusions of our existing analysis featured here were smaller than the conclusions drawn from the final SAFE rule regulatory analysis and thus it is possible that the MPCA's analysis may be under-predicting the benefits of the LEV standard. Since the conclusions were similar and ours were conservative compared to the alternative methods, the MPCA determined it was not necessary to re-run our entire analysis to update it based on the final SAFE rule regulatory analysis. Results from this review are included in the following analysis.

The costs and benefits of complying with the current GHG standards for MY 2022-2025 and beyond have already been exhaustively analyzed in the various technical analyses conducted prior to the January 2017 Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation (hereafter, "January 2017 Final Determination")³⁷ and in the subsequent Preliminary Regulatory Impact Analysis (PRIA) supporting the SAFE Rule.³⁸ As the primary source for expected costs to consumers of the LEV standard in Minnesota, we considered both the analysis in the January 2017 Final Determination as well as in the SAFE Rule PRIA. After thorough review of these two data sources, we deemed the January 2017 Final

³⁷ Available at: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100QQ91.pdf>

³⁸ Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf

Determination as the more reasonable and credible source. The analysis supporting the proposed SAFE rule has been widely criticized, including by the EPA's own Science Advisory Board,³⁹ as well as by the National Association of Clean Air Agencies⁴⁰ and a consortium of 26 states and U.S. cities that includes Minnesota.⁴¹

Given the general acceptance of the credibility of the January 2017 Final Determination analysis, the MPCA deemed the costs and benefits derived from the technical analysis underlying the January 2017 Final Determination to be the most reasonable source for economic impact analysis in Minnesota. The data from this analysis has been customized using Minnesota-specific historical data and future projections regarding light-duty vehicle sales, the mix between passenger cars and light-duty trucks in Minnesota, expected VMT per vehicle in Minnesota, and projected gasoline prices in Minnesota.

On April 30, 2020, EPA and NHTSA published the final Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks⁴² as well as a Final Regulatory Impact Analysis (FRIA)⁴³ for the rule that, among other things, analyzed the impacts on consumers of rolling back the previous standards. In addition to the January 2017 Final Determination, the MPCA has considered the analysis of costs and benefits to consumers in the SAFE FRIA. The MPCA uses the data from the January 2017 Final Determination as our core analysis because that data and analysis has undergone thorough review and is broadly accepted as reasonable. The SAFE FRIA data and analysis are very recent, very different from the PRIA, and have not undergone thorough peer review. For these reasons, the MPCA includes analysis of the costs and benefits of the Clean Cars Minnesota rule using the data from the FRIA as an alternative sensitivity to help understand the full range of potential costs and benefits of the proposed rule.

In order to meet the LEV GHG emissions standards, manufacturers would need to use additional advanced technologies. Employing these advanced technologies would probably increase the costs of manufacturing vehicles relative to what would be required under the SAFE Rule. Consistent with the analyses for the January 2017 Final Determination, in this analysis the MPCA assumes all of the per-vehicle technology costs would be passed along to new vehicle purchasers.

While the LEV standards and the current federal standards establish GHG emissions standards by model year, they do not prescribe the technologies that must be used in order to meet these standards. Rather, they provide the manufacturers with flexibility on which technologies to employ to meet the standards. This allows manufacturers to identify the most cost-effective options that can be employed for different vehicles to meet the standards. Additionally, the LEV standard (and the current federal rules) provide various other compliance flexibilities, including separate standards for trucks and cars, sliding compliance standards based on the size of the vehicles that a manufacturer sells, banking of credits, and trading of credits between manufacturers.

While these various flexibilities allow manufacturers to maximize the cost effectiveness of their compliance strategies, they create significant complexities in estimating the potential costs to comply with the applicable standards. To address these complexities, the EPA uses its own in-house developed vehicle technology/cost model, the Optimization Model for Reducing Emissions of Greenhouse Gases

³⁹ See: https://www.eenews.net/assets/2020/01/02/document_gw_06.pdf

⁴⁰ See: 4cleanair.org/sites/default/files/Documents/NACAA_COMMENTS-EPA_NHTSA_LDV_NPRM-102618.pdf

⁴¹ See: <https://oag.ca.gov/system/files/attachments/press-docs/states-and-cities-detailed-comments.pdf>

⁴² Available at: <https://www.govinfo.gov/content/pkg/FR-2020-04-30/pdf/2020-06967.pdf>

⁴³ Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/final_safe_fria_web_version_200330.pdf

from Automobiles (OMEGA) model.⁴⁴ The OMEGA model is optimized to calculate vehicle compliance costs based on the types of technologies used to achieve GHG emissions compliance, and the use of those technologies in a projected modeled fleet. EPA used the OMEGA model in the original 2012 rulemaking for MY 2017 and later light-duty vehicle GHG emissions standards as well as in the various analyses supporting the January 2017 Final Determination to determine the vehicle technology costs associated with complying with the federal and LEV GHG standards. These costs were determined for various model years, and were broken out as costs for cars, costs for light-duty trucks, and average costs per vehicle based on the national average car/truck fleet mix. We used these costs to generate average vehicle costs by model year of complying with the LEV standard in Minnesota relative to the SAFE Rule, using a Minnesota-specific car/truck fleet mix of 25%/75%. We then used these per-vehicle costs and applied them to estimated Minnesota new vehicle sales for MY 2025-2034. To determine new vehicle sales, we used MY 2019 sales data from the Auto Alliance, the most recent year for which complete and accurate new vehicle sales data is currently available. Future new vehicle sales were projected to grow or decline in each year from MY 2020 through MY 2034, in accordance with annual projections of Minnesota vehicle sales used in MnDOT's Pathways report.

As discussed in section 1(C), this analysis assumes the total number of light-duty vehicles sold in Minnesota are equal in both the Clean Cars Minnesota scenario and in the Reference scenario, since there is not clear evidence linking emissions standards, upfront costs of vehicles, fuel economy, or other specific factors with overall vehicle purchasing rates. The Minnesota new vehicle sales estimations for the time horizon of this analysis (MY 2025-2034) are presented in Table 12.

Table 12: Projected Minnesota new light-duty vehicle sales for passenger cars and light-duty trucks

Model year	Cars (number of vehicles)	Trucks (number of vehicles)	Fleet (number of vehicles)
2025	63,346	190,038	253,385
2026	62,776	188,328	251,104
2027	61,960	185,880	247,840
2028	60,845	182,534	243,379
2029	59,384	178,153	237,538
2030	57,662	172,987	230,649
2031	56,221	168,662	224,883
2032	55,658	166,975	222,634
2033	56,660	169,981	226,641
2034	59,267	177,800	237,067
TOTAL	593,779	1,781,338	2,375,118

From a starting point of MY 2019 new vehicle sales in Minnesota, the MPCA projects future model year sales based on projections used in MnDOT's Pathways report.

i. Estimated per-vehicle technology costs for the LEV standard

To determine the per-vehicle and cumulative vehicle technology costs to comply with the LEV standard in Minnesota based on the analysis supporting the January 2017 Final Determination, the MPCA started

⁴⁴ See: <https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases>

with the per-vehicle costs for cars and light-duty trucks listed in Table IV.4 of the Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation (hereafter, “Proposed Determination”).⁴⁵ As reflected in that table, the incremental costs of complying with the MY 2025 standards relative to the MY 2021 standards is \$749 for cars and \$1,018 for trucks.

Since the proposed SAFE rule would have frozen emissions standards at 2020 levels, to compare vehicle costs under a LEV standard to what would have been the case under the proposed SAFE rule, the MPCA needed to estimate the potential per-vehicle costs of the proposed LEV standard as it diverges from the proposed SAFE rule starting after MY 2020. Therefore, the Proposed Determination estimates are not sufficient for this analysis because they do not provide an annual estimation of incremental costs and do not start at MY 2020. First, to calculate the incremental cost of transitioning from MY 2020 to MY 2021 standards, the MPCA took the total incremental costs of meeting the MY 2021 standards, relative to the MY 2016 standard,⁴⁶ and divided by five, assuming a linear increase in costs during the five years from MY 2016–2021. Based on this calculation the incremental cost of going from MY 2020 to MY 2021 would be \$78 for cars and \$106 for trucks. We then summed these costs with the incremental costs from MY 2021 through MY 2025 to get a total incremental cost of transitioning from MY 2020 standards to MY 2025 standards. Assuming a linear increase, the MPCA calculated costs for MY 2022, MY 2023, and MY 2024. We then calculated the increased cost for an average Minnesota vehicle, a weighted average of 25% of new light-duty vehicles sold in Minnesota being passenger cars and 75% light-duty trucks. Table 13 lists the final per-vehicle technology costs for cars, trucks, and an average Minnesota vehicle.

Table 13: Projected per-vehicle technology costs (in 2018 dollars) for complying with LEV, based on the January 2017 Final Determination analysis

Model year	Cars	Light-duty trucks	Average Minnesota vehicle
2025	897	1,219	1,139
2026	897	1,219	1,139
2027	897	1,219	1,139
2028	897	1,219	1,139
2029	897	1,219	1,139
2030	897	1,219	1,139
2031	897	1,219	1,139
2032	897	1,219	1,139
2033	897	1,219	1,139
2034	897	1,219	1,139

⁴⁵ Proposed Determination at 38. Available at <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3DO.pdf>. As reflected in the January 2017 Final Determination, the EPA Administrator determined that no information was presented in public comments on the Proposed Determination that materially changed the analysis presented in the Proposed Determination therefore the Administrator relied on the Proposed Determination analysis in the January 2017 Final Determination (<https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100QQ91.pdf>). January 2017 Final Determination at 3.

⁴⁶ *Id.*

Once the LEV standards level off, starting in MY 2025, on average a Minnesota LEV-certified vehicle would entail \$1,139 higher technology costs relative to a vehicle certified under the proposed SAFE rule, which would be the equivalent of a vehicle certified under the current MY 2020 standards.

To calculate the cumulative vehicle technology costs of adopting the LEV standard, the MPCA multiplied the per-vehicle costs in Table 13 by the expected number of new vehicle sales listed in Table 12. These cumulative costs by model year and during the 10-year period from MY 2025-2034 are presented in Table 14.

Table 14: Projected cumulative technology costs for complying with the LEV standard, based on the January 2017 Final Determination analysis

Model year	Cars (millions of 2018 dollars)	Light-duty trucks (millions of 2018 dollars)	Fleet (millions of 2018 dollars)
2025	56.8	231.7	288.5
2026	56.3	229.6	285.9
2027	55.6	226.6	282.2
2028	54.6	222.5	277.1
2029	53.3	217.2	270.4
2030	51.7	210.9	262.6
2031	50.4	205.6	256.0
2032	49.9	203.5	253.5
2033	50.8	207.2	258.0
2034	53.2	216.7	269.9
TOTAL	532.6	2,171.5	2,704.1

Over 10 years, technology costs associated with complying with the LEV standard in Minnesota is expected to reach a total of \$2.7 billion more than the proposed SAFE rule.

Consistent with the analyses for the January 2017 Final Determination, the MPCA assumes that these technology costs would be passed on to new vehicle purchasers. There may be other costs that could be passed on to consumers beyond technology costs. For instance, there may be costs associated with dealers who currently trade with other dealerships outside of Minnesota. It is possible there would be additional transportation costs for trades since dealers in surrounding states would not be required to sell LEV-compliant vehicles. While this is a possibility, the MPCA has not found, and dealers did not submit during comments, information on how many trades Minnesota dealers engage in with dealers in surrounding states, whether the out-of-state dealers that engage in these trades would stock LEV-compliant vehicles in order to serve the Minnesota market, whether current out-of-state trades could be replaced with in-state trades, or what any potential increased costs would be for obtaining a vehicle from an out-of-state dealer that does stock LEV-certified vehicles, the manufacturer, or an in-state dealer. Thus, these potential costs cannot be reasonably quantified.

ii. LEV standard per-vehicle cumulative costs and benefits over vehicle lifetimes

As a result of the increased vehicle technology costs, vehicle purchasers would be likely to incur additional direct costs in the form of increased sales tax at the time of the purchase, and ongoing increases in the price of vehicle insurance and vehicle maintenance costs over the life of the vehicle. Offsetting these increased costs, however, GHG emissions standards typically result in fuel economy improvements, so vehicle purchasers are likely to realize ongoing fuel savings over the life of their vehicles.

EPA reports the per-vehicle consumer costs and fuel savings benefits of maintaining the MY 2022-2025 GHG standards on pages 41-43 of the Proposed Determination document. Table IV.10 of the Proposed Determination lists costs and fuel savings benefits for a cash-purchased MY 2025 vehicle on a yearly basis during the first eight years of vehicle ownership. The table estimates the cost of fuel based on the AEO projections, assumes a cash purchase, and a discount rate of 3% and is presented in Table 15. A “discount rate” is used to convert costs or benefits that will happen in the future into present value terms, which are how much the future costs or savings are worth to the consumer presently. For example, a 3% discount rate (used in Tables 15 and 16) means the average consumer would value a \$100 cost or saving that will happen a year from now at \$97.08, \$94.26 two years in the future, and \$74.41 ten years in the future. Using a higher discount rate represents a scenario where future costs or savings are less valued by the consumer in the present. Using a lower discount rate, in turn, represents a scenario where future costs or savings are more valued by the consumer in the present than if a higher discount rate was used. When future costs and benefits are monetary, as is the case in this analysis, the discount rate is very similar to an interest rate in that it is parallel to how much interest the consumer could earn from deferring a cost into the future. The MPCA often assumes a 3% annual discount rate, which is close to current high-yield interest rates. Some federal guidance on cost-benefit analyses recommends using both 3% and 7% discount rates.⁴⁷ The choice of a discount rate is fraught with complexity and involves judgements about how people value the future relative to the present. To bookend the analysis and provide a reasonable range of LEV standards economic impacts, MPCA analyzed the net costs and benefits of the rule using both a 3% discount rate and a 7% discount rate.

Table 15: Payback period for the sales-weighted average MY 2025 vehicle relative to the reference case standards, AEO 2016 Reference Fuel Price Case, Cash Purchase (3% discounting, 2015 dollars)

Year of ownership	Delta cost per vehicle	Delta taxes per vehicle	Delta insurance per vehicle	Delta purchase costs (cost of vehicle plus taxes and insurance) per vehicle	Delta maintenance costs per vehicle	Delta fuel costs per vehicle	Cumulative delta operating costs per vehicle
1st	\$863	\$47	\$16	\$926	\$6	-\$238	\$693
2nd	\$0	\$0	\$15	\$15	\$6	-\$232	\$483
3rd	\$0	\$0	\$14	\$14	\$5	-\$223	\$279
4th	\$0	\$0	\$13	\$13	\$5	-\$213	\$85
5th	\$0	\$0	\$12	\$12	\$5	-\$202	-\$100
6th	\$0	\$0	\$11	\$11	\$5	-\$189	-\$274
7th	\$0	\$0	\$10	\$10	\$4	-\$178	-\$437
8th	\$0	\$0	\$9	\$9	\$4	-\$166	-\$589

“Delta” refers to the added cost of a new vehicle compliant with MY 2025 GHG emissions standards relative to a vehicle compliant with MY 2021 standards. A positive value indicates an added cost of the lower-emitting vehicle while a negative value indicates a savings for the lower-emitting vehicle. As the table shows, due to fuel costs savings, the average consumer has recouped the cost of the initial higher vehicle purchase price by the fifth year of vehicle ownership.

Table IV.11 of the Proposed Determination document lists the same information for a MY 2025 vehicle purchased using a five year loan with a 4.25% interest rate instead of assuming a cash purchase. Many

⁴⁷ Office of Management and Budget’s Circular A-4, https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/

Minnesotans rely on loan financing to purchase their new vehicles and these are typical terms for vehicle loans in Minnesota. Thus for new-vehicle buyers that use loan financing to purchase their vehicles instead of paying the entire cost of the vehicle up front, the information from Table IV.11, presented in Table 16, may be a more accurate reflection of the Minnesota new vehicle purchaser's costs of a lower-emitting vehicle (MY 2025 compliant) versus a higher-emitting vehicle (MY 2021 compliant). As the table shows, even though the cumulative savings of the lower-emitting vehicle are lower over the eight years of ownership compared to a cash vehicle purchase (Table 16), the average purchaser of the lower-emitting vehicle still experiences cost savings in every year of ownership.

Table 16: Payback period for the sales-weighted average MY 2025 vehicle relative to the reference case standards, AEO 2016 Reference Fuel Price Case, 5-year (60 Month) Loan Purchase (3% discounting, 2015 dollars)

Year of ownership	Delta cost per vehicle	Delta taxes per vehicle	Delta insurance per vehicle	Delta purchase costs per vehicle	Delta maintenance costs per vehicle	Delta fuel costs per vehicle	Cumulative delta operating costs per vehicle
1st	\$863	\$47	\$16	\$217	\$6	-\$238	-\$16
2nd	\$0	\$0	\$15	\$209	\$6	-\$232	-\$32
3rd	\$0	\$0	\$14	\$201	\$5	-\$223	-\$49
4th	\$0	\$0	\$13	\$193	\$5	-\$213	-\$64
5th	\$0	\$0	\$12	\$184	\$5	-\$202	-\$78
6th	\$0	\$0	\$11	\$11	\$5	-\$189	-\$251
7th	\$0	\$0	\$10	\$10	\$4	-\$178	-\$414
8th	\$0	\$0	\$9	\$9	\$4	-\$166	-\$567

When loan financing is used to purchase a new-vehicle, the consumer experiences savings of a lower-emitting vehicle during every year of ownership due to fuel savings outweighing increased purchase cost, taxes, and maintenance.

Table 17 shows the same information as Table 15 using a 7% discount rate. Table 18 shows the cost and savings information using a 7% discount rate and a 72 month loan purchase. The figures in Tables 17 and 18 are from Table C.66 and Table C.71 in the appendix to the Proposed Determination document.

Table 17: Payback period for the sales-weighted average MY 2025 vehicle relative to the reference case standards, AEO 2016 Reference Fuel Price Case, Cash Purchase (7% discounting, 2015 dollars)

Year of ownership	Delta cost per vehicle	Delta taxes per vehicle	Delta insurance per vehicle	Delta purchase costs per vehicle	Delta maintenance costs per vehicle	Delta fuel costs per vehicle	Cumulative delta operating costs per vehicle
1st	\$846	\$46	\$16	\$908	\$6	-\$234	\$680
2nd	\$0	\$0	\$15	\$15	\$5	-\$219	\$481
3rd	\$0	\$0	\$13	\$13	\$5	-\$203	\$296
4th	\$0	\$0	\$12	\$12	\$5	-\$186	\$126
5th	\$0	\$0	\$10	\$10	\$4	-\$170	-\$30
6th	\$0	\$0	\$9	\$9	\$4	-\$153	-\$170
7th	\$0	\$0	\$8	\$8	\$3	-\$139	-\$298
8th	\$0	\$0	\$7	\$7	\$3	-\$125	-\$412

With a high discount rate, future fuel savings are worth less to the consumer relative to increased up-front purchase costs. Nonetheless, even with a high discount rate, the consumer of a lower-emitting vehicle recoups their increase up-front costs by the fifth year of ownership.

Table 18: Payback period for the sales-weighted average MY 2025 vehicle relative to the reference case standards, AEO 2016 Reference Fuel Price Case, 6-year (72 Month) Loan Purchase (7% discounting, 2015 dollars)

Year of ownership	Delta cost per vehicle	Delta taxes per vehicle	Delta insurance per vehicle	Delta purchase costs per vehicle	Delta maintenance costs per vehicle	Delta fuel costs per vehicle	Cumulative delta operating costs per vehicle
1st	\$862	\$47	\$16	\$187	\$6	-\$232	-\$39
2nd	\$0	\$0	\$15	\$173	\$5	-\$217	-\$78
3rd	\$0	\$0	\$13	\$160	\$5	-\$201	-\$114
4th	\$0	\$0	\$12	\$148	\$5	-\$185	-\$146
5th	\$0	\$0	\$10	\$135	\$4	-\$169	-\$175
6th	\$0	\$0	\$9	\$124	\$4	-\$152	-\$200
7th	\$0	\$0	\$8	\$8	\$3	-\$138	-\$326
8th	\$0	\$0	\$7	\$7	\$3	-\$124	-\$440

With a high discount rate, even when loan financing is used to purchase a vehicle, the new vehicle purchaser experiences cost savings in every year of ownership due to fuel savings outweighing increased purchase cost, taxes and maintenance.

Tables 17 and 18 show that even with higher discounting of future savings there are cumulative savings to the purchaser of the lower-emitting (MY 2025 compliant) vehicle relative to the higher-emitting (MY 2021 compliant) vehicle. Moreover, there are cumulative savings regardless of whether the consumer pays the entire purchase price for their new vehicle up front or instead uses loan financing to purchase their vehicle.

The MPCA then compared the results above to a sensitivity analysis based on the vehicle technology costs analysis in the SAFE FRIA. In the SAFE FRIA, the EPA and NHTSA estimated that the per-vehicle price increase for the 1.5% per year increase in GHG emission standard stringency relative to the previous federal standards as finalized in 2012 (which, again, are equivalent to Minnesota's LEV standard proposal) would be \$856 for MY 2030 passenger cars and \$1,098 for MY 2030 light-duty trucks.⁴⁸ Using the SAFE FRIA cost estimate and Minnesota's estimated proportions of new light-duty vehicles (25% cars and 75% trucks), the MPCA estimates a fleet-wide average increased cost of \$1,038 per LEV-certified vehicle relative to a SAFE-certified vehicle. These SAFE FRIA technology cost estimates are very close to the MPCA's analysis of vehicle cost premiums for LEV-certified vehicles using the January 2017 Final Determination analysis as presented above in Table 7, which showed \$897 for passenger cars, \$1,219 for light trucks, and a fleet-wide average of \$1,139. The analysis based on the SAFE FRIA estimates a slightly smaller cost difference between the Clean Cars scenario and the Reference scenario than was estimated based on the January 2017 Final Determination cost estimates. While the two analyses use different methods and data in several areas, the slightly smaller cost difference for the analysis based on the SAFE FRIA is, at least in part, because the final SAFE rule requires some technology cost increases, while the 2018 SAFE proposal did not.

⁴⁸ See Table I-4, page 12, of the SAFE FRIA:

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/final_safe_fria_web_version_200330.pdf

iii. LEV standard fuel savings in Minnesota

Since the tables above show a payback period over the first eight years of ownership for the vehicle purchaser associated with retaining the MY2022-2025 GHG standards, they do not show the full lifetime per-vehicle savings. As explained further below, we assume new vehicles in Minnesota have an average 150,000 mile lifetime, which is based on average vehicle miles traveled assumptions from EPA's MOVES model (see section 1(D) on mileage inputs), and equates to around 12 years. EPA included lifetime fuel savings and net savings information for different fuel price scenarios in Table IV.12 of the Proposed Determination document, as presented in Table 19. The table presents both the average fuel savings of the lower-emitting (MY 2025 compliant) vehicle relative to the higher-emitting (2021 compliant) vehicle and also the overall net savings, which include all the costs of vehicle ownership, including vehicle purchase, taxes, insurance, maintenance, and fuel costs.

Table 19: Lifetime fuel savings and net savings for the sales-weighted average MY 2025 vehicle purchased with cash under each of the 2016 AEO Fuel Price Cases (2015 dollars)

Case	Lifetime fuel savings, 3% discount rate	Lifetime net savings, 3% discount rate	Lifetime fuel savings, 7% discount rate	Lifetime net savings, 7% discount rate
AEO High Fuel Prices	\$4,209	\$3,054	\$3,223	\$2,145
AEO Reference Fuel Prices	\$2,804	\$1,648	\$2,128	\$1,051
AEO Low Fuel Prices	\$1,899	\$723	\$1,439	\$345

Lower-emitting vehicles entail significant fuel cost savings even assuming a high discount rate. The higher fuel sales are projected to be in the future, the higher the savings of a lower-emitting vehicle. (Our fuel savings analysis assumes the reference fuel prices projection in the 2019 AEO).

Tables 15-19 reflect the bulk of our analysis of the costs and benefits to the Minnesota new vehicle purchaser of a LEV-certified vehicle compared to a SAFE-certified vehicle, based on the proposed SAFE rule, but they are not complete. While these tables provide directional information on the consumer costs and savings associated with a Minnesota LEV standard, they do not include the additional vehicle technology costs or fuel savings associated with the incremental difference between the MY 2020 standards, which would be the final standards under the proposed SAFE Rule preferred option, and the MY 2021 standards. Nor do these tables account for the additional taxes, insurance, and maintenance costs of an average Minnesota vehicle using a 25%/75% car/truck mix. At the same time, these tables also do not account for the additional fuel savings that would be achieved by an average Minnesota vehicle. Finally, since the final SAFE rule will probably result in some fuel efficiency improvements due to the slight increases in the stringency of the standard over MYs 2021-2026, it is also necessary to consider the vehicle fuel cost analysis based on the increased annual stringency of 1.5% per year for MYs 2021-2026 in the final SAFE rule. Thus, we have made several additions and modifications to the information in these tables to assess consumer costs and savings of the LEV standard in Minnesota.

The MPCA conducted an independent calculation of the fuel savings per vehicle expected from adoption of the LEV standard using Minnesota-specific data. As described above in Section 2(B)(ii), we first calculated the expected real world per-mile fuel savings benefit for both passenger cars and light-duty trucks for every model year between 2025 and 2034, based on the difference between the LEV standards for MY 2025-2034 and the standard under the final SAFE Rule with increasing annual GHG emissions stringency of 1.5% per year for MYs 2021-2026. These calculations were based on the same fuel efficiency estimates for LEV-certified and final SAFE rule-certified passenger cars and light-duty trucks that we used to estimate emissions benefits. By MY 2025, the average LEV-certified passenger car would get approximately 6.7 more miles per gallon than the average proposed SAFE rule-certified

passenger car. By MY 2025, the average LEV-certified light-duty truck would get approximately 7.2 more miles per gallon than the average proposed SAFE rule-certified light-duty truck. To account for real world driving, the difference for each model year was multiplied by 0.8.⁴⁹ The per-mile fuel savings for cars and trucks were then converted into a Minnesota-specific weighted average per mile savings per vehicle using the 25%/75% car/truck mix.

To calculate the gallons of fuel saved for the average Minnesota vehicle for each year of vehicle life, we used standard annual values of VMT by vehicle age from EPA's MOVES model. Finally, we assumed that vehicles operate for 150,000 miles. The MOVES model estimates new vehicles are used slightly less in each successive year as they age. As shown in Figure 3, MOVES estimates a new vehicle is driven, on average, 14,724 miles in its first year of ownership, decreasing gradually to 11,373 miles in its tenth year of ownership.⁵⁰ A total average lifetime of 150,000 miles for new vehicles in Minnesota equates to just under 12 years of the vehicle being driven on Minnesota's roadways.

We multiplied this VMT by vehicle age by the per mile fuel savings numbers. Finally, we calculated dollar savings per vehicle using the calculated fuel savings and projected gasoline prices from the U.S. Energy Information Association's 2019 Annual Energy Outlook from the Reference case in its Table 12: Petroleum and Other Liquids Prices.⁵¹ These gasoline price projections are \$3.07/gallon (in 2018 dollars) in 2023 and grow at an average rate of 0.7% per year in subsequent years. The EIA, in fact, predicts that the price per gallon of gasoline will increase from now through 2050 under all scenarios (Figure 14).

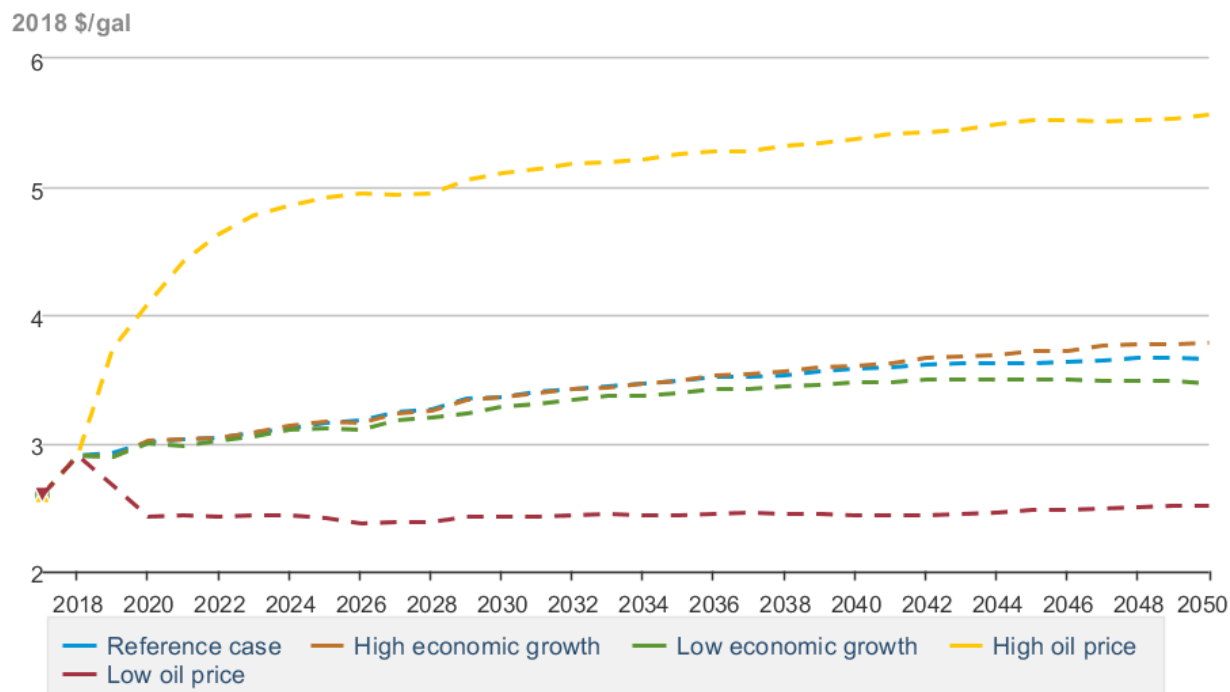
⁴⁹ Fuel economy standards assume that all GHG emissions benefits from vehicles come from increased fuel efficiency. The standards, however, allow manufacturers to take credits for things such as air conditioning improvements that reduce GHG emissions. Taking this into consideration as well as other factors that prevent vehicles on the road from meeting tested fuel economy results, the EPA commonly uses a multiplier of 0.8 to convert from fuel efficiencies that the standards would require to real-world fuel efficiency.

⁵⁰ These are weighted averages of annual passenger car and light-duty truck VMT based on MPCA's assumption that 25% of new vehicles sold are passenger cars and 75% are light-duty trucks.

⁵¹ https://www.eia.gov/outlooks/aeo/tables_ref.php

Figure 14: Petroleum prices: Transportation: Motor gasoline as projected by the EIA

In the MPCA's analysis of fuel savings in Minnesota, we assumed the EIA 2019 AEO Reference case for future gasoline prices in the state.



Source: U.S. Energy Information Administration

Table 20 presents the non-discounted dollar fuel savings per vehicle by model year and vehicle age as well as a total lifetime savings per vehicle by model year based on the EIA Reference case gasoline price projections. Even though the LEV standards plateau at MY 2025, savings continue to increase due to projected increases in gasoline prices. As Table 20 shows, the owner of a MY 2025 LEV-certified vehicle would save over \$2,000 in fuel costs (undiscounted) over the lifetime of their vehicle relative to a SAFE rule-certified vehicle while the owner of a MY 2034 LEV-certified vehicle would save nearly \$1,950 over the life of their vehicle. The reason that the estimated fuel savings for the LEV-certified vehicle decline for MY 2026 is because the final SAFE rule will still require manufacturers to make some efficiency improvements for MY 2026 while the LEV standard plateaus starting in MY 2025. Estimated increases in the fuel savings for a LEV-certified vehicle are due to projected gradual increases in gasoline prices.

Table 20: Fuel savings (2018 dollars) per vehicle (undiscounted)

Model year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
2025	\$189	\$187	\$187	\$184	\$184	\$179	\$175	\$171	\$166	\$160	\$155	\$106	\$2,043
2026	\$168	\$168	\$165	\$165	\$162	\$159	\$155	\$151	\$146	\$142	\$137	\$93	\$1,810
2027	\$171	\$170	\$170	\$166	\$164	\$160	\$156	\$152	\$147	\$143	\$138	\$94	\$1,832
2028	\$173	\$174	\$171	\$169	\$165	\$162	\$158	\$153	\$149	\$144	\$139	\$95	\$1,852
2029	\$178	\$175	\$174	\$170	\$167	\$163	\$159	\$155	\$150	\$145	\$140	\$96	\$1,871
2030	\$179	\$178	\$175	\$172	\$168	\$164	\$161	\$155	\$151	\$146	\$142	\$96	\$1,888
2031	\$182	\$179	\$177	\$173	\$170	\$166	\$161	\$157	\$152	\$148	\$142	\$97	\$1,905
2032	\$183	\$181	\$178	\$175	\$172	\$167	\$163	\$158	\$154	\$149	\$144	\$98	\$1,920
2033	\$185	\$182	\$180	\$177	\$172	\$168	\$164	\$160	\$155	\$150	\$144	\$98	\$1,935
2034	\$187	\$184	\$182	\$177	\$174	\$170	\$166	\$161	\$156	\$151	\$145	\$98	\$1,949

By MY 2034, the Minnesotan owner of a LEV-certified vehicle is projected, on average, to save nearly \$1,950 in fuel costs.

Since fuel savings occur over the lifetime of the vehicle and people generally value future savings less than savings (or costs) in the present, we modified the above calculations using a 3% and a 7% discount rate, which are respectively presented in Tables 21 and 22. The tables show that the higher the discount rate, the lower the present value of future savings, but that even with the high 7% discount rate, an average MY 2034 vehicle purchaser would save over \$1,400 over the lifetime of their vehicle.

Table 21: Per-vehicle dollar fuel savings (2018 dollars), 3% discount rate

Model year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
2025	\$184	\$177	\$171	\$164	\$158	\$150	\$143	\$135	\$127	\$119	\$112	\$74	\$1,713
2026	\$163	\$158	\$151	\$147	\$139	\$133	\$126	\$119	\$112	\$105	\$99	\$65	\$1,518
2027	\$166	\$160	\$156	\$148	\$141	\$134	\$127	\$120	\$113	\$107	\$99	\$66	\$1,537
2028	\$168	\$164	\$156	\$150	\$143	\$135	\$128	\$121	\$114	\$107	\$100	\$66	\$1,554
2029	\$173	\$165	\$159	\$151	\$144	\$137	\$129	\$122	\$115	\$108	\$101	\$67	\$1,571
2030	\$174	\$168	\$160	\$153	\$145	\$138	\$131	\$123	\$116	\$109	\$102	\$67	\$1,585
2031	\$176	\$169	\$162	\$154	\$146	\$139	\$131	\$124	\$117	\$110	\$103	\$68	\$1,599
2032	\$178	\$171	\$163	\$155	\$148	\$140	\$132	\$125	\$118	\$111	\$104	\$68	\$1,612
2033	\$180	\$172	\$164	\$157	\$149	\$141	\$133	\$126	\$119	\$112	\$104	\$69	\$1,625
2034	\$181	\$173	\$166	\$158	\$150	\$142	\$135	\$127	\$120	\$112	\$105	\$69	\$1,637

Discounting future fuel savings decreases the overall value of savings for a Minnesotan LEV-certified vehicle owner. With a 3% discount rate, the purchaser of a MY 2034 LEV-certified vehicle is expected to save nearly \$1,640 in fuel costs over the life of their vehicle.

Table 22: Per-vehicle dollar fuel savings (2018 dollars), 7% discount rate

Model year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
2025	\$177	\$164	\$152	\$140	\$131	\$119	\$109	\$99	\$90	\$82	\$74	\$47	\$1,384
2026	\$157	\$146	\$135	\$126	\$115	\$106	\$96	\$88	\$80	\$72	\$65	\$41	\$1,227
2027	\$160	\$148	\$139	\$127	\$117	\$107	\$97	\$88	\$80	\$73	\$65	\$42	\$1,243
2028	\$162	\$152	\$140	\$129	\$118	\$108	\$98	\$89	\$81	\$73	\$66	\$42	\$1,258
2029	\$166	\$153	\$142	\$130	\$119	\$109	\$99	\$90	\$81	\$74	\$67	\$42	\$1,272
2030	\$167	\$155	\$143	\$131	\$120	\$110	\$100	\$90	\$82	\$74	\$67	\$43	\$1,283
2031	\$170	\$157	\$144	\$132	\$121	\$111	\$100	\$91	\$83	\$75	\$68	\$43	\$1,295
2032	\$171	\$158	\$145	\$133	\$122	\$111	\$101	\$92	\$84	\$76	\$68	\$43	\$1,306
2033	\$173	\$159	\$147	\$135	\$123	\$112	\$102	\$93	\$84	\$76	\$69	\$43	\$1,316
2034	\$174	\$161	\$148	\$135	\$124	\$113	\$103	\$94	\$85	\$77	\$69	\$44	\$1,326

A higher discount rate suggests lower overall fuel cost savings, but a Minnesotan who purchases a MY 2034 LEV-certified vehicle is still expected to save nearly \$1,330 over the life of their vehicle.

To calculate cumulative savings, we multiplied the per-vehicle savings numbers in Tables 20, 21, and 22 by the projected Minnesota new vehicle sales from Table 12. Based on these calculations the total fuel savings from MYs 2025-2034 from the adoption of the LEV standard in Minnesota would be:

- Non-discounted (2018 dollars): \$4.51 billion
- 3% discount rate (2018 dollars): \$3.79 billion
- 7% discount rate (2018 dollars): \$3.07 billion

The MPCA then considered the lifetime fuel savings analysis in the SAFE FRIA. Again, the SAFE FRIA estimates very similar per-vehicle fuel savings estimates to the estimates based on the January 2017 Final Determination, reported above in Tables 20-22. The SAFE FRIA also applies discount rates of 3% and 7% in its fuel savings analysis. With a 3% discount rate, the SAFE FRIA estimates a \$1,392 savings in fuel costs over the life of a MY 2030 passenger car and \$1,948 savings over the life of a MY 2030 light-duty truck.⁵² Based on Minnesota's estimated fleet-mix of 25% passenger cars and 75% light-duty trucks, this would equate to a fleet-wide average fuel savings of \$1,809, which is fairly close to the estimate of \$1,585 based on the January 2017 Final Determination with a 3% discount rate, as reported above in Table 21. With a 7% discount rate, the SAFE FRIA estimates a \$1,096 savings in fuel costs over the life of a MY 2030 passenger car and \$1,504 savings over the life of a MY 2030 light-duty truck.⁵³ Again, based on Minnesota's estimated passenger car and light truck fleet mix, this equates to a \$1,283 average fleet-wide fuel savings, which is again close to the estimate of \$1,294 based on the January 2017 Final Determination with a 7% discount rate, as reported above in Table 22.

iv. Net consumer costs and benefits of the LEV standard

The MPCA estimated the per-vehicle net costs and benefits for consumers, taking into account all of the costs and savings from vehicle purchase, taxes, insurance, and fuel costs, using both 3% and 7% discount rates. The MPCA used both the purchase vehicle costs information as well as vehicle taxes, insurance,

⁵² See Table I-4, page 12, of the SAFE FRIA:

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/final_safe_fria_web_version_200330.pdf

⁵³ *Id.*

and maintenance information in the January 2017 Final Determination along with our own fuel savings analysis, which takes into account the requirements of the final SAFE rule. The MPCA additionally considered the fuel savings estimates reported in the SAFE FRIA. In the analysis based on the January 2017 Final Determination and MPCA's fuel savings analysis, the MPCA used the fuel savings numbers from Tables 21 and 22, and purchase costs, taxes, insurance and maintenance costs shown in Tables 16 and 18. Finally, MPCA also considered the impact of annual registration taxes paid by Minnesota vehicle owners. As is explained in Section 3(C), every year Minnesotan vehicle owners pay registration taxes based on the value of their vehicle. Because we project LEV-certified vehicles to have slightly higher values than vehicles certified under the final SAFE rule, the owner of a LEV-certified vehicle will pay a slightly higher amount in registration tax every year compared to the owner of an otherwise comparable SAFE-certified vehicle. We estimate that over the lifetime of a LEV-certified vehicle, the vehicle owner will pay an average \$73.85 (in present value terms) in additional registration taxes relative to the owner of a SAFE-certified vehicle at a 3% discount rate and \$66.59 at a 7% discount rate. Table 23 contains the per-vehicle net costs for the two discounting scenarios for MY 2025 -2034 vehicles.

Table 23 shows that whether there is a small net savings or small net cost for the consumer with a LEV-certified vehicle depends on the choice of discount rate. With a 3% discount rate, the purchaser of an average MY 2025 LEV-certified vehicle is expected to save \$186 over the lifetime of their vehicle, while with a 7% discount rate, the purchaser of the MY 2025 vehicle is expected to incur a cost of \$107 over the lifetime of their vehicle. These estimates of costs and savings are very small relative to the overall costs of vehicle ownership over vehicle lifetimes, which include purchase costs, fuel costs and maintenance costs, so the LEV standard can reasonably be considered to have no overall impact on Minnesota consumers' pocketbooks. The trajectory of overall consumer savings or cost from MYs 2025 to 2034 reflect the same trajectory as fuel savings. Because the final SAFE rule increases in stringency from MYs 2025-2026, manufacturers will probably have to make efficiency improvements in 2026. Conservatively, this is not reflected by an increased vehicle technology cost in MY 2026 under the final SAFE rule. In contrast, the LEV standard plateaus starting in MY 2025. The increase in expected fuel savings as well as overall net savings in subsequent years is due to gradually increasing projected gasoline prices.

Table 23: LEV standard per-vehicle net cost (in 2018 dollars) based on the January 2017 Final Determination analysis and MPCA's fuel savings analysis for MY 2025-2034 vehicles

Model year	Vehicle Technology Cost	Sales Taxes, Insurance and Maintenance		Fuel Savings		Registration Taxes		Net cost	
		3% disc rate	7% disc rate	3% disc rate	7% disc rate	3% disc rate	7% disc rate	3% disc rate	7% disc rate
2025	\$1,139	\$315	\$286	\$1,713	\$1,384	\$74	\$67	-\$186	\$107
2026	\$1,139	\$315	\$286	\$1,518	\$1,227	\$74	\$67	\$9	\$264
2027	\$1,139	\$315	\$286	\$1,537	\$1,243	\$74	\$67	-\$10	\$248
2028	\$1,139	\$315	\$286	\$1,554	\$1,258	\$74	\$67	-\$27	\$233
2029	\$1,139	\$315	\$286	\$1,571	\$1,272	\$74	\$67	-\$44	\$219
2030	\$1,139	\$315	\$286	\$1,585	\$1,283	\$74	\$67	-\$57	\$208
2031	\$1,139	\$315	\$286	\$1,599	\$1,295	\$74	\$67	-\$72	\$196
2032	\$1,139	\$315	\$286	\$1,612	\$1,306	\$74	\$67	-\$85	\$185

Model year	Vehicle Technology Cost	Sales Taxes, Insurance and Maintenance		Fuel Savings		Registration Taxes		Net cost	
		3% disc rate	7% disc rate	3% disc rate	7% disc rate	3% disc rate	7% disc rate	3% disc rate	7% disc rate
2033	\$1,139	\$315	\$286	\$1,625	\$1,316	\$74	\$67	-\$98	\$175
2034	\$1,139	\$315	\$286	\$1,637	\$1,326	\$74	\$67	-\$110	\$165

Negative values represent a net savings to the consumer and positive values represent a net cost. Whether there is an overall savings or cost depends on the consumer's discount rate. With a 3% discount rate, the purchaser of a LEV-certified vehicle is estimated to save up to \$186 over the life of their vehicle; with a 7% discount rate, the purchaser of a LEV-certified vehicle is estimated to incur a cost of \$107 to \$264 over the life of their vehicle.

Considering the overall vehicle costs information in the SAFE FRIA leads to similar overall conclusions. In fact, compared with data from the January 2017 Final Determination combined with MPCA's fuel savings analysis, data from the SAFE FRIA suggest consumers who purchase LEV-certified vehicles will save even more compared to consumers who purchase federally certified vehicles under the final SAFE rule, even at a high discount rate. With a 3% discount rate, analysis based on data in the SAFE FRIA estimates an overall consumer per-vehicle savings over the lifetime of a MY 2030 vehicle of \$708 for a passenger car and \$1,205 for a light-duty truck. Based on Minnesota's 25%/75% car/truck mix, this equates to a fleet-wide average savings of \$1,081 over the lifetime of a vehicle. With a 7% discount rate, analysis based on data in the SAFE FRIA estimates an overall consumer per-vehicle savings over the lifetime of a MY 2030 vehicle of \$351 for a passenger car and \$647 for a light duty truck. Based on Minnesota's 25%/75% car/truck mix, this equates to a fleet-wide average savings of \$573 over the lifetime of a vehicle.

Table 24 presents a direct comparison of MPCA's analysis based on the January 2017 Final Determination along with our fuel savings analysis with the SAFE FRIA vehicle costs analyses for the same model year (2030). Based on Minnesota's passenger car/light-duty truck fleet mix, the average overall vehicle lifetime savings for the owner of a MY 2030 LEV-certified vehicle would be \$57 with a 3% discount rate and a \$208 cost with a 7% discount rate. Again, the magnitude of these cost or savings estimates are very small relative to the overall costs of vehicle ownership. This appears to be a conservative estimate of the consumer impacts of the LEV standard since the SAFE FRIA reports consumer per-vehicle net savings with both discount rates.

Table 24: Comparison of January 2017 Final Determination and SAFE FRIA: Total consumer savings over vehicle lifetime for a Minnesota LEV-certified MY 2030 vehicle

Discounting Scenario	Jan 2017 Final Determination Analysis	SAFE FRIA Analysis
3%	\$57	\$1,081
7%	-\$208	\$573

The analysis for the SAFE FRIA suggests a larger overall consumer savings for a LEV-certified vehicle relative to a SAFE-certified vehicle than the MPCA analysis. With a 3% discount rate the owner on a model year LEV certified vehicle is estimated to save \$131 or \$1,081 based on the January 2017 Final Determination and SAFE FRIA analysis, respectively.

In conclusion, based on the MPCA's analysis using the analysis supporting the January 2017 Final Determination as well as NHTSA's and EPA's FRIA supporting the final SAFE rule, adopting the LEV standard in Minnesota would be likely to result in a small consumer benefit to Minnesota vehicle purchasers. The size of the benefit depends on the discount rate applied. Only based on the January 2017 Final Determination analysis and a high discount rate of 7% do we estimate a small net consumer cost to Minnesota vehicle purchasers. Assuming Minnesotans, on average, discount future costs and

benefits to the value to them in the present by a rate of 3% per year, adoption of the LEV standard is projected to result in a cost of \$9 to a benefit of \$186 to the vehicle purchaser over the lifetime of their vehicle (Table 23). This estimate seems to be conservative, since the SAFE FRIA estimates higher consumer savings. These results take into account the increased vehicle purchase price; increased taxes, insurance and maintenance costs; and fuel savings over the life of the vehicle. If instead we were to assume, on average, Minnesotans discount future costs and benefits by a rate of 7% per year, adoption of the LEV standard is projected to result in a loss of \$107 to \$264 to the vehicle purchaser over the lifetime of their vehicle.

Based on the MPCA's projections of Minnesota annual vehicle sales and the January 2017 Final Determination analysis, across the Minnesota economy, and assuming a 3% discount rate, the MPCA estimates the LEV standard would result in an average of \$16 million of net consumer benefits annually and a total consumer benefit of approximately \$161 million over the first 10 years of implementation. At a 7% discount rate, the MPCA estimates an average annual consumer cost of \$47 million, resulting in approximately \$475 million in net consumer costs total over the first 10 years of implementation. These values are small relative to the total costs of purchase and ownership of new vehicles in Minnesota every year, so the MPCA expects the LEV standard to have a close to net neutral effect on Minnesotans' pocketbooks.

B. ZEV standard consumer impact analysis

Using projections of BEV and PHEV sales that the ZEV standard would require in Minnesota (Clean Cars scenario), the MPCA compared the consumer costs and benefits to a business-as-usual scenario where no ZEV standard is adopted in Minnesota (Reference scenario). This economic impact analysis analyzes the LEV and ZEV standards separately. Therefore, the Reference scenario evaluated in this section assumes new vehicles sold in Minnesota meet LEV requirements. Thus, this analysis can be viewed as the additional costs and benefits of a ZEV standard once the LEV standard is already in place.

The analysis examines costs of compliance for manufacturers; however, the MPCA anticipates all costs of compliance borne by vehicle manufacturers and analyzed in this section would be passed on to new vehicle purchasers. At the same time, the direct benefits of operating an EV would also accrue to the vehicle purchasers.

i. EV sales estimates

If adopted, the ZEV standard would set a minimum ZEV credit percentage requirement, based on sales volume, for each vehicle manufacturer that offers new light-duty vehicles for sale in Minnesota. The ZEV standard allows manufacturers to earn credits for delivering for sale BEVs, PHEVs, and hydrogen fuel cell electric vehicles (FCEVs). Based on the Minnesota light-duty vehicles market and infrastructure, the MPCA does not expect FCEVs to be offered for sale in Minnesota over the time frame of this analysis and therefore were not included.

Under the ZEV standard, the credit percentages required for each manufacturer in each model year are calculated based on the three-year average of the manufacturer's volume of passenger cars and light-duty trucks produced and delivered for sale in Minnesota in the prior second, third, and fourth model years. For example, 2025 model year ZEV requirements would be based on Minnesota production volume average of passenger cars and light-duty trucks for MYs 2021 to 2023.

Section 1(C) explains the MPCA's estimates of EV sales under the Reference scenario and the Clean Cars scenario.

Table 25 presents the MPCA's projection of overall light-duty vehicle sales, estimated Reference scenario BEV and PHEV sales, estimated EV sales needed to comply with the ZEV standard, and the

difference between the Reference scenario and the Clean Cars scenario.

Table 25: Minnesota light-duty vehicle sales, EV linear growth projections, EV deliveries needed for compliance, and the difference between the Reference scenario and the Clean Cars scenario

Model year	Light-duty vehicle sales	Reference scenario				Clean Cars scenario					
		Projected BEV sales	Projected PHEV sales	Total	% of total LDVs	Projected BEV sales	Projected PHEV sales	Total projected EV sales	% of total LDVs	Additional BEVs to comply	Additional PHEVs to comply
2025	253,385	5,611	1,799	7,410	2.92%	11,714	7,139	18,852	7.44%	6,102	5,340
2026	251,104	6,166	1,945	8,111	3.23%	11,804	6,777	18,581	7.40%	5,638	4,832
2027	247,840	6,721	2,091	8,811	3.56%	11,865	6,401	18,266	7.37%	5,144	4,311
2028	243,379	7,276	2,236	9,512	3.91%	11,893	6,012	17,904	7.36%	4,617	3,775
2029	237,538	7,830	2,382	10,213	4.30%	11,879	5,607	17,486	7.36%	4,049	3,225
2030	230,649	8,385	2,528	10,913	4.73%	11,811	5,187	16,998	7.37%	3,426	2,659
2031	224,883	8,940	2,674	11,614	5.16%	11,682	4,752	16,434	7.31%	2,742	2,079
2032	222,634	9,495	2,820	12,314	5.53%	11,489	4,309	15,798	7.10%	1,994	1,489
2033	226,641	10,050	2,965	13,015	5.74%	11,269	3,874	15,143	6.68%	1,220	909
2034	237,067	10,604	3,111	13,716	5.79%	11,106	3,475	14,581	6.15%	501	364

LDV sales are based on Minnesota MY 2019 sales with future sales based on MnDOT Pathways report projections. Projected BEV and PHEV Reference scenario deliveries are based on linear extrapolations of Minnesota EV sales in 2015-2019. Clean Cars scenario BEV and PHEV deliveries are based on Minnesota ZEV Compliance Calculator estimates. Additional BEVs and PHEVs needed for compliance are the difference between the Clean Cars scenario and the Reference scenario.

As discussed in section 1(C), projections of future EV sales vary widely. The ZEV standard therefore serves as a regulatory backstop to ensure that Minnesota experiences at least a minimum level of EV sales. For this reason, the MPCA also includes throughout this analysis estimates of the costs and benefits of the ZEV standard without comparing to a Reference scenario. To understand these full benefits of the ZEV standard, the MPCA compared the costs and benefits for all the EVs that we estimate would be required under the ZEV standard to a hypothetical scenario where no EVs are sold at all in the future. These estimates reflect the full costs and benefits of all the EVs that would be required in order to comply with the standard.

ii. Vehicle technology costs

The MPCA developed an Excel spreadsheet calculator that estimates the monetary benefits and costs of the ZEV standard in Minnesota for MY 2025-2034, based on the compliance requirements in the chosen scenario from the ZEV Compliance Calculator compared to the linear BEVs and PHEVs sales growths reference case. This tool was adapted from a spreadsheet tool developed by Colorado for a cost-benefit analysis of its ZEV standard. We adapted it with assumptions specific to Minnesota, including electricity and gasoline costs in Minnesota, Minnesota's passenger car/light-duty truck mix, VMT, average vehicle life, and Minnesotans' expected electric vehicle charging behaviors.

The types of consumer costs and benefits expected from a ZEV standard are similar to those identified in the analysis for the LEV standard in section 3(A). Again, new vehicle purchasers, particularly purchasers of electric vehicles, would be the primary bearers and receivers of economic costs and benefits. Since the ZEV standard would not require any new vehicle purchaser to purchase an EV, Minnesota consumers who choose to purchase new ICE vehicles would not be affected by the ZEV standard. The primary costs and benefits to EV purchasers would be from vehicle purchase costs, vehicle maintenance and repair costs, and fuel (both gasoline and electricity) costs. The ZEV standard in Minnesota may also

lead to increased availability and selection of EVs available for purchase. For the purposes of this analysis, the effects of tax credits and other purchase incentives for EVs was not included.⁵⁴

The fuel costs used in this analysis, both for gasoline and for electricity, were derived from the EIA 2019 Annual Energy Outlook fuel prices.⁵⁵ The vehicle costs in this analysis are from the International Council on Clean Transportation (ICCT).⁵⁶

Table 26 shows vehicle costs by vehicle types (ICE, BEV, PHEV) and vehicle classes (car, crossover, and SUV).⁵⁷ The costs shown in Table 26 for each type and class of ICE vehicle include powertrain, vehicle assembly, and indirect costs. For BEVs and PHEVs, the costs shown in Table 26 include battery pack, non-battery powertrain, vehicle assembly, and indirect costs. Percentages of Minnesota market shares were an overall 25%/75% passenger cars/light-duty trucks mix. These shares were applied to each vehicle class, respectively, to get the average cost by market share. The differences in costs of BEVs and ICE vehicles and PHEVs and ICE vehicles were used to calculate the incremental vehicle costs.

The predicted average costs based on Minnesota market shares for ICE vehicles range from \$28,113 in MY 2025 to \$29,014 in MY 2034. The predicted average cost for a BEV starts at \$31,249 in MY 2025 and trends downward to \$22,340 in MY 2034. PHEV costs average from \$33,953 in MY 2025 to \$33,124 in MY 2034.⁵⁸

⁵⁴ There are some current tax incentives in the form of federal tax rebates for purchasers of electric vehicles, but by MY 2024, most if not all of these tax credits will have been phased out. Minnesota currently does not offer any tax incentives to Minnesotans to purchase electric vehicles.

⁵⁵ <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>

⁵⁶ Lutsey, N. & Nicholas, M., *Update on Electric Vehicle Costs in the United States through 2030*, The International Council on Clean Transportation (April 2, 2019).

⁵⁷ *Id.* Direct communication with the authors provided additional projections through 2033 and confirmed that these vehicle costs are specifically applicable for Minnesota.

⁵⁸ For this analysis we assumed a 250-mile BEV range and a 50-mile PHEV range as being representative of the average EV ranges in MY 2025-2034.

Table 26: Vehicle costs by vehicle types and classes

ICE vehicles	2025	2026	2027	2028	2029	2030	2032	2034
ICE car	\$25,760	\$25,848	\$25,936	\$26,025	\$26,113	\$26,203	\$26,381	\$26,559
ICE crossover	\$25,502	\$25,592	\$25,681	\$25,771	\$25,862	\$25,952	\$26,134	\$26,315
ICE SUV	\$32,293	\$32,409	\$32,526	\$32,643	\$32,760	\$32,878	\$33,114	\$33,349
Average by market share	\$28,113	\$28,212	\$28,312	\$28,411	\$28,511	\$28,612	\$28,813	\$29,014
BEVs	2025	2026	2027	2028	2029	2030	2032	2034
Electric car (250 mile)	\$27,516	\$26,498	\$25,586	\$24,768	\$24,035	\$23,281	\$21,772	\$20,264
Electric crossover (250 mile)	\$28,986	\$27,828	\$26,788	\$25,855	\$25,015	\$24,163	\$22,459	\$20,755
Electric SUV (250 mile)	\$36,001	\$34,488	\$33,130	\$31,910	\$30,814	\$29,713	\$27,510	\$25,308
Average by market share	\$31,249	\$29,993	\$28,866	\$27,854	\$26,945	\$26,024	\$24,182	\$22,340
PHEVs	2025	2026	2027	2028	2029	2030	2032	2034
PHEV car (40 mile)	\$29,523	\$29,506	\$29,495	\$29,489	\$29,488	\$29,491	\$29,497	\$29,502
PHEV car (60 mile)	\$31,075	\$30,942	\$30,823	\$30,718	\$30,624	\$30,541	\$30,376	\$30,211
PHEV crossover (40 mile)	\$30,308	\$30,215	\$30,132	\$30,061	\$29,998	\$29,945	\$29,839	\$29,732
PHEV crossover (60 mile)	\$31,105	\$30,959	\$30,828	\$30,709	\$30,603	\$30,509	\$30,321	\$30,133
PHEV SUV (40 mile)	\$39,059	\$38,929	\$38,813	\$38,711	\$38,622	\$38,545	\$38,391	\$38,236
PHEV SUV (60 mile)	\$40,213	\$39,993	\$39,795	\$39,617	\$39,458	\$39,316	\$39,032	\$38,749
Average by market share	\$33,953	\$33,824	\$33,709	\$33,607	\$33,517	\$33,438	\$33,281	\$33,124
Diff: BEV vs ICE	\$3,136	\$1,781	\$554	-\$557	-\$1,567	-\$2,588	-\$4,631	-\$6,674
Diff: PHEV vs ICE	\$6,083	\$5,840	\$5,612	\$5,397	\$5,195	\$4,826	\$4,468	\$4,110

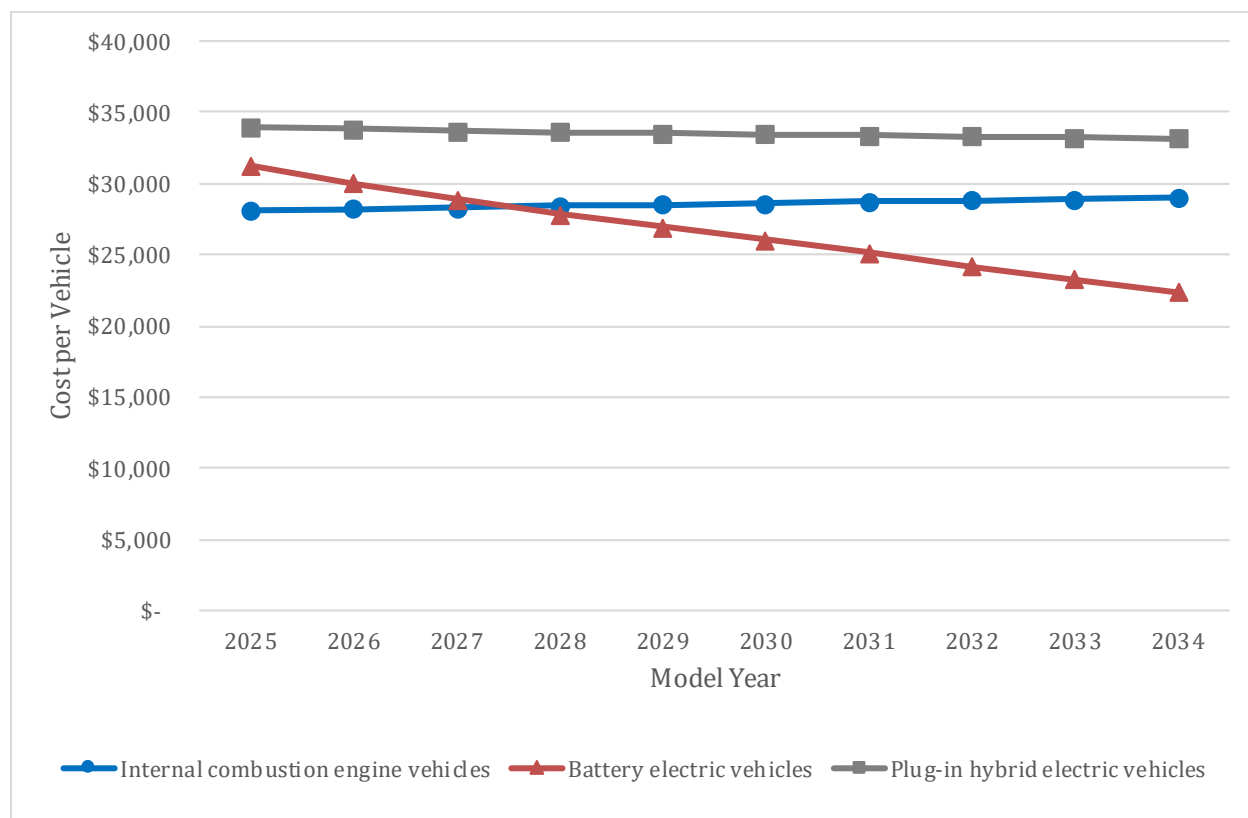
This table shows the differences in vehicle costs between different classes of ICE vehicles, BEVs and PHEVs. The cost to manufacture BEVs is expected to reach parity with ICE vehicles by MY 2028 while the cost to manufacture PHEVs is not expected to reach parity with an ICE vehicles over this time frame.

Figure 15 shows the predicted cost of a BEV reaching parity with ICE vehicles for all market segments (car, crossover, SUV) by MY 2028. The estimated reduction in BEV costs are due to multiple factors,

including the reduction in battery costs, as projected in many other analyses and reports. As battery manufacturing costs decline, the overall price of electric vehicles declines.

Figure 15: U.S. average vehicle cost based on Minnesota market shares

The cost to manufacture BEVs is expected to reach parity with ICE vehicles by MY 2028 while the cost to manufacture PHEVs is not expected to reach parity with an ICE vehicles over this time frame.



PHEVs carry higher up-front costs than BEVs, as shown in Table 26. It is expected that PHEVs will continue to be more expensive than both BEVs and ICE vehicles through 2034. BEVs will initially be more expensive than ICE vehicles at the start of this time frame but are expected to become less expensive to purchase than ICE vehicles as of MY 2028. By MY 2034, based on Minnesota market shares, BEVs are expected to be over \$6,600 less expensive to purchase than ICE vehicles.

Table 27 presents the total new vehicle costs for the numbers of new BEVs and PHEVs the MPCA projects would be required to comply with the ZEV standard and the costs of compliance relative to the Reference scenario. The expected cumulative up-front vehicle purchase costs for all the EVs required by the ZEV standard through MY 2034 are \$46 million, not considering the benefits of reduced maintenance and fuel costs. The expected increase in vehicle purchase costs of the Clean Cars scenario over the Reference scenario is \$137 million through 2034. Again, these costs do not account for fuel and maintenance savings, which more than offset the increased vehicle purchase costs.⁵⁹

⁵⁹ The estimated total up-front costs of all EVs required by the ZEV standard is less than the estimated up-front costs of just the additional EVs that the MPCA estimates would be sold under the Clean Cars scenario beyond the EV sales anticipated in the Reference scenario. The reason the costs of all EVs is less than the cost of just the additional EVs beyond the Reference scenario

Table 27: New vehicle costs (in millions of dollars) under the ZEV standard relative to Reference scenario

Model year	Total ZEV standard compliance			Clean Cars scenario relative to Reference scenario		
	BEV	PHEV	Total	BEV	PHEV	Total
2025	-\$36.74	-\$41.69	-\$78.43	-\$19.14	-\$31.18	-\$50.32
2026	-\$21.02	-\$38.03	-\$59.05	-\$10.04	-\$27.12	-\$37.16
2027	-\$6.57	-\$34.55	-\$41.12	-\$2.85	-\$23.27	-\$26.12
2028	\$6.63	-\$31.23	-\$24.60	\$2.57	-\$19.61	-\$17.04
2029	\$18.61	-\$28.07	-\$9.45	\$6.34	-\$16.14	-\$9.80
2030	\$30.57	-\$25.03	\$5.54	\$8.87	-\$12.83	-\$3.96
2031	\$42.17	-\$22.09	\$20.09	\$9.90	-\$9.66	\$0.24
2032	\$53.21	-\$19.25	\$33.96	\$9.23	-\$6.65	\$2.58
2033	\$63.70	-\$16.62	\$47.09	\$6.89	-\$3.90	\$3.00
2034	\$74.12	-\$14.28	\$59.84	\$3.35	-\$1.49	\$1.85
Total	\$224.69	-\$270.84	-\$46.14	\$15.13	-\$151.86	-\$136.73

Total costs based on all vehicle purchase costs of EVs required for compliance with the ZEV standard. Also total costs compared to the Reference scenario based on linear EV sales growth. A negative value in the table reflects a higher cost of a BEV or PHEV relative to an ICE vehicle while a positive value reflects a lower cost of a BEV or a PHEV relative to an ICE vehicle. Compliance with ZEV is predicted to result in higher cumulative new vehicle costs over this time frame.

iii. Fuel savings

Electric vehicles, including PHEVs and especially BEVs, are more energy-efficient than ICE vehicles. Expected fuel economy for ICE vehicles was determined based on LEV standards. U.S. EPA fuel economy data was used for the gasoline fraction of plug-in hybrid operation.⁶⁰ This analysis assumes PHEVs operate 75% of the time on electric battery power and 25% on gasoline power, based on the U.S. EPA fuel economy calculation. It also assumes most PHEVs and BEVs will charge at home using a level 2 charging system and at residential electric rates of \$0.1163 per kWh, which is the projected Minnesota average residential electricity price for 2022⁶¹. This analysis assumes that EV owners will use public fast charging stations 10% of the time with a charging rate of \$0.28 per kWh, based on fast charge rates quoted by Tesla.⁶² Other data sources such as Smart Charge America reference similar rates.

Table 28 shows the benefits in fuel cost savings the ZEV standard for MYs 2025-2034. The table shows both the total fuel cost savings for all the EVs the MPCA estimates would be required to comply with the ZEV standard and the difference between the Clean Cars scenario and the Reference scenario. The savings presented in the table are the combined BEVs and PHEVs savings, presented both as the savings over the full lifetime of the vehicles as well as the savings over just the first five years of ownership, representing a hypothetical first owner. We assume a vehicle lifespan of 150,000 miles.

As Table 28 shows, the MPCA's analysis estimates the total cumulative fuel savings through MY 2034 for the lifetime of all BEVs and PHEVs estimated to be required for compliance with the ZEV standard is

is that after MY 2028 BEVs are anticipated to cost less than ICE vehicles; therefore, more BEVs sold, particularly in the later years of our analysis time frame, means more cost savings and higher benefits to Minnesota consumers.

⁶⁰ The Annual Energy Outlook 2019, Appendix A Reference Case was used for the price of gasoline. U.S. Energy Information Administration, Annual Energy Outlook 2019 <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>.

⁶¹ *Id.*

⁶² See <https://www.tesla.com/support/supercharging>.

\$768 million. The expected fuel cost savings from the Clean Cars scenario over the Reference scenario is \$284 million over the lifetime of vehicles through MY 2034.

Table 28: Fuel cost savings (in millions of dollars) of projected new BEV and PHEV sales under the ZEV standard

Model year	Total ZEV standard compliance		Clean Cars scenario relative to Reference scenario	
	Vehicle (lifetime)	First five years	Vehicle lifetime	First five years
2025	\$91.63	\$42.47	\$57.76	\$26.84
2026	\$74.83	\$34.69	\$41.80	\$19.40
2027	\$75.34	\$35.20	\$38.61	\$18.06
2028	\$75.49	\$35.48	\$35.00	\$16.46
2029	\$75.23	\$35.52	\$30.91	\$14.61
2030	\$74.50	\$35.29	\$26.31	\$12.47
2031	\$73.20	\$34.77	\$21.16	\$10.06
2032	\$71.44	\$34.03	\$15.50	\$7.39
2033	\$79.61	\$38.14	\$11.97	\$5.74
2034	\$76.91	\$36.97	\$4.90	\$2.36
Total	\$768.17	\$362.55	\$283.91	\$133.39

The Total ZEV standard compliance columns show estimated the total fuel cost savings of all BEVs and PHEVs needed for compliance with the ZEV standard. The Clean Cars scenario relative to Reference scenario columns show the estimated fuel cost savings of BEVs and PHEVs necessary for ZEV compliance compared to a future scenario of linear sales growth of BEVs and PHEVs. The table shows savings for both the full lifetime of the vehicle and for the first five years to reflect the savings for a hypothetical first owner. The cumulative estimated fuel savings over the lifetimes of all model year BEVs and PHEVs in the Clean Cars scenario relative to the Reference scenario is \$284 million.

Fuel costs savings are experienced over the entire lifetime of vehicles. Thus, in order to compare these savings to changes in vehicle purchase costs, it is standard to consider them in present value terms. As discussed in section 3(A), present value takes discounting of future savings into effect to represent what the future savings are valued to the consumer.⁶³ Table 29 shows the present value for fuel savings based on a 3% discount rate. In present value terms, the total fuel cost savings for all the EVs the MPCA estimates would be required to comply with the ZEV standard through MY 2034 is \$658 million and the fuel cost savings of the Clean Cars scenario relative to the Reference scenario is \$244 million.

⁶³ A thorough explanation of discounting is presented in section 3(A)(ii). The higher the discount rate, the lower the consumer values what happens in the future (e.g. fuel saving over the life of a vehicle) relative to what happens in the present (e.g. the cost to purchase a new vehicle).

Table 29: Net present value assuming a 3% discount rate of fuel cost savings (in millions of dollars) of projected new BEVs and PHEVs required by the ZEV standard

Model year	Total ZEV standard compliance		Clean Cars scenario relative to Reference scenario	
	Vehicle (lifetime)	First five years	Vehicle lifetime	First five years
2025	\$78.38	\$39.46	\$49.54	\$24.94
2026	\$64.01	\$32.23	\$35.84	\$18.02
2027	\$64.49	\$32.70	\$33.13	\$16.78
2028	\$64.66	\$32.98	\$30.05	\$15.30
2029	\$64.47	\$33.02	\$26.55	\$13.58
2030	\$63.86	\$32.81	\$22.61	\$11.60
2031	\$62.77	\$32.33	\$18.18	\$9.35
2032	\$61.28	\$31.65	\$13.32	\$6.87
2033	\$68.33	\$35.47	\$10.29	\$5.34
2034	\$66.04	\$34.38	\$4.22	\$2.19
Total	\$658.28	\$337.04	\$243.73	\$123.99

The Total ZEV standard compliance columns show estimated the present value of total fuel cost savings of all BEVs and PHEVs needed for compliance. The Clean Cars scenario relative to Reference scenario columns show the estimated present value of fuel cost savings of BEVs and PHEVs necessary for ZEV compliance compared to a future scenario of linear sales growth of BEVs and PHEVs. The estimated cumulative present value fuel savings over the lifetimes of all model year BEVs and PHEVs in the Clean Cars scenario relative to the Reference scenario is \$294 million.

Table 30 presents net present value fuel savings, assuming a 3% discount rate, over vehicle lifetimes on a per-vehicle basis, of an EV relative to an ICE vehicle. The average EV, based on the mix of BEVs and PHEVs the MPCA estimates would be required for ZEV compliance, is estimated to save the consumer \$3,400 to \$4,900 in fuel costs in present value terms over the lifetime of the vehicle. The fuel savings declines between MY 2025 to MY 2026 is largely due to the increased stringency for MY 2026 used in the reference scenario. Thereafter, the average fuel savings generally increases in future model years is due to gradually rising gasoline prices.

Table 30: Net present value of per-vehicle fuel cost savings assuming a 3% discount rate for a Minnesota EV relative to an ICE vehicle

Model year	EV Average ⁶⁴
2025	\$4,329
2026	\$3,423
2027	\$3,504
2028	\$3,580
2029	\$3,651
2030	\$3,716

⁶⁴ The calculations in Table 30 are based on the mix of BEVs and PHEVs that would be required for compliance with the ZEV standard in Minnesota. On average, the fuel cost savings for BEVs exceed those for PHEVs due primarily to the fact that PHEVs still run on gasoline for a portion of their operation.

Model year	EV Average ⁶⁴
2031	\$3,772
2032	\$3,825
2033	\$4,837
2034	\$4,874

Based on the mix of BEVs and PHEVs required for ZEV compliance in Minnesota, the estimated present value of fuel savings for the average EV ranges from around \$3,400 to \$4,900 over the lifetime of the vehicle. Positive values in this table reflect savings to the consumer who purchases an EV compared to if they had purchased an ICE vehicle.

iv. Maintenance and repair savings

The MPCA also analyzed the costs and benefits associated with potentially reduced maintenance and repair costs for EVs. The MPCA estimated maintenance and repair costs of 6 cents per mile for cars and 7.6 cents per mile for crossovers and SUVs for ICE vehicles.⁶⁵ The MPCA estimated maintenance and repair costs for BEVs to be 2.4 cents for cars and 3.6 cents per mile for crossovers and SUVs.⁶⁶ The MPCA estimated maintenance and repair costs for PHEVs to be 4.2 cents per mile for cars and 5.5 cents per mile for crossovers and SUVs.⁶⁷

Using these values, BEVs and PHEVs as a group have significant operational and maintenance savings associated with ownership compared to ICE vehicles. As Table 31 shows, the MPCA estimates \$803 million in total maintenance savings from all BEVs and PHEVs that would be sold for compliance with the ZEV standard for 2025-2034 model year vehicles. During the first 5 years of ownership, consumers would save \$397 million. The expected maintenance and repair savings from compliance with the ZEV standard over the linearly projected Reference scenario is \$281 million for the lifetime of vehicles through MY 2034.

Table 31: Maintenance and repair savings (in millions of dollars)

Model year	Total ZEV standard compliance		Clean Cars scenario relative to Reference scenario	
	Vehicle lifetime	First five years	Vehicle lifetime	First five years
2025	\$85.76	\$42.43	\$49.36	\$24.42
2026	\$85.22	\$42.16	\$45.31	\$22.41
2027	\$84.47	\$41.79	\$41.06	\$20.31
2028	\$83.50	\$41.31	\$36.58	\$18.10
2029	\$82.26	\$40.69	\$31.83	\$15.75
2030	\$80.67	\$39.91	\$26.73	\$13.22
2031	\$78.69	\$38.93	\$21.25	\$10.51
2032	\$76.34	\$37.76	\$15.39	\$7.61

⁶⁵ Lutsey, N. & Nicholas, M., *Update on Electric Vehicle Costs in the United States through 2030*, The International Council on Clean Transportation (April 2, 2019).

⁶⁶ *Id.*

⁶⁷ *Id.*

Model year	Total ZEV standard compliance		Clean Cars scenario relative to Reference scenario	
	Vehicle lifetime	First five years	Vehicle lifetime	First five years
2033	\$73.86	\$36.54	\$9.41	\$4.65
2034	\$71.80	\$35.52	\$3.84	\$1.90
Total	\$802.55	\$397.03	\$280.75	\$138.89

The Total ZEV standard compliance columns show estimated the total maintenance cost savings from all the BEVs and PHEVs needed for compliance with the ZEV standard. The Clean Cars scenario relative to Reference scenario columns show the estimated maintenance cost savings of BEVs and PHEVs necessary for ZEV compliance compared to a future scenario of linear sales growths of BEVs and PHEVs. The cumulative estimated maintenance savings over the lifetimes of all model year BEVs and PHEVs in the compliance scenario relative to the reference scenario is over \$280 million.

As with fuel savings, maintenance and repair savings occur over the lifetimes of vehicles and it is thus informative to discount future maintenance and repair savings into present value terms. Table 32 shows the maintenance and repair savings represented in present values using a 3% discount rate.

Table 32: Net present value of maintenance and repair savings (in millions of dollars) assuming a 3% discount rate

Model year	Total ZEV standard compliance		Clean Cars scenario relative to Reference scenario	
	Vehicle lifetime)	First five years	Vehicle lifetime	First five years
2025	\$73.85	\$39.49	\$42.59	\$22.73
2026	\$73.38	\$39.24	\$39.10	\$20.86
2027	\$72.74	\$38.90	\$35.43	\$18.91
2028	\$71.90	\$38.45	\$31.56	\$16.84
2029	\$70.83	\$37.88	\$27.47	\$14.66
2030	\$69.46	\$37.15	\$23.07	\$12.31
2031	\$67.76	\$36.24	\$18.34	\$9.79
2032	\$65.73	\$35.15	\$13.28	\$7.09
2033	\$63.60	\$34.01	\$8.12	\$4.33
2034	\$61.83	\$33.06	\$3.31	\$1.77
Total	\$691.08	\$369.57	\$242.26	\$129.28

The Total ZEV standard compliance columns show estimated the present value of total maintenance cost savings from all the BEVs and PHEVs needed for compliance with the ZEV standard. Clean Cars scenario relative to Reference scenario columns show the estimated present value of maintenance cost savings of BEVs and PHEVs necessary for ZEV compliance compared to a future scenario of linear sales growths of BEVs and PHEVs. The estimated cumulative present value maintenance savings over the lifetimes of all model year BEVs and PHEVs in the compliance scenario relative to the reference scenario is \$242 million.

Table 33 presents net present value maintenance and repair savings, assuming a 3% discount rate, over vehicle lifetimes on a per-vehicle basis, of an average EV relative to an ICE vehicle. The average EV, based on the mix of BEVs and PHEVs the MPCA projects would be required for ZEV compliance, is estimated to save the consumer \$3,700 to over \$3,800 in maintenance costs in present value terms over the lifetime of the vehicle.

Table 33: Net present value of per-vehicle maintenance and repair cost savings assuming a 3% discount rate for an average Minnesota EV relative to an ICE vehicle

Model year	EV average ⁶⁸
2025	\$3,722
2026	\$3,734
2027	\$3,747
2028	\$3,761
2029	\$3,776
2030	\$3,791
2031	\$3,804
2032	\$3,813
2033	\$3,814
2034	\$3,829

Based on the mix of BEVs and PHEVs the MPCA estimates would be required for compliance with the ZEV standard in Minnesota, the estimated present value of maintenance savings for the average EV ranges from around \$3,700 to over \$3,800 over the lifetime of the vehicle. Positive values in this table reflect savings to the consumer who purchases an EV compared to if they had purchased an ICE vehicle.

v. ZEV standard cumulative costs and savings in Minnesota

Tables 34-37 consolidate the estimates of vehicle purchase costs, fuel costs, and maintenance costs for BEVs, PHEVs, and ICE vehicles to summarize the expected cumulative costs and savings of the ZEV standard in Minnesota.

In addition, Tables 34-37 include another type of costs related to ZEVs that has not already been addressed: costs (or savings) resulting from different annual registration expenses for ZEVs relative to ICE vehicles. These include both the annual fee premium of \$75 owners that Minnesota BEV owners (but not PHEV owners) are required to pay to register their vehicles in the state, as well as the different annual registration taxes relative to ICE vehicles due to relatively different values of BEVs and PHEVs. Both of these are explained further in Section 5(C). In summary, we project the registration fee premium expense to be an unchanging \$75 per year additional expense of BEV ownership. Because annual registration taxes are based on vehicle values (i.e., purchase cost minus depreciation), the different annual registration tax expenses of ZEV owners will change from model year to model year as the cost of BEVs and PHEVs relative to ICE vehicles change over time. When BEVs and PHEVs cost more than ICE vehicles, the ZEV owners will pay more registration taxes over vehicle lifetimes than owners of ICE vehicles. However, as we project BEVs to eventually become cheaper, on average, to purchase than ICE vehicles starting in model year 2028 (see Table 26 and Figure 15), BEVs will also begin to incur lower annual registration taxes.

For example, we estimate that, on average the owner of a model year 2025 BEV will pay \$222 over the course of their vehicle's lifetime more annual registration taxes than the owner of a model year 2025 ICE vehicle. In present value terms, the owner of an average model year 2025 BEV will pay \$203 more registration taxes over their vehicle's lifetime at a 3% discount rate and \$183 at a 7% discount rate. However, by model year 2034, the BEV owner will, on average, incur a \$472 savings in registration taxes

⁶⁸ As was the case for Table 30, the calculations in Table 33 are based on the mix of BEVs and PHEVs that would be required for compliance with the ZEV standard in Minnesota. On average, the maintenance and repair savings for BEVs exceed those for PHEVs.

over their vehicle's lifetime than the owner of an ICE vehicle. In present value terms, this equates to \$433 savings at a 3% discount rate and \$390 savings at a 7% discount rate. On average, the owner of a model year 2025 PHEV will pay \$413 over the course of their vehicle's lifetime more annual registration taxes than the owner of a model year 2025 ICE vehicle. In present value terms, the owner of an average model year 2025 PHEV will pay \$379 more registration taxes over their vehicle's lifetime at a 3% discount rate and \$341 at a 7% discount rate. By model year 2034, the PHEV owner will, on average, pay \$290 more registration taxes over their vehicle's lifetime than the owner of an ICE vehicle. In present value terms, this equates to a cost of \$266 at a 3% discount rate and \$240 at a 7% discount rate. All of these additional costs and savings are included in Tables 34-37, summed over the total number of BEVs and PHEVs and average vehicle lifetimes for Minnesota LDVs.

Table 34 presents the total cumulative cost savings of ZEV standard compliance in Minnesota, relative to a hypothetical alternative where all the new BEVs and PHEVs estimated to be required for ZEV compliance for MYs 2025-2034 were instead ICE vehicles. Table 35 presents the expected cumulative cost savings of a ZEV standard relative to the reference scenario based on linear EV sales growth. Tables 36 and 37 present the same estimates as Tables 34 and 35 but in net present value terms using a 3% discount rate.⁶⁹ Collectively, these tables show that greater vehicle costs for BEVs⁷⁰ and PHEVs are offset by fuel cost and maintenance savings. The total cost associated with all the EVs estimated to be required for compliance with the ZEV standard in Minnesota for the MY 2025-2034 time frame is \$1.43 billion savings in undiscounted terms (Table 34) and \$1.22 billion in present value terms with a 3% discount rate (Table 36). Relative to the Reference scenario with linear sales growth, implementing the ZEV standard in Minnesota for the MY 2025-2034 time frame results in an estimated \$389 million savings in undiscounted terms (Table 35) and \$315 million in present value terms with a 3% discount rate (Table 37). As we did for the LEV standard consumer impacts analysis, the MPCA also used a discount rate of 7% to estimate the overall saving of all the EVs estimated to be required for compliance with the ZEV standard over the ten-year time frame and the estimated savings of the additional EVs required for compliance relative to the Reference scenario. These estimates, presented in Tables 38 and 39, respectively, include a \$1.00 billion overall savings resulting from all EVs required for ZEV compliance and \$239 million savings resulting from the additional EVs relative to the Reference scenario. Regardless of the choice of discount rate, the MPCA estimates that the ZEV standard will result in considerable savings for Minnesota vehicle owners.

⁶⁹ The MPCA also analyzed fuel savings, maintenance savings and annual registration costs/savings using a 7% discount rate. These results are not presented in tables in this document, but we do report the total cumulative savings assuming both a 3% and 7% discount rate.

⁷⁰ As Tables 34-39 make clear, BEVs are only more expensive than ICE vehicles in the early years of this analysis. They are expected to reach cost parity in MY 2028.

Table 34: Total cumulative cost savings of ZEV standard compliance (in millions of dollars)

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 years average	Lifetime average	First 5 years average	Lifetime average	Lifetime average
2025	-\$36.74	-\$41.69	-\$78.43	\$91.63	\$42.47	\$85.76	\$42.43	-\$15.21	\$83.75
2026	-\$21.02	-\$38.03	-\$59.05	\$74.83	\$34.69	\$85.22	\$42.16	-\$13.91	\$87.08
2027	-\$6.57	-\$34.55	-\$41.12	\$75.34	\$35.20	\$84.47	\$41.79	-\$12.69	\$105.99
2028	\$6.63	-\$31.23	-\$24.60	\$75.49	\$35.48	\$83.50	\$41.31	-\$11.55	\$122.84
2029	\$18.61	-\$28.07	-\$9.45	\$75.23	\$35.52	\$82.26	\$40.69	-\$10.47	\$137.57
2030	\$30.57	-\$25.03	\$5.54	\$74.50	\$35.29	\$80.67	\$39.91	-\$9.35	\$151.35
2031	\$42.17	-\$22.09	\$20.09	\$73.20	\$34.77	\$78.69	\$38.93	-\$8.22	\$163.76
2032	\$53.21	-\$19.25	\$33.96	\$71.44	\$34.03	\$76.34	\$37.76	-\$7.08	\$174.65
2033	\$63.70	-\$16.62	\$47.09	\$79.61	\$38.14	\$73.86	\$36.54	-\$5.97	\$194.59
2034	\$74.12	-\$14.28	\$59.84	\$76.91	\$36.97	\$71.80	\$35.52	-\$4.93	\$203.62
Total	\$224.69	-\$270.84	-\$46.14	\$768.17	\$362.55	\$802.55	\$397.03	-\$99.38	\$1,425.20

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In undiscounted terms, the total estimated cumulative savings from all EVs estimated to be required for compliance with the ZEV standard is \$1.43 billion for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

Table 35: Total cumulative cost savings of ZEV standard compliance (in millions of dollars) relative to linear EV sales growth reference scenario

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$19.14	-\$31.18	-\$50.32	\$57.76	\$26.84	\$49.36	\$24.42	-\$8.59	\$48.20
2026	-\$10.04	-\$27.12	-\$37.16	\$41.80	\$19.40	\$45.31	\$22.41	-\$7.28	\$42.67
2027	-\$2.85	-\$23.27	-\$26.12	\$38.61	\$18.06	\$41.06	\$20.31	-\$6.09	\$47.46
2028	\$2.57	-\$19.61	-\$17.04	\$35.00	\$16.46	\$36.58	\$18.10	-\$5.01	\$49.52
2029	\$6.34	-\$16.14	-\$9.80	\$30.91	\$14.61	\$31.83	\$15.75	-\$4.03	\$48.91
2030	\$8.87	-\$12.83	-\$3.96	\$26.31	\$12.47	\$26.73	\$13.22	-\$3.11	\$45.97
2031	\$9.90	-\$9.66	\$0.24	\$21.16	\$10.06	\$21.25	\$10.51	-\$2.25	\$40.40
2032	\$9.23	-\$6.65	\$2.58	\$15.50	\$7.39	\$15.39	\$7.61	-\$1.46	\$32.00
2033	\$6.89	-\$3.90	\$3.00	\$11.97	\$5.74	\$9.41	\$4.65	-\$0.79	\$23.57
2034	\$3.35	-\$1.49	\$1.85	\$4.90	\$2.36	\$3.84	\$1.90	-\$0.28	\$10.31
Total	\$15.13	-\$151.86	-\$136.73	\$283.91	\$133.39	\$280.75	\$138.89	-\$38.90	\$389.04

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In undiscounted terms the total estimated cumulative savings of ZEV compliance, relative to the reference case EV sales growth scenario, is \$389 million for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

Table 36: Total net present value of cumulative cost savings of ZEV standard compliance (in millions of dollars) assuming a 3% discount rate

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$36.74	-\$41.69	-\$78.43	\$78.38	\$39.46	\$73.85	\$39.49	-\$13.46	\$60.34
2026	-\$21.02	-\$38.03	-\$59.05	\$64.01	\$32.23	\$73.38	\$39.24	-\$12.27	\$66.07
2027	-\$6.57	-\$34.55	-\$41.12	\$64.49	\$32.70	\$72.74	\$38.90	-\$11.15	\$84.95
2028	\$6.63	-\$31.23	-\$24.60	\$64.66	\$32.98	\$71.90	\$38.45	-\$10.10	\$101.86
2029	\$18.61	-\$28.07	-\$9.45	\$64.47	\$33.02	\$70.83	\$37.88	-\$9.10	\$116.75
2030	\$30.57	-\$25.03	\$5.54	\$63.86	\$32.81	\$69.46	\$37.15	-\$8.08	\$130.78
2031	\$42.17	-\$22.09	\$20.09	\$62.77	\$32.33	\$67.76	\$36.24	-\$7.05	\$143.57
2032	\$53.21	-\$19.25	\$33.96	\$61.28	\$31.65	\$65.73	\$35.15	-\$6.01	\$154.96
2033	\$63.70	-\$16.62	\$47.09	\$68.33	\$35.47	\$63.60	\$34.01	-\$5.00	\$174.01
2034	\$74.12	-\$14.28	\$59.84	\$66.04	\$34.38	\$61.83	\$33.06	-\$4.06	\$183.65
Total	\$224.69	-\$270.84	-\$46.14	\$658.28	\$337.04	\$691.08	\$369.57	-\$86.27	\$1,216.95

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 3% discount rate the total estimated cumulative savings from all EVs estimated to be required for compliance with the ZEV standard is \$1.22 billion for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

Table 37: Total net present value of cumulative cost savings of ZEV standard compliance (in millions of dollars) assuming a 3% discount rate relative to linear EV sales growth reference scenario.

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$19.14	-\$31.18	-\$50.32	\$49.54	\$24.94	\$42.59	\$22.73	-\$7.62	\$34.18
2026	-\$10.04	-\$27.12	-\$37.16	\$35.84	\$18.02	\$39.10	\$20.86	-\$6.44	\$31.34
2027	-\$2.85	-\$23.27	-\$26.12	\$33.13	\$16.78	\$35.43	\$18.91	-\$5.37	\$37.07
2028	\$2.57	-\$19.61	-\$17.04	\$30.05	\$15.30	\$31.56	\$16.84	-\$4.41	\$40.17
2029	\$6.34	-\$16.14	-\$9.80	\$26.55	\$13.58	\$27.47	\$14.66	-\$3.53	\$40.69
2030	\$8.87	-\$12.83	-\$3.96	\$22.61	\$11.60	\$23.07	\$12.31	-\$2.71	\$39.01
2031	\$9.90	-\$9.66	\$0.24	\$18.18	\$9.35	\$18.34	\$9.79	-\$1.94	\$34.82
2032	\$9.23	-\$6.65	\$2.58	\$13.32	\$6.87	\$13.28	\$7.09	-\$1.26	\$27.93
2033	\$6.89	-\$3.90	\$3.00	\$10.29	\$5.34	\$8.12	\$4.33	-\$0.68	\$20.73
2034	\$3.35	-\$1.49	\$1.85	\$4.22	\$2.19	\$3.31	\$1.77	-\$0.24	\$9.14
Total	\$15.13	-\$151.86	-\$136.73	\$243.73	\$123.99	\$242.26	\$129.28	-\$34.19	\$315.07

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 3% discount rate the total estimated cumulative savings of ZEV compliance, relative to the reference case EV sales growth scenario, is \$315 million for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

Table 38: Total net present value of cumulative cost savings of ZEV standard compliance (in millions of dollars) assuming a 7% discount rate

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$36.74	-\$41.69	-\$78.43	\$64.90	\$35.99	\$61.66	\$36.10	-\$11.63	\$36.51
2026	-\$21.02	-\$38.03	-\$59.05	\$52.99	\$29.39	\$61.27	\$35.87	-\$10.56	\$44.66
2027	-\$6.57	-\$34.55	-\$41.12	\$53.44	\$29.83	\$60.74	\$35.56	-\$9.54	\$63.51
2028	\$6.63	-\$31.23	-\$24.60	\$53.62	\$30.09	\$60.04	\$35.15	-\$8.60	\$80.47
2029	\$18.61	-\$28.07	-\$9.45	\$53.51	\$30.14	\$59.15	\$34.62	-\$7.70	\$95.50
2030	\$30.57	-\$25.03	\$5.54	\$53.03	\$29.96	\$58.00	\$33.95	-\$6.78	\$109.79
2031	\$42.17	-\$22.09	\$20.09	\$52.14	\$29.51	\$56.58	\$33.12	-\$5.86	\$122.95
2032	\$53.21	-\$19.25	\$33.96	\$50.92	\$28.89	\$54.89	\$32.13	-\$4.93	\$134.84
2033	\$63.70	-\$16.62	\$47.09	\$56.82	\$32.39	\$53.11	\$31.09	-\$4.03	\$152.99
2034	\$74.12	-\$14.28	\$59.84	\$54.94	\$31.40	\$51.63	\$30.22	-\$3.18	\$163.22
Total	\$224.69	-\$270.84	-\$46.14	\$546.30	\$307.58	\$577.07	\$337.82	-\$72.81	\$1,004.42

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 7% discount rate the total estimated cumulative savings from all EVs estimated to be required for compliance with the ZEV standard is \$1.00 billion for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

Table 39: Total net present value of cumulative cost savings of ZEV standard compliance (in millions of dollars) assuming a 7% discount rate relative to linear EV sales growth reference scenario.

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$19.14	-\$31.18	-\$50.32	\$41.12	\$22.75	\$35.63	\$20.78	-\$6.61	\$19.82
2026	-\$10.04	-\$27.12	-\$37.16	\$29.74	\$16.43	\$32.71	\$19.07	-\$5.56	\$19.73
2027	-\$2.85	-\$23.27	-\$26.12	\$27.52	\$15.30	\$29.64	\$17.28	-\$4.62	\$26.42
2028	\$2.57	-\$19.61	-\$17.04	\$24.97	\$13.96	\$26.41	\$15.40	-\$3.77	\$30.57
2029	\$6.34	-\$16.14	-\$9.80	\$22.09	\$12.40	\$22.98	\$13.40	-\$3.01	\$32.26
2030	\$8.87	-\$12.83	-\$3.96	\$18.82	\$10.59	\$19.30	\$11.25	-\$2.29	\$31.86
2031	\$9.90	-\$9.66	\$0.24	\$15.14	\$8.54	\$15.34	\$8.95	-\$1.64	\$29.08
2032	\$9.23	-\$6.65	\$2.58	\$11.10	\$6.27	\$11.11	\$6.48	-\$1.05	\$23.74
2033	\$6.89	-\$3.90	\$3.00	\$8.58	\$4.88	\$6.79	\$3.96	-\$0.56	\$17.81
2034	\$3.35	-\$1.49	\$1.85	\$3.52	\$2.00	\$2.77	\$1.62	-\$0.19	\$7.95
Total	\$15.13	-\$151.86	-\$136.73	\$202.59	\$113.13	\$202.69	\$118.18	-\$29.32	\$239.23

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 7% discount rate the total estimated cumulative savings of ZEV compliance, relative to the reference case EV sales growth scenario, is \$239 million for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of all MY 2025-2034 vehicles.

The cumulative per-vehicle cost savings to an EV purchaser and owner relative to a purchaser and owner of an ICE vehicle in undiscounted terms, in present value terms with a 3% discount rate, and in present value terms with a 7% discount are presented in Tables 40, 41, and 42, respectively. As technological developments lead to reductions in purchase prices of EVs relative to ICE vehicles, the overall cost savings of an EV relative to an ICE vehicle increases. By MY 2034, the average savings over the life of an EV relative to an ICE vehicle is around \$13,800 in undiscounted terms (Table 40), around \$12,400 in net present value terms using a 3% discount rate (Table 41). Even with a high discount rate of 7%, the average savings is \$11,000 in net present value terms (Table 42).

Table 40: Average per-vehicle cost impacts by model year (dollars per vehicle)

Model year	Incremental vehicle cost ⁷¹			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$3,136	-\$5,840	-\$3,812	\$5,048	\$2,346	\$4,314	\$2,134	-\$751	\$4,799
2026	-\$1,781	-\$5,612	-\$2,738	\$3,992	\$1,853	\$4,327	\$2,141	-\$695	\$4,886
2027	-\$554	-\$5,397	-\$1,765	\$4,084	\$1,910	\$4,342	\$2,148	-\$644	\$6,017
2028	\$557	-\$5,195	-\$881	\$4,170	\$1,962	\$4,359	\$2,156	-\$597	\$7,051
2029	\$1,567	-\$5,005	-\$76	\$4,250	\$2,008	\$4,376	\$2,165	-\$554	\$7,996
2030	\$2,588	-\$4,826	\$735	\$4,324	\$2,050	\$4,393	\$2,173	-\$511	\$8,941
2031	\$3,610	-\$4,647	\$1,546	\$4,389	\$2,086	\$4,408	\$2,181	-\$466	\$9,877
2032	\$4,631	-\$4,468	\$2,357	\$4,449	\$2,121	\$4,418	\$2,186	-\$420	\$10,804
2033	\$5,653	-\$4,289	\$3,167	\$5,622	\$2,699	\$4,420	\$2,187	-\$373	\$12,836
2034	\$6,674	-\$4,110	\$3,978	\$5,663	\$2,727	\$4,437	\$2,195	-\$327	\$13,751

Negative values indicate higher costs for a BEV or PHEV relative to an ICE vehicle. Positive values indicate savings for a BEV or PHEV relative to ICE vehicles. In undiscounted terms the total estimated savings for the purchaser of an average MY 2034 EV is approximately \$13,800 compared to if they had purchased an ICE vehicle instead. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of the vehicle.

Table 41: Net present value average per-vehicle cost impacts by model year (dollars per vehicle) assuming a 3% discount rate

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$3,136	-\$5,840	-\$3,812	\$4,329	\$2,180	\$3,722	\$1,986	-\$666	\$3,573
2026	-\$1,781	-\$5,612	-\$2,738	\$3,423	\$1,721	\$3,734	\$1,993	-\$615	\$3,804
2027	-\$554	-\$5,397	-\$1,765	\$3,504	\$1,775	\$3,747	\$2,000	-\$568	\$4,918
2028	\$557	-\$5,195	-\$881	\$3,580	\$1,823	\$3,761	\$2,007	-\$525	\$5,936
2029	\$1,567	-\$5,005	-\$76	\$3,651	\$1,867	\$3,776	\$2,015	-\$485	\$6,866
2030	\$2,588	-\$4,826	\$735	\$3,716	\$1,906	\$3,791	\$2,023	-\$445	\$7,797
2031	\$3,610	-\$4,647	\$1,546	\$3,772	\$1,940	\$3,804	\$2,030	-\$403	\$8,719
2032	\$4,631	-\$4,468	\$2,357	\$3,825	\$1,972	\$3,813	\$2,035	-\$361	\$9,633
2033	\$5,653	-\$4,289	\$3,167	\$4,837	\$2,511	\$3,814	\$2,035	-\$318	\$11,500
2034	\$6,674	-\$4,110	\$3,978	\$4,874	\$2,537	\$3,829	\$2,043	-\$275	\$12,406

Negative values indicate higher costs for a BEV or PHEV relative to an ICE vehicle. Positive values indicate savings for a BEV or PHEV relative to ICE vehicles. In present value terms, assuming a 3% discount rate, the total estimated savings for the purchaser of an average MY year 2034 EV is approximately \$12,400 compared to if they had purchased an ICE vehicle instead. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of the vehicle.

Table 42: Net present value average per-vehicle cost impacts by model year (dollars per vehicle) assuming a 7% discount rate

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$3,136	-\$5,840	-\$3,812	\$3,594	\$1,988	\$3,114	\$1,816	-\$578	\$2,318
2026	-\$1,781	-\$5,612	-\$2,738	\$2,841	\$1,570	\$3,124	\$1,822	-\$532	\$2,695
2027	-\$554	-\$5,397	-\$1,765	\$2,910	\$1,618	\$3,135	\$1,828	-\$489	\$3,791
2028	\$557	-\$5,195	-\$881	\$2,976	\$1,664	\$3,147	\$1,835	-\$450	\$4,792
2029	\$1,567	-\$5,005	-\$76	\$3,037	\$1,704	\$3,159	\$1,842	-\$414	\$5,706
2030	\$2,588	-\$4,826	\$735	\$3,092	\$1,740	\$3,172	\$1,849	-\$377	\$6,622
2031	\$3,610	-\$4,647	\$1,546	\$3,140	\$1,771	\$3,183	\$1,856	-\$339	\$7,530
2032	\$4,631	-\$4,468	\$2,357	\$3,185	\$1,801	\$3,190	\$1,860	-\$301	\$8,431
2033	\$5,653	-\$4,289	\$3,167	\$4,032	\$2,293	\$3,191	\$1,860	-\$263	\$10,127
2034	\$6,674	-\$4,110	\$3,978	\$4,064	\$2,317	\$3,204	\$1,868	-\$224	\$11,022

Negative values indicate higher costs for a BEV or PHEV relative to an ICE vehicle. Positive values indicate savings for a BEV or PHEV relative to ICE vehicles. In present value terms, assuming a 7% discount rate, the total estimated savings for the purchaser

of an average MY year 2034 EV is approximately \$11,000 compared to if they had purchased an ICE vehicle instead. This is the sum of incremental vehicle costs, fuel savings, maintenance savings, and annual vehicle registration premiums and taxes for the lifetimes of the vehicle.

Based on the additional BEVs and PHEVs needed to comply with the ZEV standard and assuming a 3% discount rate, the MPCA estimates the ZEV standard would result in an average of \$34.9 million of vehicle lifetime benefits for each model year from 2025 to 2034 and a total consumer benefit of \$315 million over vehicle lifetimes for the 10 model years. Due in large part to declining EV purchase costs relative to ICE vehicles, the consumer benefits of the ZEV standard would initially increase for each model year, peaking at nearly \$41 million for MY 2029, assuming a 3% discount rate. After MY 2029, the MPCA's analysis projects total consumer benefits for each model year may decline slightly due to projected declines in overall light-duty vehicle sales and thus the number of EVs needed for ZEV standard compliance, projected increases in EV sales in the reference scenario while ZEV standard compliance requirements plateau starting in MY 2025, and projected increases in fuel efficiency of ICE vehicles. For MY 2034, total vehicle lifetime consumer benefits of ZEV compliance are projected to be around \$9.1 million, again assuming a 3% discount rate. At a 7% discount rate, the total consumer benefit for the 10 model years from 2025 to 2034 are estimated to be \$239 million, peaking at around \$32 million for MY 2029 and declining to \$7.9 million for MY 2034.

The MPCA's analysis also found the total benefit over vehicle lifetimes of all BEV and PHEV sales required by the ZEV standard through MY 2034, and again assuming a 3% discount rate, would reach approximately \$184 million annually by MY 2034 and \$1.22 billion total over the 10 model years. With a 7% discount rate, the total benefit over vehicle lifetimes of all BEV and PHEV sales required by the ZEV standard through MY 2034 would reach \$163 million annually by MY 2034 and \$1.00 billion total over the 10 model years.

C. LEV and ZEV standards impact on state tax revenue

The proposed rule could also have an impact on state tax revenues. However, due to the estimated losses in some revenue streams, such as fuel tax revenues, being almost exactly offset by the gains in other revenue streams, such as sales tax revenues, the proposed rule is estimated to overall be very close to revenue neutral for the state.

The analysis of fuel savings for the proposed rule estimates reduced gasoline consumption over vehicle lifetimes for MYs 2025-2034 of 674 million gallons. This estimate is based on estimates of the average fuel efficiency of LEV-certified vehicles relative to final SAFE rule-certified vehicles⁷¹ along with projected light-duty vehicle sales in Minnesota and projected VMT in Minnesota. The LEV standard is an overall fleet average that includes EVs. Therefore, the fuel savings from EVs resulting from the ZEV standard are captured in the average fuel savings estimated to result from the LEV standard.

To the extent that adopting the proposed rule results in lower gasoline spending by Minnesota vehicle owners, the state would generate less revenue from its fuel tax; however, to the extent that LEV-certified ICE vehicles and EVs have a higher up-front cost, most of this revenue would be made back through vehicle sales tax. Another portion would be made back through increased registration taxes paid each year by Minnesota vehicle owners, which are based on the value of the vehicles. Thus, higher-priced LEV-certified ICE vehicles and EVs will also incur higher registration taxes throughout the vehicles' lifetimes. Finally, the annual state registration fee premiums for BEVs is also an additional

⁷¹ *Basing this analysis on the final SAFE rule would likely result in a slightly lower fuel savings based on the slightly increased emissions stringency of the final SAFE rule compared to the proposed SAFE rule.*

source of revenue for the state that results from more BEVs in Minnesota.

Minnesota currently has a flat gas tax of \$0.285 per gallon: \$0.25 plus a \$0.035 debt service surcharge that is intended to partially cover the debt obligations for capital projects on the state's highway system. Assuming no changes to the \$0.285 per gallon fuel tax, this translates to an estimated total reduction in fuel tax revenue associated with implementation of the proposed rule over this time frame of approximately \$192 million. It should be noted that while this is a loss in state revenue, it is not an overall cost as the loss of revenue to the state is exactly offset by the avoided costs to Minnesotan consumers, so that the money that does not go to the state remains in Minnesotans' pockets.

Some of this lost state fuel tax revenue would be offset by the annual registration fee premium that BEV owners are required to pay. Currently, BEV owners pay an annual premium of \$75 to register their vehicles in Minnesota. If BEV owners continue to pay a \$75 per year registration fee premium, based on the MPCA's projections of additional BEVs that adopting the ZEV standard would be likely to require in Minnesota relative to the linear sales growth Reference scenario, the registration fee would result in an estimated \$18.5 million in increased state revenue over the first 10 years of implementation in the Clean Cars scenario.

Some of the remaining revenue shortfall between reduced gasoline tax paid by owners of EVs and LEV-certified vehicles and the added revenue from BEV registration fee premiums would be made up by increased sales tax revenues due to the generally higher purchase price of BEVs and PHEVs relative to ICE vehicles. The current Minnesota state sales tax rate for motor vehicles is 6.5%. Based on the projected increased vehicle costs for BEVs and PHEVs relative to ICE vehicles in the initial years after implementation of the proposed rule, and increased vehicle costs for PHEVs relative to ICE vehicles for the entire 10-year time frame, the ZEV standard is estimated to result in about \$9.4 million in added sales tax revenue in Minnesota relative to the linear sales growth Reference scenario over this time frame.

Furthermore, the higher purchase costs of LEV-certified vehicles would also lead to increased sales tax revenue for the state. As demonstrated in Tables 15-18, the average LEV-certified vehicle may cost the purchaser around \$47 in increased sales tax relative to a SAFE-certified vehicle. Based on LDV sales projections in Minnesota for MYs 2025-2034 (see Table 1), the MPCA estimates this would mean a \$112 million increase in sales tax revenues for the state of Minnesota over this time frame, offsetting a majority of the estimated \$192 million in lost fuel tax revenue resulting from implementation of the proposed rule.

Finally, the registration taxes paid by Minnesota vehicle owners every year is directly related to the value of the vehicles. Minnesota LDV owners pay 1.285% of the value of their vehicles in annual registration taxes. The MPCA has estimated the total increase in vehicle registration taxes over the MY 2025-2034 time frame resulting from both the LEV and the ZEV standard. As presented in Section 3(A)(i), the MPCA estimates that, on average, a LEV-certified vehicle will incur a purchase cost premium of \$1,139 compared to a non-LEV-certified vehicle (see Table 13). Based on the total MY 2025-2034 LDV sales projections (see Table 1), and assuming that vehicle values depreciate, on average, 10% every year, the MPCA has estimated that the total additional registration taxes paid by Minnesotans over the MY 2025-2034 time frame will be \$135 million higher under a LEV standard. To estimate the impact of the ZEV standard on vehicle registration taxes, the MPCA considered the projected increased BEV and PHEV sales relative to the Reference scenario (see Table 25) along with the projected price differences between BEVs and PHEVs compared to ICE vehicles (see Table 26). Again assuming a 10% annual depreciation in the value of vehicles, the MPCA estimates that as a result of the ZEV standard, the increase in registration taxes paid by Minnesotans over the MY 2025-2034 time frame will be \$9.5 million.

Summing all the lost fuel tax revenue for the proposed rule along with the added sales tax revenue, added registration tax revenue, and registration fee revenue totals only an overall \$92 million gain in revenues for the state of Minnesota over the first 10 years of rule implementation. Due to the small magnitude of this value along with the uncertainty and speculative nature of these projections, our estimation is that the rule is likely to be close to overall revenue-neutral for the state. Table 43 summarizes the MPCA's estimates of state revenue increases and reductions over the first 10 years of implementation of the proposed rule. In 2019, Minnesota's total fuel tax revenue was about \$937.6 million and its total revenue from all taxes was \$23.5 billion. An increase of \$92 million over the course of 10 years, which is approximately 0.39% of Minnesota's tax revenue for the single 2019 year, would be small compared to these overall state revenues.

Table 43: Estimated impacts of the proposed rule on Minnesota state revenue over first 10 years of implementation

Impact type	Estimated state revenue impact
Fuel tax	\$192.1 million reduction
Sales tax from LEV	\$111.6 million increase
Sales tax from ZEV	\$9.4 million increase
Registration tax from LEV	\$135.4 million increase
Registration tax from ZEV	\$9.5 million increase
BEV registration fees	\$18.5 million increase
Total net state revenues for proposed rule	\$92 million increase

The proposed rule would reduce state revenues from fuel taxes but this lost state revenue would be offset by increased sales tax revenues, increased registration tax revenues, and registration fee premiums. The net effect of both standards is estimated to be close to revenue-neutral for the state over the 10-year time frame.

All of the state revenue impacts listed in Table 43 are transactions between Minnesota consumers and the state of Minnesota. As such, revenue increases for the state are also costs to Minnesota consumers while revenue decreases for the state are also benefits to Minnesota consumers. These impacts have been incorporated into MPCA's analysis of costs and benefits to Minnesota consumers. The fuel savings analyses for both the LEV standard (Section 3(A)(iii)) and the ZEV standard (Section 3(B)(iii)) are based on retail gasoline prices that include fuel taxes, so we have already considered the loss of fuel tax revenue for the state as a benefit to Minnesota vehicle owners. The additional sales tax for more expensive LEV-certified vehicles, which is a source of revenue for the state, has also already been considered as a consumer cost (Section 3(A)(ii)).

The registration tax revenues for the state resulting from both LEV and ZEV standards as well as the additional BEV registration fees resulting from the ZEV standard, however, were incorporated in the net consumer costs and benefits analyses of the LEV and ZEV standards in Sections 3(A)(iv) and 3(B)(v), respectively. While, in aggregate, summed across all Minnesota purchasers of new LDVs, these account for considerable revenues for the state (see Table 43), the cost or benefit to each Minnesota vehicle owner is much smaller. For the LEV standard, MPCA estimates an average added registration tax cost for the owner of a LEV-certified vehicle relative to a non-LEV-certified vehicle of only \$14.63 in the first year of vehicle ownership. Due to depreciation of the value of the vehicle as well as discounting of future costs, the added registration tax cost of a LEV-certified vehicle declines in each successive year. Over the lifetime of a LEV-certified vehicle, and assuming a 3 percent discount rate, the MPCA estimates that the vehicle owner will pay an average \$73.85 (in present value terms) in additional registration taxes relative to the owner of a non-LEV-certified vehicle. At a 7 percent discount rate, the estimated average increased registration tax of a LEV-certified vehicle over the vehicle's lifetime is \$66.59.

For the ZEV standard, the calculation of the cost of added registration taxes for the EV owner relative to the owner of an ICE vehicle is more complex due to the fact that average costs of BEVs and PHEVs relative to ICE vehicles are expected to change over time. In the first year of ownership of a model year 2025 BEV, the vehicle owner will pay, on average, an estimated \$40.29 more than the owner of a model year 2025 ICE vehicle. For the first year of ownership of a model year 2025 PHEV, the owner will pay, on average, an estimated \$75.04 more than the owner of a model year 2025 ICE vehicle. In subsequent years, the added registration tax cost for the owner of a model year 2025 EV decreases, again due to depreciation and discounting. Over a model year 2025 vehicle's lifetime, the owner of a BEV will pay (in present value terms) an estimated \$203.36, on average, in added registration taxes relative to an ICE vehicle owner, assuming a 3 percent discount rate and \$183.35, assuming a 7 percent discount rate. The owner of a model year 2025 PHEV will pay an estimated \$378.70, on average, in added registration taxes relative to an ICE vehicle owner, assuming a 3 percent discount rate and \$341.43, assuming a 7 percent discount rate. These estimated added registration tax costs for BEV and PHEV owners relative to ICE vehicles decline in future model years as the purchase costs of EVs are expected to decline relative to ICE vehicles. By model year 2028, when BEVs are expected to become cheaper to purchase than ICE vehicles, the owner of a BEV will, on average, get a registration tax benefit for having a less expensive vehicle.

The consumer cost impact of the \$75 annual registration fee premium for BEV owners is more straightforward. Using the MPCA's estimated average vehicle lifetime for LDVs in Minnesota of around 11 years, and assuming a 3% discount rate, the BEV owner will pay \$714.76, on average, in increased registration fee premiums (in present value terms) over their vehicle's lifetime. Assuming a 7% discount rate, the BEV owner will pay \$601.77 in increased registration fee premiums, in present value terms, over their vehicle's lifetime.

4. Health and equity analysis

Lower emissions of GHGs provides global benefits in the form of reduced climate impacts. Lower emissions of NMOG, NO_x, and PM, however, result in reductions of harmful health impacts regionally and locally to people exposed to those emissions. The MPCA has modeled the expected health benefits resulting from the reduced tailpipe and upstream emissions of these non-GHG pollutants presented in Section 2 of this TSD. The majority of these health benefits will occur in Minnesota and based on the proximity of where people live and breathe to these sources of pollution, not all people and communities equally benefit from these emissions reductions. For this reason, MPCA has also analyzed the equity implications of Clean Cars Minnesota to address the questions of who is likely to be most affected and who is likely to most benefit from LEV and ZEV standards in Minnesota.

A. Health benefits analysis

i. Methodology

For the health benefits analysis, the MPCA started with the estimated reduced emissions of PM, NO_x, and NMOG that would result from Clean Cars Minnesota and used two different methods used by the U.S. EPA to translate these emissions reductions into predicted health benefits as well as economic values of the health benefits. Both methods focus on the health impacts of fine particles, or particulate matter less than 2.5 microns in diameter (PM_{2.5}), which is a subset of total PM emissions. The two methods are:

1. **EPA's Benefit per Ton of Reducing PM_{2.5} Precursors from 17 Sectors ("Benefit per Ton values").**⁷² These are estimates of the health and economic benefits from reductions of direct emissions of PM_{2.5} and NO_x from 17 different sectors of the U.S. economy. For this analysis, the MPCA considered reduced tailpipe emissions to be in the "On-road mobile sources" sector; reduced upstream emissions associated with gasoline production were considered to be in the "Refineries" sector; and increased emissions from the electricity generation needed to meet higher electricity demands to power EVs were considered to be in the "Electricity generation" sector. For this last category of emissions in the electricity sector, using an average mix of fuels used for power generation in Minnesota, we estimated potential increased emissions to meet higher electricity demands; therefore, the resulting health impacts from these emissions are included as health costs, not health benefits. In its economic valuation, this tool applies discount rates of both 3% and 7% to discount the values of future health benefits into present value terms
2. **EPA's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening Tool.**⁷³ The COBRA model is a reduced-form screening tool to estimate the human health benefits in the U.S. and the economic value of those benefits from changes in air pollutant emissions resulting from clean energy policies and programs. The COBRA model only considers how changes in direct PM_{2.5} emissions and NO_x emissions lead to PM_{2.5} pollution, and thus only considers the health impacts of PM_{2.5} pollution. Unlike the Benefit per Ton values described above, COBRA does consider geographic specificity of where the emissions reductions take place, down to the county level, to estimate the health benefits of those reductions. Similar to the Benefit per Ton values, the sector that is the source of emissions matters in determining health impacts (or health benefits of emissions reductions). For this analysis, all tailpipe emissions reductions were considered to be in COBRA's "Highway Vehicles" sector. COBRA also applies discount rates of both 3% and 7% to discount future health benefits into present value terms.

Both of these methods look solely at the health impacts of PM_{2.5} pollution, considering both directly emitted PM_{2.5} as well as the emissions of the precursors that lead to atmospheric PM_{2.5} formulation, even though pollution from vehicles results in other health-impacting air pollutants as well. Moreover, these methods do not consider an exhaustive list of all the health problems associated with air pollution. Thus, this analysis is probably an underestimation of all of the possible health benefits of Clean Cars Minnesota. The purpose of this analysis is not to provide a comprehensive and precise accounting of the health benefits of these standards, but rather to acknowledge that there are meaningful health benefits of this rule and to approximate what those benefits might be.

ii. Results

Using the first method of EPA's Benefit per Ton values, all Clean Cars Minnesota emissions reductions from vehicle tailpipes were considered to be in the "On-road mobile sources" sector; emissions reductions from upstream gasoline production were considered to be in the "Refineries" sector; and emissions increases from electricity production were considered to be in the "Electricity generation"

⁷² U.S. EPA Environmental Protection Agency Office of Air and Radiation, "Technical Support Document: Estimating the Benefit per Ton of Reducing PM_{2.5} Precursors from 17 Sectors, February 2018. Available at: <https://www.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-17-sectors>.

⁷³ Information about COBRA, including the model itself, is available at <https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool>.

sector. The MPCA considered the changes of PM_{2.5} and NO_x emissions resulting from this rule. For the economic valuation of health benefits both 3% and 7% discount rates were considered. Table 44 presents the estimated health benefits associated with this rule over the first 10 years (MY 2025-2034) of its implementation. Table 45 presents the estimated economic benefit of these health benefits.

Table 44: Estimated health benefits of the proposed rule over first 10 years of implementation based on EPA's Benefit per Ton values

Avoided health outcome	Estimate
Premature deaths	149 - 348
Respiratory emergency room visits	82
Acute bronchitis	214
Lower respiratory symptoms	2,724
Upper respiratory symptoms	3,812
Minor restricted activity days	108,438
Work loss days	18,453
Asthma exacerbation	4,405
Cardiovascular hospitalizations	41
Respiratory hospitalizations	38
Non-fatal heart attacks	17 - 157

The proposed rule could prevent 149-348 early deaths from air pollution relative to the business-as-usual reference scenario. Additionally, many less severe health outcomes would also be avoided. These are estimated benefits throughout the U.S. resulting from the change in emissions in Minnesota, but given the local and regional qualities of these pollutants, the majority of these benefits would occur in Minnesota.

Table 45: Estimated economic value of health benefits of the proposed rule over first 10 years of implementation based on EPA's Benefit per Ton values

Economic benefit	Estimate
3% discount rate	\$1.46 billion - \$3.21 billion
7% discount rate	\$1.31 billion - \$2.92 billion

Depending on the choice of discount rate, the economic value of the health benefits of this rule could be between \$1.3 billion and \$3.2 billion.

The reason for the ranges of reduced deaths and non-fatal heart attacks in Table 44 is that there are different widely-accepted concentration-response relationships that relate PM_{2.5} exposure to premature death and non-fatal heart attacks. Rather than choosing between these different relationships, the EPA and the MPCA often choose to report ranges. This is also the reason for the ranges of economic values in Table 45. The lower dollar value reflects the lower ends of the health outcomes in Table 44 while the higher value reflects the higher ends of the health outcomes ranges. Including ranges reflects the uncertainty in this analysis. Again, our intent is not to give a precise accounting on health benefits of the proposed rule, but rather a general sense of the magnitude of the health benefits of this rule proposal.

Using COBRA, the second method for estimating health benefits of this proposed rule, the MPCA considered the geographic specificity of where tailpipe emissions will take place. The tailpipe emissions reductions were allocated across Minnesota's 87 counties according to vehicle miles travelled in each

county from MOVES.⁷⁴ Because we cannot determine specific geographic locations of gasoline production and electricity production upstream emissions, the MPCA only used COBRA to model health impacts of vehicle tailpipe emissions and continued to use the Benefit per Ton values to consider health and economic impacts of upstream emissions. Table 46 presents the tailpipe emissions benefit from the proposed rule. Because COBRA takes into account the geographic locations of emissions sources as well as the geographic locations of where emissions impacts occur, Table 46 presents estimated health impacts for the whole U.S. as well as those specifically in Minnesota.

Table 46: Estimated health benefits from reduced tailpipe emissions resulting from the proposed rule over first 10 years of implementation based on EPA’s COBRA model

Avoided health outcome	Nationwide	Minnesota
Premature deaths	50 - 113	39 - 87
Respiratory emergency room visits	23	18
Acute bronchitis	88	71
Lower respiratory symptoms	1,120	909
Upper respiratory symptoms	1,599	1,297
Minor restricted activity days	43,181	35,213
Work loss days	7,323	5,981
Asthma exacerbation	1,649	1,336
Cardiovascular hospitalizations	16	12
Respiratory hospitalizations	13	10
Non-fatal heart attacks	6 - 54	4 - 41

Nationwide, from tailpipe emissions reductions alone, Clean Cars Minnesota is estimated to prevent 50 to 113 early deaths as well as numerous less severe health outcomes.

Table 47 adds the upstream health impacts, both health benefits from gasoline production emissions benefits and health costs from electricity production emissions, to the tailpipe emissions health benefits in Table 46 to estimate the overall health benefits of the rule over the first 10 years of implementation. Table 48 presents the total economic values of the health benefits in Table 47.

⁷⁴ See section 1(D) for an explanation of the MOVES model and data.

Table 47: Estimated health benefits from tailpipe and upstream emissions changes resulting from the proposed rule over first 10 years of implementation based on combination of EPA's Benefit per Ton values and COBRA model.

Avoided health outcome	Estimate
Premature deaths	62 - 141
Respiratory emergency room visits	30
Acute bronchitis	107
Lower respiratory symptoms	1,358
Upper respiratory symptoms	1,936
Minor restricted activity days	52,483
Work loss days	8,887
Asthma exacerbation	2,042
Cardiovascular hospitalizations	19
Respiratory hospitalizations	16
Non-fatal heart attacks	18 - 56

These are nationwide health benefits. Benefits from reduced tailpipe emissions were estimated with EPA's COBRA model, taking into account geographic locations of emissions, while benefits from upstream emissions changes were estimated with EPA's Benefit per Ton values.

Table 48: Estimated economic value of health benefits of the proposed rule over first 10 years of implementation based on combination of EPA's COBRA model and Benefit per Ton values

Economic benefit	Estimate
3% discount rate	\$626 million - \$1.42 billion
7% discount rate	\$560 million - \$1.26 billion

The economic value of health benefits from reduced tailpipe emissions were estimated using COBRA while the economic value of health impacts from changes in upstream emissions were estimated using EPA's Benefit per Ton values.

Considering these two methods to estimate health benefits together gives a sense of the magnitude of health benefits from the proposed rule. It could prevent 62 to 348 early deaths plus many more avoided less severe health outcomes. While this analysis cannot pinpoint the exact economic value of these benefits, both the Benefit per Ton and COBRA methods show that it is likely to be at least several hundreds of million dollars.

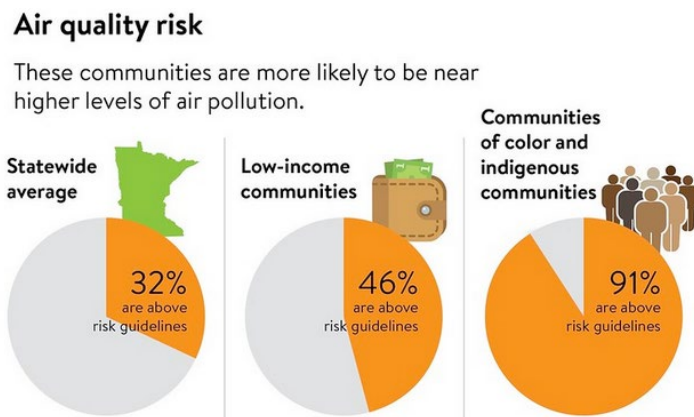
B. Equity analysis

Black, Indigenous, and People of Color communities in Minnesota are exposed to higher levels of air pollution, an inequality that is especially apparent in the distribution of air pollution from vehicles (Figure 16). Compounding this inequity is the fact that the people most impacted by traffic also tend to own fewer vehicles and produce smaller pollution footprints by driving less and being more likely to carpool, use public transit, and get around using other car-free modes.⁷⁵ The pollution from traffic is widespread and degrades the air quality not only around homes, but also around hospitals, schools, nursing homes, and daycares.

⁷⁵ *Traffic, Air Pollution, Minority and Socio-Economic Status: Addressing Inequities in Exposure and Risk.* Gregory C. Pratt, et al. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4454972/>

Figure 16: Disparities in air pollution risk faced by Minnesota communities⁷⁶

Not all Minnesota communities face the same risks from air pollution. In general, low-income communities and especially communities of color and indigenous communities face higher risks than the state as a whole.



Housing segregation, the result of discriminatory housing and lending policies, underpins many of the environmental disparities we see today. A history of redlining, racial covenants, and inequitable highway routing has put the homes of these communities near busier roads.⁷⁷ These structural inequalities built into Minnesota's public systems continue to harm Black, Indigenous, and People of Color communities. Cities in Minnesota rank poorly in terms of housing segregation and racial disparities in health outcomes.⁷⁸ Within Minneapolis and St. Paul, historical construction projects for highways I-94 and I-35 cut through prominent Black communities.⁷⁹ Despite occurring decades ago, these highway construction projects and housing policies that benefitted white residents have had lasting effects on the segregation of Minnesota's cities and the disparities in air pollution. These communities continue to be placed at greater risk of negative health impacts from traffic's pollution, noise, and physical hazards, such as pedestrian injuries.

The analysis below highlights where elevated light-duty traffic emissions in Minnesota are occurring today and identifies the areas that would benefit most from cleaner vehicles in the future. Three data sources were used for the equity analysis below:

⁷⁶ MPCA, "Disproportionate Impacts in Minnesota," <https://www.pca.state.mn.us/air/disproportionate-impacts-minnesota> (accessed 7/13/2020)

⁷⁷ For one example of these racially-motivated policies, see the Mapping Prejudice project at <https://www.mappingprejudice.org/index.html>.

See also, Institute on Metropolitan Opportunity, University of Minnesota, "Redlining in the Twin Cities in 1934: 1960s and Today," <https://umn.maps.arcgis.com/apps/MapSeries/index.html?appid=8b6ba2620ac5407ea7ecfb4359132ee4> (accessed on 7/27/2020)

⁷⁸ For one recent study, see the Washington Post, "Racial inequality in Minneapolis is among the worst in the nation" at <https://www.washingtonpost.com/business/2020/05/30/minneapolis-racial-inequality/> (accessed on 7/7/2020)

⁷⁹ See MNopedia, "Neighborhood Resistance to I-94, 1953-1965," <https://www.mnopedia.org/event/neighborhood-resistance-i-94-1953-1965>.

See also, MnDOT, Rethinking I-94, "I-94 Documentary, Part One – Interstate 94: A History and Its Impact,"

<https://www.dot.state.mn.us/i-94/minneapolis-stpaul/background.html> (accessed 7/23/2020)

See also, A Public History of 35W, <https://35w.heritage.dash.umn.edu/> (accessed 7/23/2020)

- a) **Areas of concern for environmental justice:** The MPCA considers tribal lands and Census Tracts with higher proportions of low-income residents and higher proportions of Black, Indigenous, and people of color residents as areas of concern for environmental justice.
- b) **Light-duty traffic density and emissions:** The MN Department of Transportation (MnDOT) counts the frequency of vehicles on roads across the state. This information provides the location of high traffic road segments in Minnesota, as well as an estimate of the total traffic density for any area. EPA's mobile source emissions tool, MOVES, was used to calculate the emissions produced by the monitored light-duty vehicle traffic levels. These emissions in turn were input into EPA's air dispersion model AERMOD to find the expected pollutant concentrations to which a person may be exposed.
- c) **Sensitive land uses:** Maps are publicly-available for four institution types providing essential services to more vulnerable populations: licensed hospitals, elementary schools, daycares, and nursing homes.

i. **Areas of concern for environmental justice**

The state of Minnesota is committed to ensuring pollution does not have a disproportionate impact on any group of people and that everyone has opportunities to participate in decisions that may affect their environment or health. As a screening tool for prioritizing areas with the potential for disproportionate environmental impacts, the MPCA uses U.S. Census Tracts as a geographic unit to identify areas of concern for environmental justice.⁸⁰

These areas include:

- Tribal lands
- Census Tracts with at least 50% of the population identifying as Black, Indigenous, and people of color
- Census Tracts with greater than 40% of household incomes below 185% of the Federal poverty level

ii. **Light-duty vehicle traffic density**

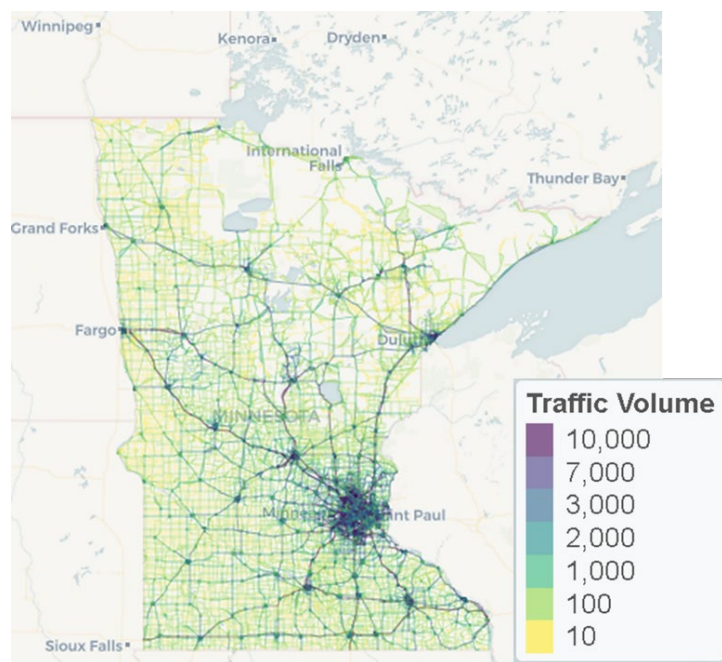
Roads serve many purposes, not least of which is to serve as a primary route of transport for the people, goods, and services in our cities and around our state. Depending on where one lives, the amount of traffic on the nearest roads may range from as few as 10 vehicles per day to over 100,000 vehicles per day. In general, the average road sees close to 3,000 vehicles per day. For this analysis, the busiest 10% of road segments with over 10,000 vehicles per day are classified as “busy roads.” The traffic monitoring data shown in Figure 17 is provided by MnDOT.⁸¹

⁸⁰ More about MPCA's environmental justice framework, including maps of all areas of concern for environmental justice in Minnesota, can be found at www.pca.state.mn.us/EJ.

⁸¹ MnDOT, Traffic forecasting and analysis, <http://www.dot.state.mn.us/traffic/data/tma.html>.

Figure 17: Daily light-duty traffic volume

The map below shows Minnesota's road network color-coded by the average daily number of vehicles in 2014. Darker lines show busier road segments. MnDOT reports each road's traffic volume in units of Annual Average Daily Traffic, or the number of vehicles one would expect to see on that road each day.



The MPCA followed these steps to calculate air pollution concentrations from the light-duty vehicle traffic volumes shown above.

1. The MPCA used EPA's MOVES model to calculate the emissions to the light-duty vehicle traffic levels monitored above. While there are hundreds of pollutants emitted by vehicles,⁸² this analysis focuses primarily on the emissions of PM_{2.5}. The analysis focuses on PM_{2.5} because of its well-understood and documented health effects, and because the proposed rule specifically targets PM_{2.5} emission reductions from vehicle tailpipes.
2. We next found where the pollution from roads is transported by using EPA's regulatory air dispersion model AERMOD⁸³ to apply the influence of wind, temperature, and other meteorology factors to the emissions from vehicles. With this information, the model generates the expected annual average concentration of PM_{2.5} produced by light-duty vehicle traffic at every location around the state.

The results showed that the annual average concentration of PM_{2.5} contributed by light-duty vehicle traffic in the Twin Cities Metro Area ranges from roughly 0.5 µg/m³ to 4 µg/m³. At the high end, 4 µg/m³ represents about one third of the federal air quality standard for PM_{2.5}, which is currently set at a level of 12 µg/m³. For some areas near busy roads, light-duty vehicle traffic is the number one source of

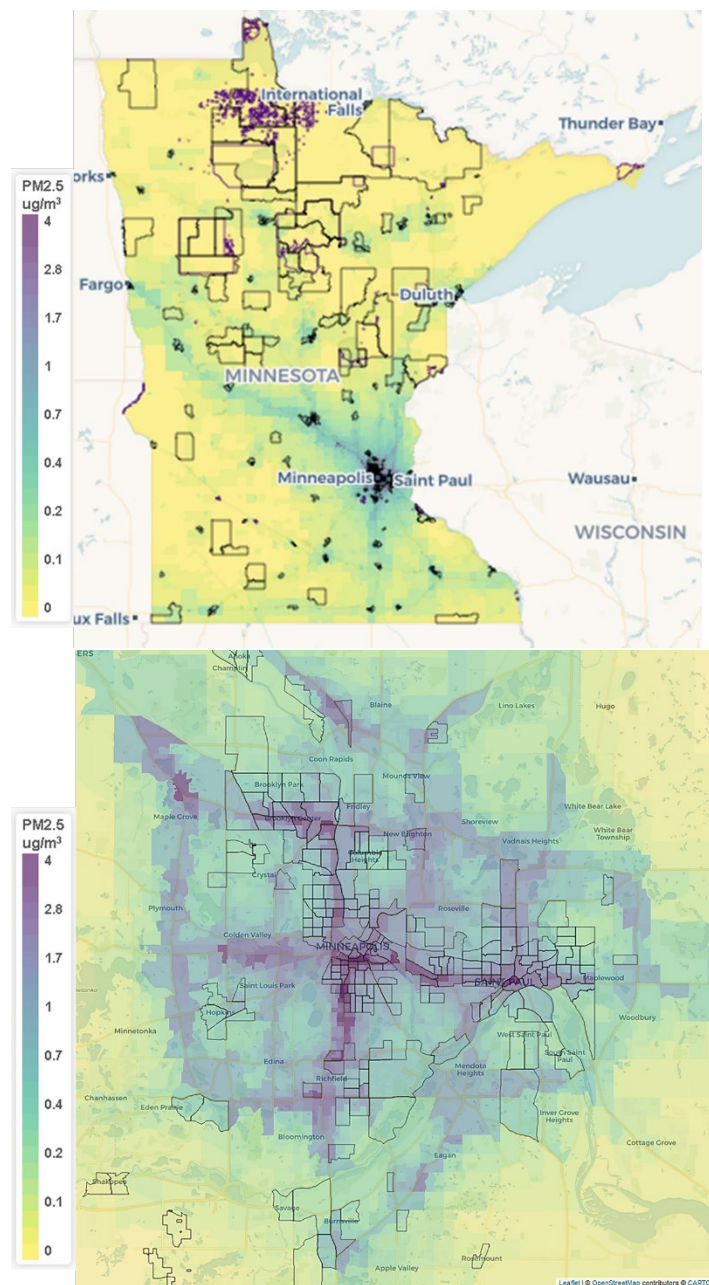
⁸² EPA, "Expanding and updating the master list of compounds emitted by mobile sources—phase III: final report," February 2006, <https://nepis.epa.gov/Exe/ZyPDF.cgi/P1004LIZ.PDF?Dockkey=P1004LIZ.PDF>.

⁸³ EPA, Air quality dispersion modeling—preferred and recommended models, <https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models> (accessed July 1, 2020).

direct emissions of PM_{2.5}. Figure 18 shows the range of pollutant concentration results for the light-duty vehicle traffic densities observed across Minnesota. Depending on one's proximity to high-traffic roads, the expected PM_{2.5} concentration from light-duty vehicle traffic may be more than ten times higher than what one would breathe near less busy roads.

Figure 18: Modeled PM_{2.5} pollution concentrations from light-duty vehicle traffic

Modeling results show light-duty vehicle traffic contributes between 0.1 µg/m³ of PM_{2.5} in remote rural areas and up to roughly 4 µg/m³ near the busiest roadways in the Twin Cities Metro Area. The amount of traffic pollution (yellow to blue shading) is overlaid with MPCA's areas of concern for environmental justice (outlined shapes in grey) and tribal boundaries (outlined shapes in purple), showing the alignment between vehicle pollution and areas of concern for environmental justice.

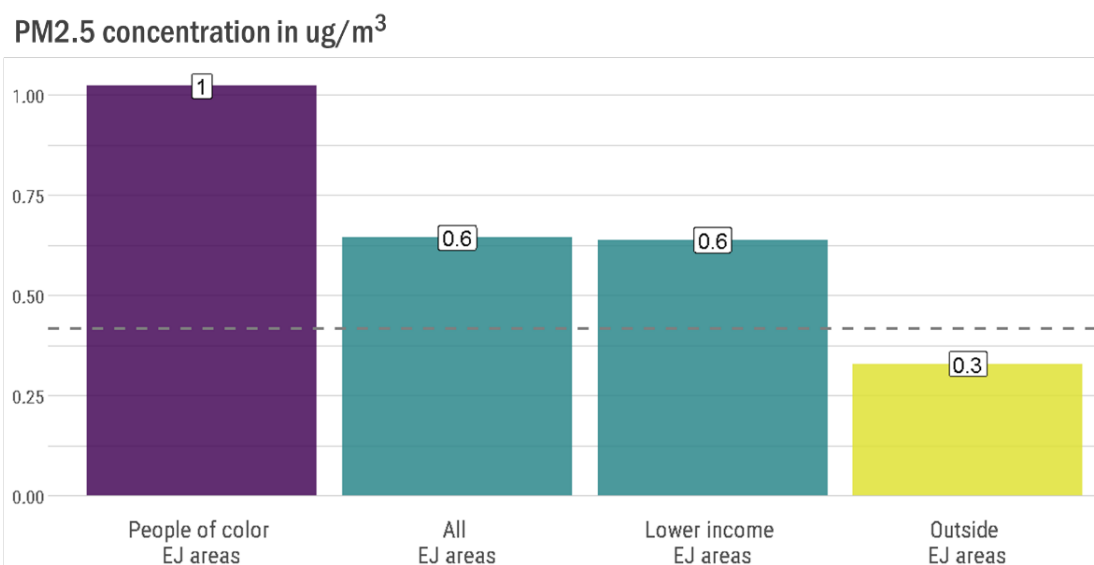


iii. Disproportionate impacts

When looking at where the highest light-duty vehicle traffic emissions occur, we find higher modeled concentrations of air pollution in Census Tracts identified as areas of concern for environmental justice, and especially in those Census Tracts with higher proportions of residents identifying as Black, Indigenous, and people of color, as can be seen in Figure 19.

Figure 19: Current light-duty vehicle pollution higher in areas of concern for environmental justice

The figure shows the average modeled PM_{2.5} concentrations from light-duty vehicle traffic for areas of concern for environmental justice. The concentrations are higher for areas of concern for environmental justice in general, and even more so for areas with higher proportions of Black, Indigenous, and people of color (note that the figure uses “People of Color” to identify these populations).



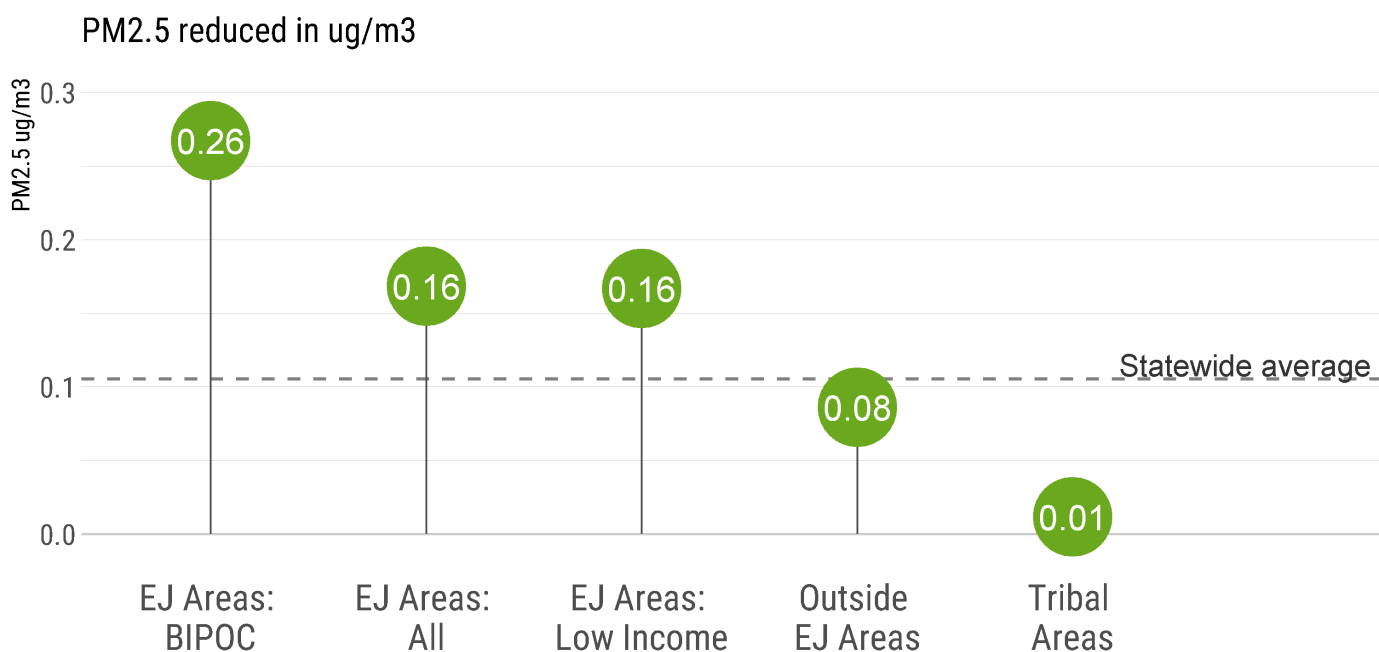
iv. Increasing benefits over time

While emissions benefits from the proposed rule are expected the first year of implementation, the rule's benefits will continue to grow as the share of new cars increases in the fleet. By 2034, MPCA's analysis estimates the proposed rule would result in an annual reduction of 530 tons of PM_{2.5} emissions compared to the reference (business as usual) scenario. Based on current light-duty vehicle traffic, this reduction is equivalent to 25% of the total PM_{2.5} emitted in one year from light-duty vehicles. Depending on an area's light-duty vehicle traffic density, the improvement in air pollution from cleaner vehicles will result in a range of pollution benefits. In remote low-traffic areas with less light-duty vehicle traffic-related air pollution, the decrease in PM_{2.5} may be less than 0.01 µg/m³, while reductions in areas with higher traffic density are expected to approach 1.0 µg/m³.

By distributing the emission benefits from Clean Cars Minnesota in proportion to current light-duty vehicle traffic patterns we found that the areas of concern for environmental justice would see the greatest reductions in PM_{2.5} pollution, especially in areas with higher proportions of residents who are Black, Indigenous, and people of color (Figure 20). For tribal lands in rural parts of the state, the roads generally have lower volumes of light-duty vehicle traffic and therefore may experience lower than average air quality benefits. For each of the categories below, the average pollutant concentration was calculated using a population-weighted mean across all of the Census Tracts. This ensures that a Census Tract with 1,000 people will count more towards the average than a Census Tract with fewer than 100 people.

Figure 20: Greater pollution benefits for areas of concern for environmental justice, PM2.5 reduced in 2034.

This figure shows the average annual PM_{2.5} air concentration reductions in units of $\mu\text{g}/\text{m}^3$ that are estimated to result from the proposed rule in year 2034. The air quality benefits are higher for areas of concern for environmental justice (referred to as “EJ Areas” in the graphic) in general, and even more so for areas with higher proportions of Black, Indigenous and People of Color (note that the figure uses the abbreviation “BIPOC” to identify these populations). Areas of the state, including Tribal lands, with lower light-duty vehicle traffic volumes and therefore lower light-duty vehicle traffic-related PM_{2.5} concentrations are anticipated to experience smaller reductions in PM_{2.5} from vehicles.



v. Sensitive land uses

Certain land uses, such as hospitals, schools, nursing homes, and daycares concentrate people who are more vulnerable to the harmful effects of air pollution due to age or health conditions. Important services like hospitals and daycares are often sited near major roads and transport hubs to make them more accessible. These siting decisions can mean that people who use these services, who are often more vulnerable to the effects of air pollution, may be exposed to higher levels of traffic-related air pollution. For this reason, reductions to light-duty vehicle emissions will benefit some of the most vulnerable to air pollution. In this analysis, the MPCA examined the potential benefits of the proposed rule on air quality near sensitive land uses, and how these benefits would be distributed in relation to areas of concern for environmental justice.

Sensitive land uses are areas or places used by individuals that are more vulnerable to health risks from exposure to poor air quality. For example, individuals older than 65 years of age are more susceptible to air pollution-related illnesses such as stroke, asthma, heart disease, lung cancer, and other respiratory diseases. Similarly, individuals with pre-existing medical conditions, such as people admitted to hospitals and other healthcare facilities, are more prone to developing air pollution-related illnesses. We evaluated four institution types that provide public services to populations more vulnerable to air pollution.

- 1. Licensed hospitals:** MDH provides location information for all licensed hospitals in the state at <https://gisdata.mn.gov/dataset/health-facility-hospitals>.

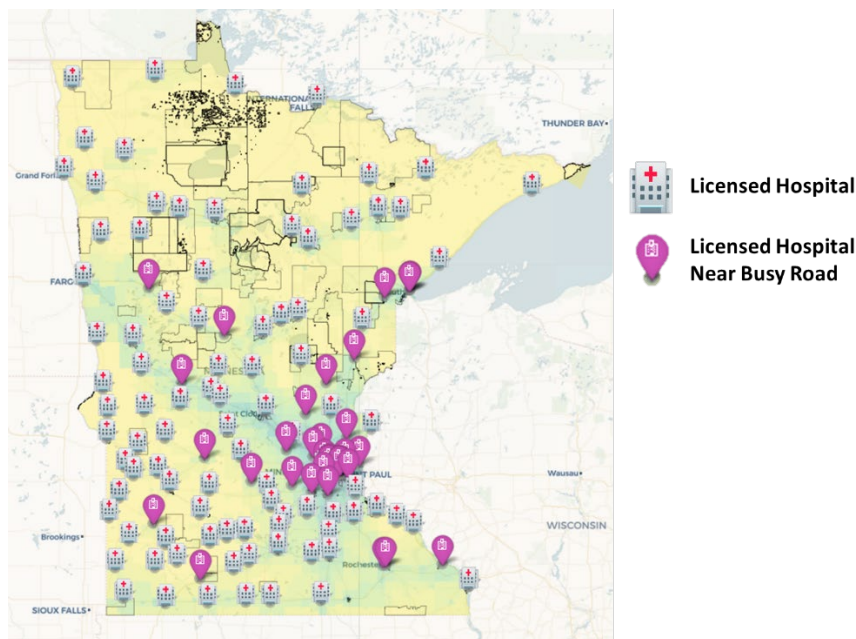
2. **Daycares:** Minnesota Department of Human Services provides location information for all daycares in the state. It is publicly available by request.
3. **Elementary schools:** Minnesota Department of Education provides location information for all schools in the state. It is publicly available by request.
4. **Nursing homes:** MDH provides location information for all licensed nursing and boarding care homes in the state at <https://gisdata.mn.gov/dataset/health-facility-nursing-boarding>.

Using licensed hospitals as an example, the steps below show how we calculated the relative light-duty vehicle traffic emissions across the areas of concern for environmental justice:

1. We started by highlighting the hospitals that are located within 300 meters of a busy roadway. Busy roads are defined for this analysis as those with more than 10,000 vehicles per day on average. As can be seen in Figure 21, the result for licensed hospitals is that roughly 28% (38 out of the 134) are near high levels of light-duty vehicle traffic.

Figure 21: Licensed hospitals near busy roads.

There are 134 licensed hospitals distributed across the entire state of Minnesota. The 34 located within 300 meters of a high traffic roadway are highlighted below.



2. We then found the likelihood of someone's closest hospital being near a busy roadway if they live in an area of concern for environmental justice. For people living in lower income Census Tracts, their closest hospital was near high traffic roughly 65% of the time. For Census Tracts with a higher proportion of residents identifying as Black, Indigenous and people of color, that percentage rose to 90%.
3. Finally, using the PM_{2.5} modeling from above we estimated the air quality for each Census Tract's closest hospital. In Minnesota, the PM_{2.5} concentration contributed by light-duty vehicle traffic to a Census Tract's closest hospital was 0.57 µg/m³ on average. Looking specifically at hospitals near areas with lower incomes, the average PM_{2.5} pollution contributed from light-duty vehicle traffic was 0.74 µg/m³. The greatest impacts on air quality were estimated for the closest hospitals serving

areas with a higher proportion of residents identifying as Black, Indigenous and people of color. For these hospitals, the average PM_{2.5} concentration was 1.1 µg/m³.

The steps outlined above were used to analyze air pollution around licensed hospitals as well as the other identified sensitive land uses: elementary schools, daycares, and nursing homes. Tables 49-51 summarize the results of these analyses. The MPCA found that sensitive land uses that serve areas of concern for environmental justice are more often near high-traffic roadways (Table 49) and therefore more often have higher levels of PM_{2.5} from light-duty vehicle traffic (Table 50).

Table 49: Sensitive land uses for areas of concern for environmental justice more often near high traffic roads.

Land Use	Statewide Count	Outside EJ Areas	EJ Areas: Low Income	EJ Areas: BIPOC	Tribal Areas
Licensed Hospitals	134	57%	65%	90%	20%
Elem. Schools	1,302	27%	44%	58%	20%
Daycares	1,815	47%	51%	66%	20%
Nursing Homes	374	43%	45%	58%	13%

The table below shows the percent of each of the services that are located near high light-duty vehicle traffic. The percentages increase for services near areas of concern for environmental justice in general, and even more so for areas with higher proportions of Black, Indigenous, and people of color.

Table 50: Current light-duty vehicle PM_{2.5} is higher for sensitive land uses near areas of concern for environmental justice.

Land Use	Outside EJ Areas	EJ Areas: Low Income	EJ Areas: BIPOC	Tribal Areas
Licensed Hospitals	0.5	0.7	1.1	0.1
Elem. Schools	0.3	0.6	1	0.02
Daycares	0.3	0.7	1	0.1
Nursing Homes	0.4	0.7	1.2	0.04

The table below shows the average modeled PM_{2.5} concentrations in units of µg/m³ from light-duty vehicle traffic for each of the sensitive land uses. The concentrations are higher for services near areas of concern for environmental justice in general, and more so for services near areas having higher proportions of Black, Indigenous, and people of color.

The MPCA's analysis also estimated that sensitive land uses in areas of concern for environmental

justice would likely see greater than average PM_{2.5} exposure benefits as a result of the Clean Cars Minnesota rule (Table 51).

Table 51: Estimated PM_{2.5} reduction benefits of Clean Cars Minnesota for sensitive land uses in 2034.

Land Use	Outside EJ Areas	EJ Areas: Low Income	EJ Areas: BIPOC	Tribal Areas
Licensed Hospitals	0.13	0.18	0.28	0.03
Elem. Schools	0.08	0.15	0.25	0.01
Daycares	0.08	0.18	0.25	0.03
Nursing Homes	0.1	0.18	0.3	0.01

The table below shows the average modeled PM_{2.5} air concentration reduction in µg/m³. The air quality benefits are higher for the services near areas of concern for environmental justice in general, and more so for areas having higher proportions of Black, Indigenous, and people of color.

In conclusion, the equity analysis indicated that communities that are disproportionately burdened with air pollution are anticipated to benefit most from this proposed rule, although their air pollution exposure will remain higher than the statewide average. The Clean Cars Minnesota rule would help begin to close the gap in air pollution exposure from vehicles and other sources between communities of concern for environmental justice and the rest of the state, but is only one step among many that will be needed to achieve equitable air quality.

5. Economic slowdown sensitivity analysis

The MPCA also considered the impact that the ongoing COVID-19 pandemic, and the associated economic impacts, could have on the analysis conducted as part of this rulemaking. The pandemic may result in yet-unknown, but potentially significant economic repercussions that could affect the overall passenger vehicle market in the state, including EVs. Even though these standards are not expected to be implemented until MY 2025 at the earliest,⁸⁴ if the economic impacts of COVID-19 last long enough, they could affect both the business-as-usual Reference scenario as well as the Clean Cars Minnesota scenario and all the future emissions benefits; consumer impacts; and health, equity, and climate estimates that the MPCA has analyzed. In this section, we examine the potential impacts of a future low economic growth scenario on the analysis of LEV and ZEV standards of Minnesota.

To consider the potential impacts of an economic downturn in Minnesota due to COVID-19 in our analysis, the MPCA adjusted various key inputs, including total annual LDV and EV sales, to reflect a

⁸⁴ Even though the standards will not be implemented before MY 2025, EV and LDV sales are relevant to the analysis of establishing an initial ZEV credit bank (addressed in Section 6), which may take into account “early-action” sales as soon as MY 2022.

potentially economically depressed future. The resulting outputs were compared to the results of our emissions benefits analysis and costs and benefits to Minnesota consumers analysis in Sections 2(C), 3(A), and 3(B) of this document. We refer to the inputs and results from Sections 2 and 3 as our “primary analysis and results”.

To adjust LDV and EV sales to reflect a potential economic downturn, MPCA referred to the EIA 2020 AEO Reference scenario as well as the EIA 2020 AEO Low Economic Growth scenario projections of total LDV sales for the West North Central region of the U.S. as well as projections of BEV and PHEV sales.⁸⁵ The EIA 2020 AEO Low Economic Growth scenario assumes a 0.5 percentage points lower annual growth in U.S. gross domestic product relative to the reference case.⁸⁶ Since economic growth largely drives consumption and demand, including for vehicles, and the economic repercussions of the COVID-19 pandemic may slow economic growth in Minnesota and the U.S. as a whole, using the EIA’s Low Economic Growth scenario is a reasonable way to reflect how the pandemic may affect the benefits and costs of the proposed rule. We used the proportional differences between the EIA 2020 AEO’s Reference scenario LDV sales for the West North Central Region to the Low Economic Growth LDV sales to adjust our Reference scenario LDV sales to our Economic Slowdown scenario LDV sales. For example, total 2025 LDV sales in the 2020 AEO Low Economic Growth scenario are 5.02% lower than in the 2020 AEO Reference scenario. Thus, in the MPCA’s Economic Slowdown scenario MY 2025 LDV sales were reduced from our primary analysis Reference scenario by 5.02%, from 253,385 vehicles to 240,674 vehicles. The percentage difference between the 2020 AEO Reference scenario LDV sales and the 2020 AEO Low Economic Growth scenario grows over the remaining years. Table 52 lists the annual differences between the two 2020 AEO scenarios and how those differences were used to adjust the MPCA’s Reference scenario LDV sales used in our primary analysis to MPCA’s Economic slowdown LDV sales..

Table 52: Total LDV sales reduction for low economic growth scenario.

Model year	MPCA Reference scenario LDV sales	LDV sales reduction from EIA 2020 AEO	MPCA Economic Slowdown scenario LDV sales
2025	253,385	-5.02%	240,674
2026	251,104	-5.82%	236,485
2027	247,840	-6.29%	232,248
2028	243,379	-6.63%	227,252
2029	237,538	-8.34%	217,725
2030	230,649	-9.22%	209,375
2031	224,883	-9.83%	202,772
2032	222,634	-10.37%	199,539
2033	226,641	-10.84%	202,081
2034	237,067	-11.40%	210,051

The MPCA used the proportional differences between the EIA 2020 AEO’s Reference scenario LDV sales for the West North Central Region to the Low Economic Growth LDV sales to adjust our Reference scenario LDV sales to our Economic Slowdown scenario LDV sales.

⁸⁵ EIA 2020 AEO Reference Scenario and Low Economic Growth Scenario projections can be found at:

https://www.eia.gov/outlooks/aeo/tables_ref.php

⁸⁶ A fuller description of the EIA 2020 AEO Low Economic Growth scenario can be found at

<https://www.eia.gov/outlooks/aeo/pdf/aeo2020.pdf>.

Similarly, for both BEV and PHEV sales in MPCA's Economic Slowdown scenario, we adjusted the linear growth sales used in our primary analysis Reference scenario by the proportional differences in BEV and PHEV sales between the EIA 2020 AEO's Reference scenario BEV and PHEV sales for the West North Central region and the EIA 2020 AEO's Low Economic Growth BEV and PHEV sales for the region. Thus, in the MPCA's Economic Slowdown scenario, BEV and PHEV sales grow at slower rates than they would be if following linear trajectories from recent Minnesota BEV and PHEV sales. The resulting EV sales total used for MPCA's Economic Slowdown scenario were 8.0 - 11.5% lower than those used in our primary analysis.

An economic slowdown also affects the number of EV sales needed to comply with the ZEV standard. The ZEV standard compliance requirements (calculated using the ZEV Compliance Calculator, as described above in Section 1(C)(ii)) are based on total LDV sales in the prior second, third, and fourth model years. Therefore, with lower LDV sales, compliance requirements are reduced. Since compliance requirements are based on total LDV sales in the prior second, third, and fourth model years, the economic downturn today reduces compliance requirements several years from now. Thus, EV sales in the Clean Cars scenario under an Economic Slowdown scenario were 8.1 – 11.6% lower than those used in the primary analysis. Table 53 presents the Economic Slowdown scenario EV sales for MYs 2025-2034 along with the BEV and PHEV sales the MPCA estimates would be required for compliance (calculated using the ZEV Compliance Calculator), and additional BEV and PHEV sales that would be needed to comply with the ZEV standard.

Table 53: Minnesota Economic Slowdown scenario LDV, BEV, and PHEV sales, BEVs and PHEVs estimated to be required for ZEV standard compliance, and the additional BEVs and PHEVs sales that would be required for compliance

Model year	LDV sales	BEV sales in absence of ZEV standard	PHEV sales in absence of ZEV standard	Total EV sales in absence of ZEV standard	% of total LDV sales	BEVs needed for compliance	PHEVs needed for compliance	Additional BEVs to comply	Additional PHEVs to comply
2025	240,674	5,163	1,645	6,808	2.8%	10,865	6,637	5,702	4,992
2026	236,485	5,627	1,775	7,402	3.1%	11,072	6,370	5,444	4,595
2027	232,248	6,114	1,907	8,021	3.5%	11,262	6,086	5,148	4,179
2028	227,252	6,611	2,042	8,653	3.8%	11,268	5,705	4,657	3,663
2029	217,725	7,006	2,145	9,151	4.2%	11,180	5,287	4,174	3,142
2030	209,375	7,500	2,268	9,768	4.7%	11,051	4,863	3,551	2,595
2031	202,772	7,984	2,389	10,373	5.1%	10,830	4,416	2,846	2,027
2032	199,539	8,444	2,514	10,958	5.5%	10,535	3,962	2,091	1,448
2033	202,081	8,967	2,634	11,601	5.7%	10,208	3,521	1,240	887
2034	210,051	9,395	2,730	12,125	5.8%	9,981	3,134	585	405

This table estimates Minnesota BEV and PHEV sales in MPCA's Economic Slowdown scenario as well as ZEV standard compliance requirements and additional BEV and PHEV sales that would be necessary to meet ZEV standard requirements in the Economic Slowdown scenario. ZEV requirements flat line in MY 2025, so the gap between business-as-usual sales and ZEV compliance shrinks after 2025 even when business-as-usual entails slower than linear growth rates.

A potential economic slowdown also affects MPCA's analysis of the establishment of initial ZEV credit banks. These affects are addressed in Section 6.

A. Emissions benefits results

The MPCA estimates under our Economic Slowdown scenario that low economic growth could result in fewer emissions benefits compared to the analysis in Section 2. Under the Economic Slowdown scenario, the MPCA estimates implementation of the proposed rule would result in a GHG emissions reduction of 6.6 million tons from vehicle tailpipes, measured in carbon dioxide equivalents (CO₂e), over the first 10 model years of implementation, which a decrease of 0.5 million tons from our primary results (see Section 2(C) for primary emissions benefit results), or about a 7% decrease in tailpipe GHG benefits. The proposed rule would result in a reduction of 1.1 million tons of tailpipe GHG emissions in the year 2034, which equates to a 2.5% reduction from 2005 transportation GHG emission levels, and a 3.2% reduction from 2005 levels of surface transportation emissions. Maximum annual projected GHG reductions in vehicle tailpipe emissions beyond 2034 are estimated to be 1.6 million tons annually (down from 2.0 million), equating to a 4.8% reduction from 2005 surface transportation emissions (down from 5.8% in our primary analysis).

MPCA estimates that the proposed rules under a low economic growth scenario would also result in a total upstream GHG emissions reduction of 1.2 million tons over the 10 years leading up to 2034 (down from 1.3 million) from a reduction in upstream liquid fuel extraction, transportation, and production, even after considering the upstream emissions from electricity generation to power additional EVs.

The MPCA's analysis estimates that by 2034 annual well-to-wheel GHG emissions benefits under a low economic growth scenario would be 1.3 million tons, down from 1.4 million as estimated in our primary analysis.

MPCA's analysis indicates that implementation of the proposed rules together under a low economic growth scenario would result in an annual well-to-wheel emission reduction of 920 tons of NMOG + NO_x (down from 998) and 579 tons of PM (down from 637) in 2034. These well-to-wheel emissions reductions equate to 5,658 tons of NMOG + NO_x and 2,979 tons of PM reduced over the first 10 years of the rule (down from 6,059 and 3,245, respectively). Over the first 10 years, our analysis estimates the proposed rules would reduce PM tailpipe emissions by 2,785 tons (down from 3,032).

In summary, an economic slow-down that resulted in fewer LDVs and EVs being sold in Minnesota would still result in an emissions benefit of all three pollutants, and would not significantly reduce the emissions benefits achieved otherwise.

B. Costs and benefits to Minnesota consumers

The analysis of costs and benefits to Minnesota consumers presented above in Section 3 showed there is likely to be positive consumer benefits resulting from both the LEV and ZEV standards in Minnesota. Since this analysis showed likely per-vehicle benefits for both standards, even if there are fewer new vehicles sold in an economic slowdown, there would still be overall consumer benefits. In this section we estimate how the consumer benefits presented in Section 3 may change in an economic slowdown over the MY 2025-2034 time frame. As we did in Section 3, we first evaluate the LEV standard and then evaluate the additional consumer impacts of the ZEV standard.

i. LEV standard consumer impacts in an economic slowdown

With the same assumptions as the analysis in Section 3,⁸⁷ except for the number of LDVs sold in Minnesota, the total consumer economic impact of the LEV standard in Minnesota in the Economic

⁸⁷ For example, we assume that even with the reduced demand for LDVs caused by the economic slowdown, that the relative cost difference between a LEV-certified vehicle and a SAFE-certified vehicle is unchanged.

Slowdown scenario is straightforward. The consumer impact per vehicle would be the same as estimated in Section 3, so to estimate the total consumer impact over vehicle lifetimes for MYs 2025-2034 vehicles purchased in Minnesota, all that is needed is to multiply the same per-vehicle consumer impact by the Economic Slowdown scenario vehicle sales. For example, in Section 3, the MPCA presented consumer estimates based on the January 2017 Final Determination and MPCA's fuel saving analysis of an MY 2025 LEV-certified vehicle: using a 3% discount rate, there is an average consumer savings of \$186 over a vehicle's lifetime and using a 7% discount rate, there is an average consumer cost of \$107 over a vehicle's lifetime. Multiplying the LEV consumer costs or savings for each 2025-2034 model year by the estimated number of Minnesota LDV sales for each model year in the Economic Slowdown scenario results in an estimated total consumer benefit of \$147 million using a 3% discount rate. For comparison the total estimated consumer benefit using a 3% discount rate under the Reference scenario in Section 3 was \$161 million. Using a 7% discount rate, the total estimated consumer cost in the Economic Slowdown scenario is \$437 million, compared to a total estimated consumer cost using a 7% discount rate under the Reference scenario in Section 3 of \$475 million.

Using the total estimated per-vehicle consumer savings in the SAFE FRIA, which were significantly higher than the consumer savings the MPCA derived from the January 2017 Final Determination analysis, would lead to even larger consumer benefits, regardless of the effect of economic conditions on Minnesota LDV sales.

One potential adjustment to our assumptions, besides total LDV sales, in the Economic Slowdown scenario stems from the potential impacts of an economic slowdown on gasoline prices. The Alliance for Automotive Innovation pointed out to the MPCA that economic conditions in the wake of the COVID-19 pandemic may include lower fuel prices, which could diminish the fuel savings to the Minnesota purchaser of a LEV-certified vehicle relative to a SAFE-certified vehicle.⁸⁸ To address this possibility, the MPCA reanalyzed the LEV fuel savings, but instead of using the EIA's 2019 AEO Reference case gasoline prices, we considered the EIA's Low Economic Growth scenario gasoline prices and the EIA's Low Oil Price scenario gasoline prices. As can be seen above in Figure 14, the Low Economic Growth scenario fuel prices are very close to the Reference case fuel prices. However, as Figure 14 shows, the Low Oil Price gasoline prices are considerably lower. Table 54 summarizes the variation in projected gasoline prices in these three scenarios.

Table 54: Motor gasoline projected prices (in 2018 dollars) in three future scenarios in EIA 2019 AEO⁸⁹.

2019 AEO scenario	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Reference	\$3.12	\$3.15	\$3.18	\$3.24	\$3.26	\$3.34	\$3.36	\$3.39	\$3.42	\$3.44	\$3.46	\$3.48
Low Economic Growth	\$3.10	\$3.11	\$3.10	\$3.18	\$3.20	\$3.23	\$3.28	\$3.30	\$3.33	\$3.36	\$3.37	\$3.38
Low Oil Price	\$2.43	\$2.41	\$2.37	\$2.38	\$2.38	\$2.42	\$2.42	\$2.42	\$2.43	\$2.44	\$2.43	\$2.44

The EIA projects future gasoline prices to be only slightly affected in the future Low Economic Growth scenario relative to the reference case. Future gasoline prices in the Low Oil Price scenario, however, are more severely impacted.

⁸⁸ Specifically, the Auto Innovators commented that "...we caution that AEO's low economic growth scenario may not be conservation [sic] enough to assess the uncertainty presented by COVID-19's yet-to-be determined impacts on the economy, the vehicle market, and advanced technology sales. Additionally, PCA might consider the AEO 2020 "Low Oil Price" scenario."

⁸⁹ All data in this graph available at: <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019®ion=1-4&cases=ref2019&start=2017&end=2033&f=A&linechart=~ref2019-d111618a.6-3-AEO2019.1-4&map=ref2019-d111618a.4-3-AEO2019.1-4&ctype=linechart&sourcekey=0>

MPCA has repeated the per-vehicle LEV standard fuel savings analysis presented above in Section 3(A)(iii), but with the Low Economic Growth scenario and the Low Oil Price scenario. Again, we have considered undiscounted fuel savings over vehicle lifetimes as well as fuel savings discounted at 3% and 7% rates for each 2025-2034 model year. These results are summarized in Table 55. For comparison, the table also shows the results using the Reference scenario gasoline prices, which were presented above in Tables 20-22.

Table 55: Comparison of LEV standard per-vehicle lifetime fuel savings (in 2018 dollars) under three different EIA 2019 AEO gasoline prices scenarios.

Model Year	Reference Scenario gasoline prices			Low Economic Growth scenario gasoline prices			Low Oil Price scenario gasoline prices		
	Un-discounted	3% disc. rate	7% disc. rate	Un-discounted	3% disc. rate	7% disc. rate	Un-discounted	3% disc. rate	7% disc. rate
2025	\$2,042	\$1,712	\$1,384	\$1,993	\$1,672	\$1,352	\$1,476	\$1,240	\$1,006
2026	\$1,809	\$1,517	\$1,227	\$1,764	\$1,479	\$1,196	\$1,297	\$1,090	\$883
2027	\$1,831	\$1,536	\$1,243	\$1,785	\$1,498	\$1,212	\$1,304	\$1,096	\$889
2028	\$1,851	\$1,553	\$1,257	\$1,802	\$1,513	\$1,224	\$1,311	\$1,102	\$894
2029	\$1,871	\$1,570	\$1,271	\$1,820	\$1,528	\$1,237	\$1,318	\$1,108	\$899
2030	\$1,887	\$1,584	\$1,283	\$1,837	\$1,543	\$1,249	\$1,322	\$1,112	\$902
2031	\$1,904	\$1,599	\$1,295	\$1,852	\$1,556	\$1,260	\$1,327	\$1,116	\$906
2032	\$1,920	\$1,612	\$1,306	\$1,867	\$1,568	\$1,270	\$1,332	\$1,121	\$909
2033	\$1,935	\$1,625	\$1,316	\$1,880	\$1,579	\$1,280	\$1,337	\$1,124	\$912
2034	\$1,949	\$1,637	\$1,326	\$1,891	\$1,589	\$1,288	\$1,341	\$1,128	\$916

Per-vehicle fuel savings would be lower if there are lower future gasoline prices. There is not much difference between the Reference scenario and the Low Economic Growth scenario but a larger difference between the Reference scenario and the Low Oil Price scenario.

Table 56 compares the total cumulative fuel savings over the lifetimes of vehicles for MYs 2025-2034. These totals were derived by multiplying the per-vehicle savings for each model year by the total projected Minnesota vehicle sales. For the Reference scenario, the total projected Minnesota LDV sales are from the Reference scenario (see Table 1) while for the Low Economic Growth scenario and Low Oil Price scenario, the total projected Minnesota LDV sales are from the Economic Slowdown scenario (see Table 52).

Table 56: Total cumulative fuel savings (in 2018 dollars) over vehicle lifetimes for MYs 2025-2034 in Minnesota under LEV standard using different EIA projections of future gasoline prices.

Discounting scenario	Reference Scenario gasoline prices	Low Economic Growth scenario gasoline prices	Low Oil Price scenario gasoline prices
Undiscounted	\$4.51 billion	\$4.39 billion	\$3.18 billion
3% discount rate	\$3.79 billion	\$3.69 billion	\$2.67 billion
7% discount rate	\$3.06 billion	\$2.98 billion	\$2.17 billion

Total projected cumulative fuel savings in Minnesota under a LEV standard decrease in future scenarios of lower gasoline prices.

The estimated fuel savings under a LEV standard in Minnesota is clearly sensitive to future gasoline prices. Given the relatively small lifetime per-vehicle savings (or costs) that MPCA has estimated for a LEV-certified vehicle relative to a SAFE-certified vehicle (See Section 3(A)(iii)), if future gasoline prices are significantly reduced as a result of an economic slowdown, it could tip the balance from an overall

net benefit to an overall net cost for the vehicle owner. No one, however, can confidently predict future gasoline prices and they could very well be higher than those we have used in our base analysis. Thus, the MPCA determined it is reasonable to use the analysis based on reference fuel prices, even under an economic slowdown in the wake of the COVID-19 pandemic.

The SAFE FRIA also considered a Low Oil Price Sensitivity Case in its estimation of per-vehicle fuel savings and per-vehicle overall consumer savings.⁹⁰ Using a 3% discount rate, the SAFE FRIA still found a small overall per-vehicle savings for the average vehicle under existing federal standards (equivalent to the LEV standard) relative to the final SAFE rule. Using a 7% discount rate, the SAFE FRIA found a small overall per-vehicle cost for the average vehicle under existing federal standards relative to the final SAFE rule. Based on all the analyses and future scenarios considered by the MPCA, most show an overall consumer benefit for the owner of a LEV-certified vehicle while a few show an overall consumer cost.

ii. ZEV standard consumer impacts in an economic slowdown

As Table 53 shows, an economic slowdown may affect the number of new EVs in Minnesota under a ZEV standard. The MPCA has reanalyzed the ZEV standard consumer impacts (presented above in Section 3(B)) with the Economic Slowdown scenario projected new BEV and PHEV sales.

Tables 57-60 summarize the expected cumulative costs and savings of the ZEV standard in Minnesota under the Economic Slowdown scenario, just as Tables 34-37 consolidated these results for the base analysis in Section 3(B)(v). Table 57 presents the total cumulative cost savings of ZEV standard compliance in Minnesota, relative to a hypothetical alternative where all the new BEVs and PHEVs estimated to be required for ZEV compliance for MYs 2025-2034 were instead ICE vehicles. Table 58 presents the expected cumulative cost savings of a ZEV standard relative to the Economic Slowdown scenario with lower than linear EV sales growth. Tables 59 and 60 present the same estimates as Tables 57 and 58 but in net present value terms using a 3% discount rate.⁹¹

Just as was the case in the base analysis in Section 3(B)(v), these tables show that greater vehicle costs for BEVs and PHEVs are offset by fuel cost and maintenance savings. Table 57 shows that the total cost associated with all the EVs estimated to be required for compliance with the ZEV standard in Minnesota for the MY 2025-2034 in the Economic Slowdown scenario is \$1.32 billion savings in undiscounted terms (Table 57, slightly less than the \$1.43 billion savings in the base scenario), \$1.13 billion savings using a 3% discount rate (Table 59, again slightly less than the \$1.22 billion savings in the base scenario), and \$900 million savings with a 7% discount rate (again slightly less than the \$1.00 billion savings in the base scenario). Relative to the Economic slowdown business-as-usual sales with slower than linear sales growth, implementing the ZEV standard in Minnesota for the MY 2025-2034 time frame results in an estimated \$391 million savings in undiscounted terms (Table 58, almost exactly equal to the \$389 million savings in the base scenario), \$318 million savings in present value terms with a 3% discount rate (Table 60, again nearly the same as the \$315 million savings in the base scenario), and \$243 million savings with a 7% discount rate (again very close to the \$239 million savings in the base scenario).

⁹⁰ See Tables VII-476 and VII-477, on pages 1783-1788 of SAFE FRIA:

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/final_safe_fria_web_version_200330.pdf

⁹¹ The MPCA also analyzed fuel savings and maintenance savings using a 7% discount rate. These results are not presented in tables in this document, but we do report the total cumulative savings assuming both a 3% and 7% discount rate.

Table 57: Total cumulative cost savings of ZEV standard compliance in the Economic Slowdown scenario (in millions of dollars).

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 years average	Lifetime average	First 5 years average	Lifetime average	Lifetime average
2025	-\$34.07	-\$38.76	-\$72.84	\$85.08	\$39.44	\$79.59	\$39.37	-\$14.51	\$77.33
2026	-\$19.71	-\$35.75	-\$55.46	\$70.24	\$32.57	\$79.97	\$39.56	-\$13.31	\$81.44
2027	-\$6.24	-\$32.85	-\$39.09	\$71.55	\$33.43	\$80.21	\$39.68	-\$12.20	\$100.48
2028	\$6.28	-\$29.64	-\$23.36	\$71.56	\$33.63	\$79.14	\$39.15	-\$11.03	\$116.31
2029	\$17.52	-\$26.46	-\$8.94	\$70.85	\$33.45	\$77.45	\$38.31	-\$9.89	\$129.46
2030	\$28.60	-\$23.47	\$5.13	\$69.74	\$33.04	\$75.50	\$37.35	-\$8.73	\$141.65
2031	\$39.09	-\$20.52	\$18.57	\$67.90	\$32.25	\$72.98	\$36.10	-\$7.52	\$151.94
2032	\$48.79	-\$17.70	\$31.09	\$65.56	\$31.23	\$70.03	\$34.65	-\$6.29	\$160.39
2033	\$57.70	-\$15.10	\$42.60	\$72.19	\$34.59	\$66.94	\$33.11	-\$5.09	\$176.63
2034	\$66.61	-\$12.88	\$53.73	\$69.20	\$33.26	\$64.56	\$31.94	-\$4.00	\$183.48
Total	\$204.58	-\$253.14	-\$48.56	\$713.88	\$336.88	\$746.37	\$369.23	-\$92.57	\$1,319.11

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In undiscounted terms, the total estimated cumulative savings from all EVs estimated to be required for compliance with the ZEV standard is \$1.32 billion for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, and maintenance savings for the lifetimes of all MY 2025-2034 vehicles.

Table 58: Total cumulative cost savings of ZEV standard compliance in the Economic Slowdown scenario (in millions of dollars) relative to business-as-usual slower than linear growth EV sales

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$17.88	-\$29.16	-\$47.04	\$53.99	\$25.09	\$46.12	\$22.82	-\$8.26	\$44.81
2026	-\$9.69	-\$25.79	-\$35.48	\$40.09	\$18.61	\$43.55	\$21.54	-\$7.12	\$41.04
2027	-\$2.85	-\$22.56	-\$25.41	\$38.12	\$17.82	\$40.70	\$20.13	-\$6.09	\$47.32
2028	\$2.60	-\$19.03	-\$16.44	\$34.73	\$16.34	\$36.48	\$18.05	-\$5.05	\$49.73
2029	\$6.54	-\$15.73	-\$9.19	\$31.14	\$14.71	\$32.29	\$15.97	-\$4.14	\$50.11
2030	\$9.19	-\$12.52	-\$3.33	\$26.62	\$12.62	\$27.24	\$13.48	-\$3.21	\$47.31
2031	\$10.27	-\$9.42	\$0.85	\$21.42	\$10.18	\$21.68	\$10.73	-\$2.33	\$41.62
2032	\$9.68	-\$6.47	\$3.21	\$15.78	\$7.52	\$15.81	\$7.82	-\$1.54	\$33.26
2033	\$7.01	-\$3.80	\$3.21	\$11.92	\$5.72	\$9.46	\$4.68	-\$0.81	\$23.77
2034	\$3.91	-\$1.66	\$2.24	\$5.58	\$2.69	\$4.42	\$2.19	-\$0.35	\$11.90
Total	\$18.77	-\$146.14	-\$127.37	\$279.38	\$131.30	\$277.76	\$137.41	-\$38.90	\$390.87

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In undiscounted terms the total estimated cumulative savings of ZEV compliance, relative to the

reference case EV sales growth scenario, is \$391 million for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, and maintenance savings for the lifetimes of all MY 2025-2034 vehicles.

Table 59: Total net present value of cumulative cost savings of ZEV standard compliance in the Economic Slowdown scenario (in millions of dollars) assuming a 3% discount rate.

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$34.07	-\$38.76	-\$72.84	\$72.79	\$36.65	\$68.54	\$36.65	-\$12.85	\$55.63
2026	-\$19.71	-\$35.75	-\$55.46	\$60.08	\$30.25	\$68.86	\$36.82	-\$11.74	\$61.74
2027	-\$6.24	-\$32.85	-\$39.09	\$61.25	\$31.06	\$69.07	\$36.94	-\$10.72	\$80.51
2028	\$6.28	-\$29.64	-\$23.36	\$61.29	\$31.26	\$68.15	\$36.44	-\$9.65	\$96.44
2029	\$17.52	-\$26.46	-\$8.94	\$60.71	\$31.10	\$66.69	\$35.66	-\$8.60	\$109.85
2030	\$28.60	-\$23.47	\$5.13	\$59.79	\$30.72	\$65.01	\$34.77	-\$7.54	\$122.40
2031	\$39.09	-\$20.52	\$18.57	\$58.23	\$29.99	\$62.84	\$33.61	-\$6.44	\$133.20
2032	\$48.79	-\$17.70	\$31.09	\$56.23	\$29.04	\$60.31	\$32.25	-\$5.33	\$142.30
2033	\$57.70	-\$15.10	\$42.60	\$61.96	\$32.17	\$57.64	\$30.82	-\$4.24	\$157.96
2034	\$66.61	-\$12.88	\$53.73	\$59.41	\$30.94	\$55.59	\$29.73	-\$3.25	\$165.48
Total	\$204.58	-\$253.14	-\$48.56	\$611.74	\$313.17	\$642.69	\$343.69	-\$80.37	\$1,125.51

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 3% discount rate the total estimated cumulative savings from all EVs estimated to be required for compliance with the ZEV standard is \$1.13 billion for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, and maintenance savings for the lifetimes of all MY 2025-2034 vehicles. Although the table does not show it, if a 7% discount rate were applied instead, the total estimated cumulative saving would be \$900 million.

Table 60: Total net present value of cumulative cost savings of ZEV standard compliance (in millions of dollars) assuming a 3% discount rate relative to business-as-usual slower than linear growth EV sales.

Model year	Incremental vehicle cost			Fuel cost savings		Maintenance savings		Annual registration fees and taxes	Total net cost savings
	BEV	PHEV	Total	Lifetime average	First 5 Years average	Lifetime average	First 5 Years average	Lifetime average	Lifetime average
2025	-\$17.88	-\$29.16	-\$47.04	\$46.30	\$23.31	\$39.80	\$21.24	-\$7.34	\$31.73
2026	-\$9.69	-\$25.79	-\$35.48	\$34.38	\$17.29	\$37.58	\$20.05	-\$6.30	\$30.17
2027	-\$2.85	-\$22.56	-\$25.41	\$32.71	\$16.56	\$35.12	\$18.74	-\$5.37	\$37.05
2028	\$2.60	-\$19.03	-\$16.44	\$29.82	\$15.18	\$31.48	\$16.80	-\$4.43	\$40.43
2029	\$6.54	-\$15.73	-\$9.19	\$26.75	\$13.68	\$27.86	\$14.87	-\$3.62	\$41.81
2030	\$9.19	-\$12.52	-\$3.33	\$22.87	\$11.73	\$23.51	\$12.54	-\$2.80	\$40.25
2031	\$10.27	-\$9.42	\$0.85	\$18.41	\$9.47	\$18.71	\$9.98	-\$2.02	\$35.95
2032	\$9.68	-\$6.47	\$3.21	\$13.56	\$6.99	\$13.64	\$7.28	-\$1.33	\$29.09
2033	\$7.01	-\$3.80	\$3.21	\$10.25	\$5.32	\$8.16	\$4.36	-\$0.69	\$20.93
2034	\$3.91	-\$1.66	\$2.24	\$4.80	\$2.50	\$3.82	\$2.04	-\$0.30	\$10.57
Total	\$18.77	-\$146.14	-\$127.37	\$239.85	\$122.04	\$239.68	\$127.90	-\$34.20	\$317.96

Negative values indicate higher costs for BEVs or PHEVs relative to ICE vehicles. Positive values indicate savings for BEVs and PHEVs relative to ICE vehicles. In present value terms with a 3% discount rate the total estimated cumulative savings of ZEV compliance, relative to the reference case EV sales growth scenario, is \$318 million for MYs 2025-2034. This is the sum of incremental vehicle costs, fuel savings, and maintenance savings for the lifetimes of all MY 2025-2034 vehicles. Although the table does not show it, if a 7% discount rate were applied instead, the total estimated cumulative saving would be \$243 million.

Collectively, comparing the cumulative consumer savings in the Economic Slowdown scenario in Tables 57-60 to the base scenario cumulative consumer savings in Tables 34-37, we see that a future economic slowdown is not likely to have significant impacts on the consumer benefits of a ZEV standard in Minnesota. It should be noted, however, that all these analyses assume the same EIA 2019 AEO Reference scenario gasoline prices. As was the case in the analysis of consumer impacts of the LEV standard in Section 5(B)(i), the consumer impacts of a Minnesota ZEV standard are also sensitive to gasoline prices. However, since the overall consumer benefits of the ZEV standard in Minnesota are considerably larger and are affected as much by maintenance costs savings as by fuel costs savings,⁹² we can conclude that even in a future with considerably lower gasoline prices, the ZEV standard is likely to produce considerable benefits to Minnesota consumers.

iii. Health and equity impacts in an economic slowdown

With slightly lower emissions benefits in the Economic Slowdown scenario, as presented in Section 5(A), we expect slightly lower health benefits of the proposed rule in a future economic slowdown. However, since the estimated differences in emissions of PM, NMOG and NO_x in a future economic slowdown presented in Section 5(A) are relatively small and given the general uncertainties in health impacts analysis, we would expect the overall magnitude of health benefits to be close to the base scenario

⁹² It is also possible that a future economic slowdown will lead to reductions in electricity prices such that the cost to fuel an EV will also be lower in a depressed economy as would the cost to fuel an ICE vehicle.

health benefits of the proposed rule presented in Section 4(A).

The distribution of benefits across the geography of Minnesota, as presented in the Equity analysis in Section 4(B) is not expected to be affected by a future economic slowdown. There may be slightly lower health benefits of the proposed rule in an economic slowdown, but the patterns of benefits to areas of concern for environmental justice and to sensitive land uses relative to the state as a whole is not expected to be any different. Thus, regardless of the impacts of the COVID-19 pandemic on Minnesota's economy, we expect positive equity implications of the proposed rule.

6. Establishing an initial ZEV credit bank

Establishing an initial ZEV credit bank for manufacturers for use in the first years of compliance with the ZEV standard is an important mechanism for providing the compliance flexibilities envisioned by the ZEV standard. California has been implementing iterations of the ZEV standard since the 1990s and does not provide a mechanism for establishing an initial bank of ZEV credits. Establishing an initial bank is outside of the standards set by California and is, therefore, an implementation and enforcement choice left to each state. Precedent in other states has established that states adopting the ZEV standard for the first time have the ability to establish their own mechanism for developing an initial credit bank.

The MPCA has two primary goals in establishing an initial ZEV credit bank: to incentivize EV sales in Minnesota even before they are required, and to provide manufacturers reasonable mechanisms for compliance flexibility, especially in the initial years of implementation. The MPCA analyzed several different mechanisms to establish an initial credit bank. Most of these mechanisms entail manufacturers selling BEVs and PHEVs in Minnesota prior to the date compliance with the ZEV standard is required, but the means of accruing "early action" credits varies across the mechanisms. As in other parts of the MPCA's analysis, we used MY 2025 as the first effective model year, or first implementation year, of the ZEV standard. While the first effective model year will be determined by when California's CAA waiver is deemed valid, MY 2025 is the earliest the ZEV rule could potentially be implemented in Minnesota. The MPCA considered the following five mechanisms for establishing an initial ZEV credit bank:

- 1. Early action only:** Vehicle manufacturers earn bankable credits for sales of BEVs and PHEVs in Minnesota for the three model years (anticipated to be MYs 2022, 2023, and 2024) before implementation of the ZEV standards.
- 2. Early action with multipliers:** Early action credits for the model years before implementation of the ZEV standard (estimated three model years, 2022-2024) are multiplied by factors greater than one so that early action sales earn more credits. This mechanism would provide extra incentive for manufacturers to deliver vehicles for sale in the early action years and would also be likely to result in larger initial credit banks. The MPCA considered a multiplier of 1.5 for both BEV and PHEV sales in the early action years. Increasing (or decreasing) these multipliers would increase (or decrease) the number of accrued credits in the initial ZEV credit bank.
- 3. Early action plus look-back:** Instead of three years of early action credits, manufacturers would receive five years to earn early action credits: the three model years between adoption of the ZEV standard and the first effective model year (anticipated to be MYs 2022-2024) as well as the two "look back" model years before that (MYs 2020 and 2021).
- 4. Early action plus one-time allotment:** This mechanism includes early action credits (estimated three model years) plus a one-time deposit into each manufacturer's credit bank a number of ZEV credits equivalent to what would be needed for compliance in the first effective model year of the ZEV standard. The rationale for this mechanism is that the MPCA received comments from vehicle manufacturers stating they prefer to maintain a year worth of credits in their ZEV credit banks in

order to manage risk of an annual slump in EV sales.⁹³ The one-time allotment would therefore provide the vehicle manufacturers with this buffer; however, since manufacturers typically maintain that minimum number of credits in their bank, the MPCA does not anticipate this allotment would substantively affect the number of EVs delivered for sale in Minnesota. In two additional variants of this mechanism, the MPCA considered providing manufacturers an additional deposit of ZEV credits equivalent to the number needed for compliance in the first two years of the ZEV standard instead of just the first year⁹⁴ and an additional deposit of ZEV credits equivalent to half of the number needed for compliance in the first year of the ZEV standard.

5. **Proportional credits based on California credit bank:** In this mechanism, a number of credits proportional to California's ZEV credit balance at the time that MPCA begins implementation of the ZEV standard (anticipated to be MY 2025) would be deposited in Minnesota's ZEV credit bank. The proportion of the California balance that would be deposited is based on the ratio of Minnesota total LDV sales to California total LDV sales. The proportional credit bank is the one mechanism analyzed by the MPCA which does not involve manufacturers selling EVs in Minnesota to earn credits for their initial credit banks.

Variations of these mechanisms have been used in other states and Canadian provinces that have adopted ZEV standards.

Various assumptions are necessary to estimate the number of credits that might be deposited in the initial Minnesota ZEV credit bank as a result of each of the above mechanisms. For the first four mechanisms, it is necessary to project how many BEVs and PHEVs would be sold in Minnesota during the early action years – MYs 2022-2024 for mechanisms 1, 2, and 4, and MYs 2020-2024 for mechanism 3 – as well as the expected number of ZEV credits that BEVs and PHEVs sold in Minnesota would earn in each of those years. For mechanism 5, it is necessary to project the size of California's ZEV credit balance as of the start of MY 2025 as well as the magnitude of Minnesota's total LDV sales relative to California's.

To understand an upper and lower bound of possible numbers of credits that manufacturers might accrue through each of the mechanisms, the MPCA used a range of projections of BEV and PHEV sales in Minnesota for the early action years:

1. BEV and PHEV sales in Minnesota would continue according to the same linear trends in each of their sales in Minnesota based on sales from 2015-2019.
2. BEV and PHEV sales in Minnesota follow the projections made by the U.S. EIA 2019 AEO Reference case EV sales projections⁹⁵ for the West North Central region of the U.S.⁹⁶
3. BEV and PHEV sales in Minnesota follow the projections made by the U.S. EIA 2020 AEO Reference case EV sales for the West North Central region of the U.S.

93 Alliance for Automotive Innovation presentation to MPCA in response to MPCA's proposed early action credit mechanism, February 6, 2020, slide 26.

94 This variant could use trigger language in the rule to establish that "If, after the first effective model year, the commissioner determines that the ZEV sales rate is less than the rate needed to reasonably achieve compliance in the second effective model year, the commissioner may grant a second credit allotment equivalent to the second effective model year's ZEV credit requirement for that motor vehicle manufacturer." This trigger could use ZEV sales percentages to estimate whether sales most resemble linear growth, quadratic growth, or the 2020 AEO projection.

95 <https://www.eia.gov/outlooks/aeo/>

96 EIA's West North Central Region is comprised of Minnesota along with Iowa, Kansas, Missouri, Nebraska, North Dakota, and South Dakota.

4. BEV and PHEV sales in Minnesota continue according to the quadratic trends in each of their sales in Minnesota based on sales from 2013-2019.
5. BEV and PHEV sales in Minnesota are negatively impacted by the economic slowdown caused by the COVID-19 pandemic and thus not even the linear sales trajectories are achieved.

All five of these EV sales estimates are different business-as-usual estimates and do not reflect the potential for the adoption of the ZEV standard and early action mechanisms to induce increased EV sales in Minnesota. Since an early action credit mechanism would be voluntary, the MPCA cannot reasonably predict how many EVs manufacturers might deliver for sale in Minnesota in the early action years. The MPCA therefore examined a range of projections of EV sales to understand a range of potential outcomes and used a conservative, linear estimate of EV growth as a baseline.

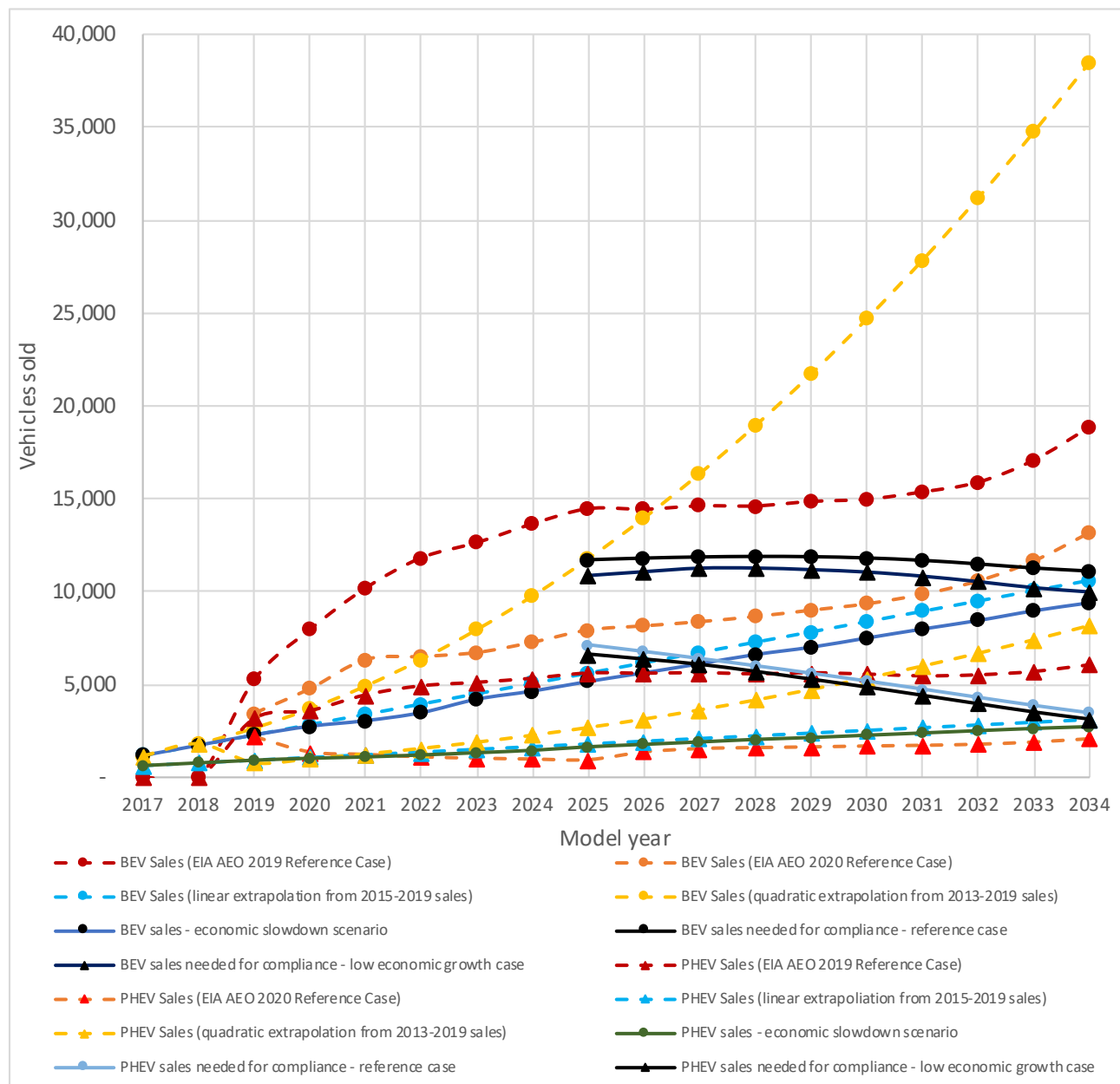
As was noted in the discussion of emissions and consumer impacts analysis, the EIA 2019 AEO projects relatively high BEV and PHEV sales. If this projection were to occur for these early action model years, vehicle manufacturers would build up large initial credit banks that would not even be needed by manufacturers since the 2019 AEO predicts BEV and PHEV sales will be significantly higher than what would be required to comply with the ZEV standard. If the comparatively more conservative EIA 2020 AEO EV projections were to occur for these years, vehicle manufacturers would build up smaller initial credit banks than with the 2019 AEO projection, but still more credits than in the linear sales growth scenario. If the quadratic sales projection were to occur, manufacturers would establish even larger initial credit banks. Finally, if an economic downturn depresses EV sales to be even lower than linear growth trends, then manufacturers may only be able to accrue somewhat less credits than the linear growth scenario. However, in this last scenario it is important to point out that an economic downturn would probably impact not only EV sales in Minnesota, but the entire LDV market. If LDV sales are lower, then the number of credits needed for ZEV compliance will also be lower, especially since compliance requirements are based on average LDV sales for the three-year period up to two years before the compliance year. Thus, an economic slowdown may result in lower initial credit banks, but also may result in lower compliance burdens that the initial credit banks seek to alleviate.

As was also described in Section 5, to estimate projected business-as-usual EV sales in the low economic growth scenario, in each future year we scaled down our linear projections by the proportional difference between ZEV or PHEV sales in EIA's 2020 AEO Reference Scenario sales projections for the west north central region and the ZEV or PHEV sales in EIA's 2020 AEO Low Economic Growth Scenario sales projections for the west north central region. We also projected total LDV sales in a low economic growth scenario by similarly scaling down our reference scenario LDV sales in each year by the proportional difference in total LDV sales in EIA's 2020 AEO Reference Scenario and Low Economic Growth Scenario.

Figure 22 presents the projected BEV and PHEV sales for the linear, quadratic, 2019 AEO, 2020 AEO, and economic slowdown sales growth projections and also shows the BEV and PHEV sales needed for ZEV standard compliance starting in MY 2025.

Figure 22: Minnesota BEV and PHEV sales: Business as usual compared with sales needed for ZEV compliance

Initial credit banks from early action EV sales were estimated based on the BEV and PHEV linear extrapolations from 2015-2019 sales. Projected Minnesota BEV and PHEV sales based on the EIA 2019 AEO, the EIA 2020 AEO, quadratic extrapolations from 2013-2019 sales, and low economic growth sales are included here as alternative future scenarios.



As was discussed in section 1(C) of this document, the EIA's 2020 AEO projects significantly lower EV sales over our analysis time frame and over the anticipated early action years compared to the EIA 2019 AEO projections. While the 2020 AEO projection is still generally higher than MPCA's linear EV sales growth projections (see Figure 22), it is reasonably close to our linear projections. It thus reinforces the reasonableness of the conservative linear EV sales growth estimates as the Reference scenario in the MPCA's emissions and consumer impacts analyses as well as to calculate early action credit accrual estimates. However, especially taking into consideration that the adoption of the ZEV standard and early action credit mechanism would probably result in higher EV sales, considering other future EV sales

scenarios in evaluating the reasonableness of mechanisms to establish initial ZEV credit banks helps the MPCA understand a range of potential outcomes.

The average number of credits earned per BEV and PHEV in the early action model years are based on estimates derived in the ZEV Compliance Calculator, described in Section 1(C)(ii). For MY 2020, the calculator estimates a BEV earns an average of 3.5 credits and a PHEV earns 0.6 credits. By MY 2023, the calculator estimates a BEV earns nearly 4 credits while a PHEV earns nearly 1.1 credits. Based on the linear sales projections and these credits per vehicle estimates, the MPCA estimated the number of early action credits that could be accrued in each of the five potential early action years, MYs 2020-2024, summarized in Table 61.

Table 61: Estimated possible early action credits accrual from Minnesota sales by model year (MY)

	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024
Projected BEV sales / projected credits per BEV	2,837 / 3.53	3,392 / 3.68	3,947 / 3.84	4,502 / 4.00	5,056 / 4.00
Projected PHEV sales / projected credits per PHEV	1,070 / 0.63	1,216 / 0.65	1,362 / 0.66	1,507 / 1.09	1,653 / 1.10
Potential BEV credits (BEV sales x credit per BEV)	10,021	12,494	15,166	18,006	20,226
Potential PHEV credits (PHEV sales x credits per PHEV)	675	787	905	1,637	1,819
Total potential credits (BEVs + PHEVs)	10,696	13,281	16,071	19,643	22,044

Estimates of early action credits are calculated by multiplying sales of BEVs and PHEVs in early action years by the average credits earned per BEV and PHEV. The projected early action sales are based on linear projections of Minnesota BEV and PHEV sales, which are conservative lower-bound projections. Furthermore, they do not take into account the likelihood that adoption of the ZEV standard and early action credit mechanism would result in higher Minnesota EV sales in the early action years.

From this information, the MPCA estimated the total credits that might be earned through each of the potential mechanisms using the following operations:

- 1. Early action only:** Sum the total potential credits for MYs 2022, 2023, and 2024 to get 57,758 credits in the initial credit bank.
- 2. Early action with multipliers:** Multiply BEV credits and PHEV credits by 1.5 for MYs 2022 through 2024 and sum to get 86,637 credits in the initial credit bank.
- 3. Early action plus look-back:** Sum the total potential credits for MYs 2020 through 2024 to get 81,735 credits in the initial credit bank.
- 4. Early action plus one-time allotment:** Using the Minnesota ZEV compliance calculator, the MPCA estimated that manufacturers would need 54,706 credits⁹⁷ to comply with the ZEV standard in the first year of implementation (anticipated to be MY 2025) and 54,669 credits⁹⁸ to comply with the ZEV standard in the second year of implementation (anticipated to be MY 2026). For an allotment of

⁹⁷ This is based on manufacturers needing to sell 11,714 BEVs and 7,139 PHEVs for MY 2025, based on the projections of our ZEV Compliance Calculator. It also takes into account that the ZEV standard allows FCEV travel credits from FCEV sales in California to help manufacturers satisfy their ZEV compliance requirements in Minnesota. We estimate that FCEV travel credits would equal approximately 1,500 credits per model year.

⁹⁸ This is based on manufacturers needing to sell 11,804 BEVs and 6,777 PHEVs and again takes into account approximately 1,500 FCEV travel credits.

ZEV credits equivalent to the number of credits required for one year of compliance, the MPCA added the 57,758 credits projected to be accrued from early action for MYs 2022 through 2024 plus 54,706 credits for a total of 112,465 credits in the initial credit bank. With an allotment equivalent to the number of ZEV credits required for two years of compliance, we estimate that manufacturers would have 57,758 plus 54,706 plus 54,669 credits, for a total of 167,133 credits in the initial credit bank. With an allotment equivalent to half the number of ZEV credits required for compliance, the MPCA added 27,353 credits (half of 54,706) for a total of 85,111 credits in the initial credit bank.

5. **Proportional credits based on California credit bank:** For the proportional credit deposit based on California's credit balance, the MPCA projected California's credit balance as of January 1, 2024 based on current and recent past totals in California's ZEV credit bank.⁹⁹ As of August 31, 2019, California's ZEV credit balance was 962,000 credits,¹⁰⁰ significantly higher than its credit balance a year earlier of 816,000 credits.¹⁰¹ Based on an extrapolation of California's ZEV credit balance to the end of MY 2023, the MPCA estimates that the number of ZEV credits in California's bank by the beginning of MY 2025 may be between 1.8 million to 2.5 million. Currently, Minnesota's total annual LDV sales are approximately 250,000, roughly 13% of California's current annual LDV sales of approximately 2 million. The MPCA multiplied the ratio of Minnesota's sales to California's sales by the estimated number of ZEV credits in California's credit bank by MY 2024. This calculation results in an estimate that approximately 234,000-325,000 credits would be deposited Minnesota's ZEV credit bank by the beginning of MY 2025 if a proportional credit mechanism were used to establish Minnesota's initial ZEV credit bank.¹⁰²

Figure 23 presents the estimated number of ZEV credits that might form the initial ZEV credit bank under each mechanism, assuming linear growth of both BEV and PHEV sales, along with the number of credits the MPCA estimates would be required for compliance in the first year of the ZEV standard.

⁹⁹ California's ZEV credit balances for 2009-2019 can be found here: <https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/zev-program/zero-emission-vehicle-credit-balances>

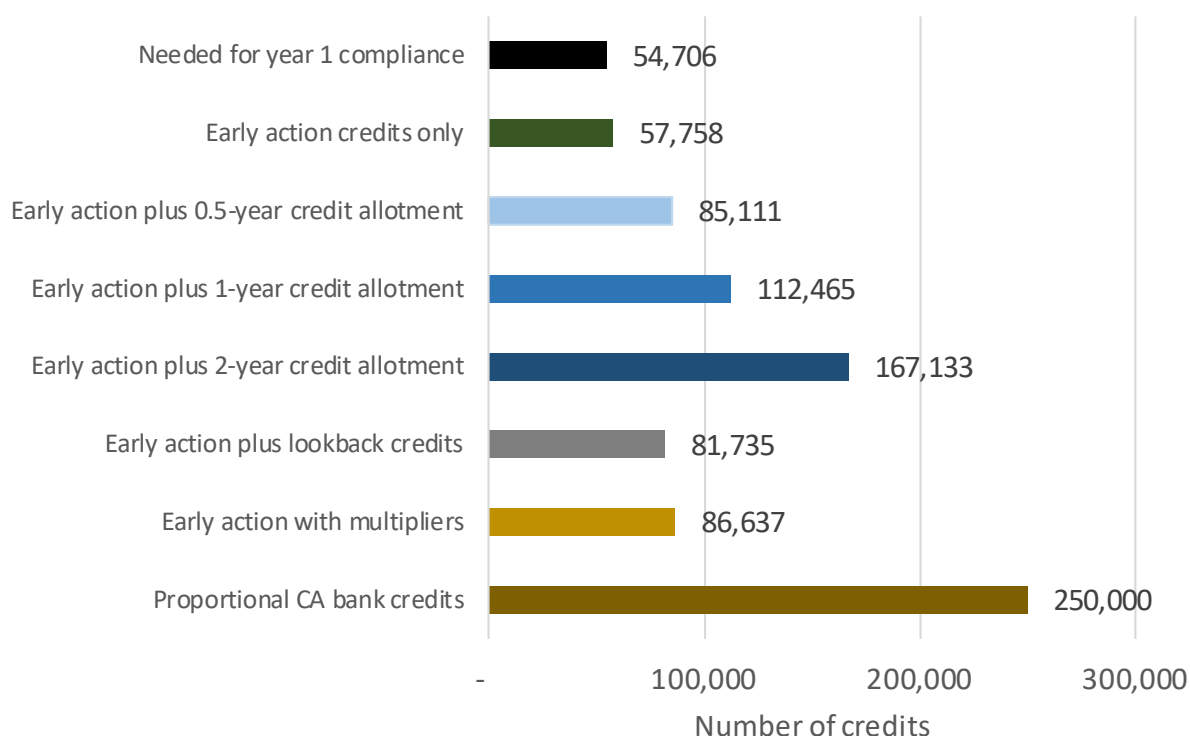
¹⁰⁰ https://ww2.arb.ca.gov/sites/default/files/2020-01/2018%20ZEV%20Credits_ac.pdf

¹⁰¹ https://ww2.arb.ca.gov/sites/default/files/2020-01/2017_zev_credits_ac.pdf

¹⁰² In Figure 23 we show an estimate of 250,000 ZEV credits that could be available to transfer from California. However, due to the high level of uncertainty in projecting future California ZEV credits balances, we feel more comfortable estimating a range of 234,000-325,000 credits that could be available to transfer from California to Minnesota's initial ZEV credit bank.

Figure 23: Estimated initial credit bank for each potential early action scenario.

Based on linearly projected sales growth of BEVs and PHEVs, the MPCA estimated the number of early action credits that would be accrued under each potential mechanism for establishing an initial ZEV credit bank. We used the Minnesota ZEV compliance calculator to estimate how many credits would be earned for each BEV and PHEV sold and to estimate the number of credits that would be required for compliance in the first year of the ZEV standard.



For each of these five initial credit bank mechanisms, the MPCA next estimated how much of manufacturers' compliance burden could be satisfied with the initial bank in the initial year(s) of the ZEV standard. As explained above, we estimated manufacturers' EV sales requirements in every year starting in MY 2025 using the ZEV Compliance Calculator. We estimate that manufacturers would need 54,706 credits for compliance in the first year. In the second model year, we estimate that manufacturers would need 54,669 credits.¹⁰³ The MPCA then considered how many years' worth of compliance manufacturers might be able to cover using the credits accumulated through each initial ZEV credit bank mechanism, without taking into account credits that would be accrued through BEV and PHEV sales during the initial implementation years. This analysis is summarized in Table 62.

¹⁰³ Based on 11,804 BEVs and 6,777 PHEVs, and, again, FCEV travel credits from California to Minnesota are factored into this estimate.

Table 62: Estimated ZEV compliance requirements that could be satisfied with initial credit bank.

	Early action	Early action with multipliers	Early action plus look back	Early action plus 0.5-yr initial buffer	Early action plus 1-yr initial buffer	Early action plus 2-yr initial buffer	Proportional CA balance transfer
Projected credits in initial bank	57,758	86,637	81,735	85,111	112,465	167,133	234,000 - 325,000
Years of ZEV compliance that could be satisfied	All of first year plus 6% of second	All of first year plus 58% of second	All of first year plus 49% of second	All of first year plus 56% of second	First two years plus 6% of third	First three years plus 6% of fourth	Five years

This table presents the estimated size of the initial ZEV credit bank for each mechanism that the MPCA analyzed along with the number of years of ZEV standard compliance that could potentially be satisfied with the initial credit bank, not taking into account ZEV credits that would be accrued in the initial year(s) of standard implementation.

But what if there is an economic slowdown as a result of the COVID-19 pandemic?

MPCA re-estimated initial credit banks for all of these accrual mechanisms with revised projections of LDV, BEV, and PHEV sales for each of the possible early action years as well as the initial years of ZEV standard compliance. Again, these estimates were generated by adjusting our linear projections of BEV and PHEV sales according to expected decreases in sales in the EIA 2020 AEO Reference Scenario relative to its Low Economic Growth Scenario. To estimate ZEV standard compliance requirements in an economic slowdown, we additionally adjusted our reference case LDV sales by the proportional difference in LDV sales in the EIA 2020 AEO Reference Scenario relative to its Low Economic Growth Scenario. Table 63 presents an alternate version of the projected BEV and PHEV sales in Table 61 under economic slowdown vehicle sales expectations.

Table 63: Estimated possible early action credits accrual from Minnesota sales by model year in a possible COVID-19 economic slowdown

	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024
Projected BEV sales / projected credits per BEV	2,749 / 3.53	3,051 / 3.68	3,482 / 3.84	4,210 / 4.00	4,645 / 4.00
Projected PHEV sales / projected credits per PHEV	1,027 / 0.63	1,099 / 0.65	1,206 / 0.66	1,327 / 1.09	1,457 / 1.10
Potential BEV credits (BEV sales x credit per BEV)	9,710	11,238	13,382	16,838	18,580
Potential PHEV credits (PHEV sales x credits per PHEV)	648	711	802	1,441	1,603
Total potential credits (BEVs + PHEVs)	10,357	11,949	14,184	18,280	20,183

Estimates of early action credits are calculated by multiplying sales of BEVs and PHEVs in early action years by the average credits earned per BEV and PHEV. The projected early action sales are based on linear projections of Minnesota BEV and PHEV sales, which are conservative lower-bound projections. Furthermore, they do not take into account the likelihood that adoption of the ZEV standard and early action credit mechanism would result in higher Minnesota EV sales in the early action years.

Just as we did for the linear sales projections, the MPCA estimated the total credits that might be earned through each of the potential mechanisms in a potential economic slowdown:

- 1. Early action only:** Sum the total potential credits for MYs 2022, 2023, and 2024 to get 52,646 credits in the initial credit bank.

2. **Early action with multipliers:** Multiply BEV and PHEV credits by 1.5 for MYs 2022 through 2024 and sum to get 78,969 credits in the initial credit bank.
3. **Early action plus look-back:** Sum the total potential credits for MYs 2020 through 2024 to get 74,952 credits in the initial credit bank.
4. **Early action plus one-time allotment:** With reduced projected LDV sales in an economic slowdown, the ZEV compliance requirement also goes down. Using the Minnesota ZEV compliance calculator, the MPCA estimated that manufacturers would need 50,760 credits¹⁰⁴ to comply with the ZEV standard in the first year of implementation (anticipated to be MY 2025) and 51,293 credits¹⁰⁵ to comply with the ZEV standard in the second year of implementation (anticipated to be MY 2026). For an allotment of ZEV credits equivalent to the number of credits required for one year of compliance, the MPCA added the 52,246 credits projected to be accrued from early action for MYs 2022 through 2024 plus 50,760 credits for a total of 103,406 credits in the initial credit bank. With an allotment equivalent to the number of ZEV credits required for two years of compliance, we estimate that manufacturers would have 52,646 plus 50,760 plus 51,293 credits, for a total of 154,699 credits in the initial credit bank. With an allotment equivalent to half the number of credits required for one year of compliance, we estimate that manufacturers would have 52,646 credits plus 25,380 credits (half of the year one compliance requirement), which equals 78,026 credits.
5. **Proportional credits based on California credit bank:** California's EV sales could also be potentially impacted by an economic downturn, so its ZEV credit balance as of January 1, 2024 may be less than in the reference scenario. Trying to predict California's ZEV credit balance years into the future involves a high degree of uncertainty whether under normal economic conditions or in an economic slowdown. We adjusted the expected range of credits that could be transferred to Minnesota on January 1, 2024 down to 200,000-300,000 credits, and used 225,000 credits (instead of 250,000) as our point estimate.

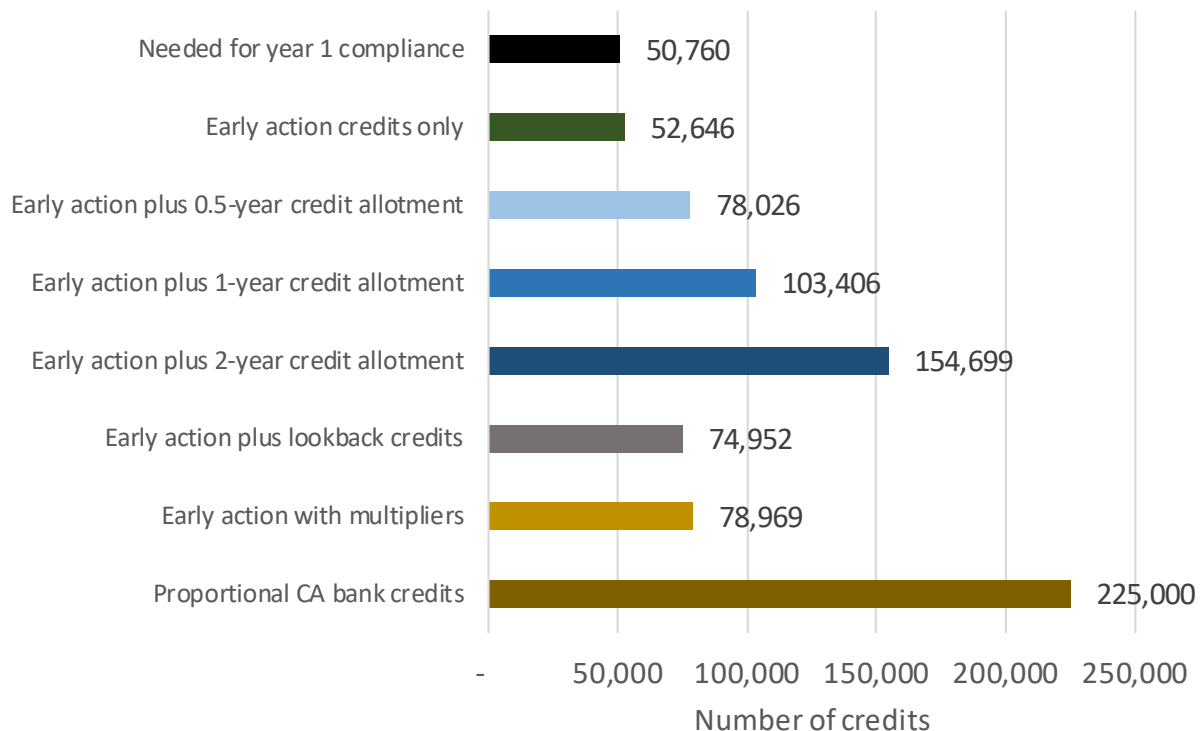
Figure 24 reproduces Figure 23, but under economic downturn assumptions, to present the estimated number of ZEV credits that might form the initial ZEV credit bank under each mechanism, along with the number of credits the MPCA estimates would be required for compliance in the first year of the ZEV standard.

¹⁰⁴ This is based on manufacturers needing to sell 10,865 BEVs and 6,637 PHEVs for MY 2025, based on the projections of our ZEV Compliance Calculator. It also takes into account that the ZEV standard allows FCEV travel credits from FCEV sales in California to help manufacturers satisfy their ZEV compliance requirements in Minnesota. We estimate that FCEV travel credits would equal approximately 1,500 credits per model year.

¹⁰⁵ This is based on manufacturers needing to sell 11,072 BEVs and 6,370 PHEVs and again takes into account approximately 1,500 FCEV travel credits.

Figure 24: Estimated initial credit bank for each potential early action scenario in a possible COVID-19 economic slowdown.

Based on diminished linearly projected sales growth of BEVs and PHEVs that could represent depressed EV sales in an economic slowdown, the MPCA estimated the number of early action credits that would be accrued under each potential mechanism for establishing an initial ZEV credit bank. We used the Minnesota ZEV compliance calculator with diminished expectations of total LDV sales to estimate how many credits would be earned for each BEV and PHEV sold and to estimate the number of credits that would be required for compliance in the first year of the ZEV standard.



For each of these five initial credit bank mechanisms, the MPCA again estimated how much of manufacturers' compliance burden could be satisfied with the initial bank in the initial year(s) of the ZEV standard. Using the ZEV Compliance Calculator, we estimate that manufacturers would need 50,760 credits for compliance in the first year. In the second model year, we estimate that manufacturers would need 51,293 credits. The MPCA again considered how many years' worth of compliance manufacturers might be able to cover using the credits accumulated through each initial ZEV credit bank mechanism, without taking into account credits that would be accrued through BEV and PHEV sales during the initial implementation years. This analysis is summarized in Table 64.

Table 64: Estimated ZEV compliance requirements that could be satisfied with initial credit bank in a possible COVID-19 economic slowdown

	Early action	Early action with multipliers	Early action plus look back	Early action plus 0.5-yr initial buffer	Early action plus 1-yr initial buffer	Early action plus 2-yr initial buffer	Proportional CA balance transfer
Projected credits in initial bank	52,646	78,969	74,952	78,026	103,406	154,699	200,000 - 300,000
Years of ZEV compliance that could be satisfied	All of first year plus 4% of second	All of first year plus 55% of second	All of first year plus 47% of second	All of first year plus 53% of second	First two years plus 3% of third	First three years plus 2% of fourth	Four to five years

This table presents the estimated size of the initial ZEV credit bank for each mechanism that the MPCA analyzed along with the number of years of ZEV standard compliance that could potentially be satisfied with the initial credit bank, using low economic growth assumptions for projected LDV, BEV, and PHEV sales. Again, this does not take into account ZEV credits that would be accrued in the initial year(s) of standard implementation.

Comparing Tables 62 and 64, shows that an economic slowdown will likely not significantly interfere with manufacturers' ability to establish initial ZEV credit banks. In an economic slowdown, depressed EV sales may mean that manufacturers accrue fewer early action ZEV credits; however, due to depressed LDV sales, fewer ZEV credits are needed for compliance in the early years of the rule. In combination, these two factors seem to have minimal effects on the value of initial ZEV credit banks.

Comparison of initial ZEV credit bank mechanisms over a longer time frame

The two primary goals for establishing an initial ZEV credit bank are to incentivize EV sales in Minnesota as soon as possible and to provide manufacturers reasonable mechanisms for compliance flexibility, especially in the initial years of implementation. Addressing these two goals requires a balanced approach. A mechanism that results in too many initial ZEV credits may lead to a situation where manufacturers do not need to increase EV deliveries in order to comply with the ZEV standard, which would undermine the first goal. On the other hand, a mechanism that results in too few initial ZEV credits could lead to a situation where manufacturers struggle to achieve the requirements of the standard.

The MPCA analyzed the potential effect of each mechanism for establishing an initial credit bank on the compliance obligations for manufacturers. To analyze how initial credit banks would provide compliance flexibility, it is necessary to project both EV sales further into the future and the number of ZEV credits that manufacturers would need to comply with the standard. For each of the mechanisms, the MPCA estimated the accrual of credits for each model year as well as the number of credits that would be needed to comply with the ZEV standard, assuming four different future business-as-usual EV sales projections: linear sales growth, quadratic sales growth, growth according to EIA 2020 AEO Reference case projections for the West North Central region, and depressed EV and LDV sales due to the COVID-19 economic slowdown. The Economic Slowdown scenario includes both lower EV sales (and thus lower ZEV credits earnings) than the linear but also lower ZEV compliance requirements due to lower overall LDV sales. Combining these estimates, we have added estimated accrued credits and deducted estimated compliance credits for each model year to estimate the end-of-model-year ZEV credit balances. This analysis is summarized in Table 65. In the table, year-end credit surpluses are colored blue, while year-end credit deficits, or credit gaps, are colored orange. Again, the EV sales projections are for business as usual and do not account for increased EV sales resulting from the adoption of the ZEV standard and the initial credit bank mechanism. Therefore, a deficit in this analysis indicates that vehicle manufacturers will need to increase EV deliveries to Minnesota beyond business-as-usual in

order to comply with the standard. Since the ZEV standard is intended to require manufacturers to increase EV deliveries to Minnesota, it is reasonable to use a mechanism for establishing an initial credit bank that shows deficits in this analysis. Mechanisms that show surpluses in all years would not require manufacturers to increase deliveries beyond business as usual.

Table 65: Projected ZEV credits balance at end of model year across different mechanisms for establishing an initial ZEV credit bank and EV sales growth projections

Early action scheme and projected EV sales growth	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032	MY 2033	MY 2034
Early action credits only													
Linear sales growth	16,071	35,714	57,758	27,476	(390)	(25,708)	(48,329)	(68,071)	(84,699)	(97,953)	(107,567)	(113,444)	(115,850)
EIA 2020 projected sales growth	25,732	53,740	83,918	61,993	41,454	22,180	4,401	(11,483)	(25,202)	(35,838)	(42,267)	(42,892)	(36,146)
Quadratic sales growth	33,463	80,525	135,445	144,133	162,149	190,439	229,969	281,737	346,795	426,219	521,091	632,323	760,468
Economic slowdown	14,184	32,463	52,646	24,348	(2,484)	(27,674)	(50,334)	(70,488)	(87,545)	(101,157)	(111,113)	(117,051)	(119,837)
Early action plus 0.5-year credit allotment													
Linear sales growth	16,071	35,714	85,111	54,829	26,963	1,646	(20,976)	(40,717)	(57,346)	(70,600)	(80,213)	(86,091)	(88,496)
EIA 2020 projected sales growth	25,732	53,740	111,271	89,346	68,807	49,533	31,754	15,870	2,151	(8,485)	(14,913)	(15,539)	(8,793)
Quadratic sales growth	33,463	80,525	162,798	171,486	189,502	217,792	257,322	309,090	374,148	453,572	548,444	659,676	787,821
Economic slowdown	14,184	32,463	78,026	49,728	22,897	(2,294)	(24,954)	(45,107)	(62,165)	(75,777)	(85,733)	(91,671)	(94,457)
Early action plus 1-year credit allotment													
Linear sales growth	16,071	35,714	112,465	82,182	54,316	28,999	6,377	(13,364)	(29,993)	(43,247)	(52,860)	(58,738)	(61,143)
EIA 2020 projected sales growth	25,732	53,740	138,624	116,699	96,160	76,886	59,108	43,223	29,504	18,868	12,440	11,814	18,561
Quadratic sales growth	33,463	80,525	190,152	198,839	216,855	245,145	284,675	336,444	401,501	480,925	575,797	687,029	815,174

Early action scheme and projected EV sales growth	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032	MY 2033	MY 2034
Economic slowdown	14,184	32,463	103,406	75,108	48,277	23,086	427	(19,727)	(36,784)	(50,397)	(60,353)	(66,291)	(69,077)
Early action plus 2-year credit allotment													
Linear sales growth	16,071	35,714	167,133	136,851	108,985	83,668	61,046	41,305	24,676	11,422	1,809	(4,069)	(6,474)
EIA 2020 projected sales growth	25,732	53,740	193,293	171,368	150,829	131,555	113,776	97,892	84,173	73,537	67,109	66,483	73,229
Quadratic sales growth	33,463	80,525	244,820	253,508	271,524	299,814	339,344	391,113	456,170	535,594	630,466	741,698	869,843
Economic slowdown	14,184	32,463	154,699	126,401	99,570	74,379	51,720	31,566	14,509	896	(9,060)	(14,998)	(17,784)
Early action plus lookback credits													
Linear sales growth	40,048	59,691	81,735	51,453	23,587	(1,731)	(24,352)	(44,094)	(60,722)	(73,976)	(83,590)	(89,467)	(91,873)
EIA 2020 projected sales growth	67,626	95,634	125,812	103,887	83,348	64,074	46,295	30,411	16,692	6,056	(373)	(998)	5,748
Quadratic sales growth	81,543	128,605	183,525	192,213	210,229	238,519	278,049	329,817	394,875	474,299	569,171	680,403	808,548
Economic slowdown	36,490	54,770	74,952	46,655	19,823	(5,367)	(28,027)	(48,181)	(65,238)	(78,850)	(88,807)	(94,744)	(97,530)
Early action with multipliers													
Linear sales growth	24,107	53,571	86,637	56,355	28,489	3,171	(19,450)	(39,192)	(55,820)	(69,074)	(78,688)	(84,565)	(86,970)
EIA 2020 projected sales growth	38,597	80,610	125,876	103,952	83,412	64,139	46,360	30,476	16,757	6,120	(308)	(933)	5,813
Quadratic sales growth	50,194	120,787	203,168	211,856	229,871	258,161	297,691	349,460	414,517	493,941	588,813	700,045	828,190
Economic slowdown	21,275	48,695	78,969	50,671	23,839	(1,351)	(24,011)	(44,165)	(61,222)	(74,834)	(84,790)	(90,728)	(93,514)

Early action scheme and projected EV sales growth	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032	MY 2033	MY 2034
Proportional CA bank credits													
Linear sales growth	-	-	250,000	219,717	191,852	166,534	143,913	124,171	107,543	94,289	84,675	78,797	76,392
EIA 2020 projected sales growth	-	-	250,000	228,075	207,536	188,262	170,484	154,599	140,880	130,244	123,816	123,190	129,937
Quadratic sales growth	-	-	250,000	258,688	276,703	304,994	344,524	396,292	461,350	540,773	635,645	746,878	875,023
Economic slowdown	-	-	225,000	196,702	169,871	144,680	122,021	101,867	84,810	71,197	61,241	55,303	52,517

Based on different mechanisms for establishing an initial ZEV credit bank and different EV sales growth projections, the MPCA estimates the total Minnesota ZEV credit balance at the end of each model year for the early action years and first 10 years of ZEV standard implementation. Positive numbers (shaded blue) are year-end credit surpluses while negative numbers (shaded orange) are year-end credit deficits or gaps. The EV sales projects are for business as usual sales and do not take into account potential increased EV sales resulting from the adoption of the ZEV standard and mechanism for establishing the initial credit bank. Therefore, deficit in this analysis indicates vehicle manufacturers will need to increase EV deliveries beyond business-as-usual in order to comply with the standard.

Table 65 shows that maintaining positive ZEV credit balances once the ZEV standard is implemented depends primarily on future EV sales and secondarily on the mechanism for establishing the initial credit bank. Since the purpose of the ZEV standard and the mechanism for establishing the initial ZEV credit bank is to increase deliveries of EVs to Minnesota, it is reasonable to expect sales will be higher than the linear, business-as-usual EV sales projections.