State Greenhouse Gas Technical Report - I-270 Corridor Improvements Project

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Authorship Attribution Statement

Sonoma Technology conducted the Motor Vehicle Emissions Simulator (MOVES) and Infrastructure Carbon Estimator (ICE) modeling of greenhouse gases (GHGs) and calculated the lifetime GHG emissions and social cost of carbon (SCC) for the I-270 Corridor Improvements Project (the Project). Sonoma Technology authored Section 1.2 and documented the modeling and technical analysis of GHGs and SCC for the Project in Sections 5 through 8 and Appendices A and B of this report. All other sections of the report were authored by specialists in the CDOT Air and Climate Section.

Contents

Acronyms and Abbreviations

Acronym	Definition
2GPL+1EL	Two General-Purpose Lanes and One Express Lane That Accommodates Transit
3GPL	Three General-Purpose Lanes
%	percent
°F	degree(s) Fahrenheit
AADT	average annual daily traffic
APCD	Air Pollution Control Division
AVFT	Alternate Vehicle Fuel and Technology
CRS	Colorado Revised Statutes
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Department of Public Safety
CH_4	methane
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
CSA	Community Study Area
DI Communities	Disproportionately Impacted Communities
DRCOG	Denver Regional Council of Governments
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAQ	Frequently Asked Question
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GHG	greenhouse gas
GWP	global warming potential
HB	House Bill
HFC	hydrofluorocarbon
I-25	Interstate 25
I-270	Interstate 270
I-70	Interstate 70
I-76	Interstate 76
ICE	Infrastructure Carbon Estimator
I/M	inspection and maintenance
LOS	level of service
MMT	million metric tons
mph	mile(s) per hour
MOVES	Motor Vehicle Emissions Simulator
MPO	metropolitan planning organization

Acronym	Definition
MSAT	mobile source air toxic
MT	metric tons
NEPA	National Environmental Policy Act
NETC	Northeast Transportation Connections
N_2O	nitrous oxide
PM	particulate matter
RS	regionally significant
RTD	Regional Transportation District
RTP	Regional Transportation Plan
RunSpecs	run specifications
SCC	Social Cost of Carbon
TC	transportation capacity
TDM	Travel Demand Model
U.S.	United States
US 36	U.S. Highway 36
VMT	vehicle miles traveled

1.0 Introduction

The Federal Highway Administration (FHWA) and Colorado Department of Transportation (CDOT) are preparing an Environmental Impact Statement (EIS) to evaluate potential improvements to the Interstate 270 (I-270) corridor (I-270 Corridor Improvements Project, or the Project). FHWA and CDOT are the lead agencies for the National Environmental Policy Act (NEPA) process, which was initiated in 2020 and anticipated as an Environmental Assessment. Moving into 2023, CDOT determined that a more detailed environmental review was needed and requested that an EIS be prepared.

This technical report documents the greenhouse gas (GHG) analysis that was conducted to meet state regulatory requirements. GHGs are a class of pollutants that contribute to global warming and climate change. Transportation-sector GHGs include, primarily, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons. Each of these GHGs has a different global warming potential (GWP), which is a measure of how much energy a GHG absorbs in a given time period relative to that of CO_2. For example, in terms of its capacity to absorb energy, the emission of one ton of CH_4 is equivalent to the emission of 25 tons of CO_2 (based on the 100-year GWP of CH_4 used in this analysis). CO_2 is the most prevalent anthropogenic GHG and accounts for 96 percent (%) of transportation GHG emissions in the United States (U.S.). All transportation-sector GHGs are often quantified together as CO_2 equivalent (CO_2e) to standardize their global warming effect.

GHG emissions are produced from construction and maintenance of transportation projects and operation of vehicles on project roadways. Construction of transportation projects results in GHG emissions from the operation of construction equipment, worker travel, materials transport and embodied carbon materials. Maintenance of transportation facilities results in GHG emissions from use of fuel for snow removal, vegetation management, and other routine maintenance practices (CDOT 2024).

1.1 Project Background

I-270 in Colorado is a controlled-access interstate highway with two through lanes in each direction between Interstate 25 (I-25)/US Highway 36 (US 36) and Interstate 70 (I-70) in central Denver and Commerce City (Figure 1). It has a posted speed limit of 55 miles per hour (mph). The Project limits include the I-270 interchanges with Interstate 76 (I-76), York Street, Vasquez Boulevard, and Quebec Street. The Project would tie into the I-25/US 36 and I-70 system interchanges but improvements to these interchanges are part of projects on I-25 and I-70 and will be designed and approved separately.

The purpose of the I-270 Corridor Improvements project is to implement transportation solutions that modernize the I-270 corridor to accommodate existing and forecasted transportation demands. The Project needs are:

- Traveler safety on the corridor
- Travel time and reliability on the corridor
- Transit on the corridor
- Bicycle and pedestrian connectivity across I-270
- Freight operations on the corridor

In addition to addressing Project needs, CDOT, FHWA, and Cooperating and Participating Agencies established a key project goal: to minimize environmental and community impacts resulting from the Project.

Figure 1. I-270 Corridor Improvements Project Limits

1.2 Report Overview

The key GHG analyses documented in this report include estimates of the lifetime direct and indirect vehicle emissions associated with the Project, including the construction and ongoing maintenance emissions, and the Social Cost of Carbon (SCC). This report describes the methods used to estimate GHG emissions and calculate the SCC, potential impacts to GHGs and considerations of GHG commitments, resilience, and community impacts. This report was written by Sonoma Technology and staff in the CDOT Air and Climate Section: Sonoma Technology conducted and documented the modeling and technical analysis of GHG emissions; and specialists in the CDOT Air and Climate Section developed and documented the discussion of travel demand modeling, the affected environment, effects of the modeled GHG emissions and related projects, GHG commitments and other considerations, and conclusions about the analysis.

2.0 Alternatives

CDOT developed a range of potential alternatives for I-270 improvements. The alternatives ranged from no improvements to minimal infrastructure improvements without added highway capacity to alternatives that added one or two travel lanes in each direction, which could be operated as transit, general-purpose, or Express Lanes.

A two-level alternatives evaluation process was used to screen the alternatives based on the Project's purpose and need and goal, and two build alternatives were carried forward for detailed analysis in the EIS:

- Three General-Purpose Lanes Alternative (3GPL Alternative)
- Two General-Purpose Lanes and One Express Lane that Accommodates Transit Alternative (2GPL+1EL Alternative)

The No Action Alternative is also fully evaluated as a baseline for comparison.

Additional information on the alternatives development and evaluation process for the build alternatives is included in the *I-270 Corridor Improvements Environmental Impact Statement Alternatives Development Technical Report* (CDOT 2025a).

2.1 No Action Alternative

The No Action Alternative evaluates operations of I-270 if a build alternative would not occur along the corridor. It does not address the Project purpose and need but is carried forward as a baseline for comparison. This alternative would maintain the existing highway configuration of two general-purpose travel lanes in each direction. Bridges and pavement would be maintained and repaired continuously, but underlying infrastructure deficiencies would remain.

The No Action Alternative would include substantial ongoing maintenance and the rehabilitation of 19 existing structures, including seven locations that have structures that are at or will be reaching the end of their useful life. The age of the structure, recent bridge inspections, and current ongoing maintenance costs, both planned and emergency maintenance, determine if a structure is or will be reaching the end of its useful life. The seven structure locations (CDOT structure numbers in parentheses) along the I-270 corridor that are at or will be reaching the end of their useful life are as follows:

- Vasquez Bridge over Sand Creek (E-17-AT)
- York Street Bridge over I-270 (E-17-IC)
- I-270 over South Platte River Eastbound and Westbound Bridges (E-17-IE & E-17-ID)
- I-270 over Burlington Ditch Eastbound and Westbound Bridges (E-17-IG & I-17-IF)
- I-270 over Brighton Boulevard, Union Pacific Railroad (UPRR) and BNSF Railway (BNSF) Eastbound and Westbound Bridges (E-17-II & E-17-IH)
- I-270 over 60th Avenue & BNSF Eastbound and Westbound Bridges (E-17-IK & E-17-IJ)
- I-270 over East 56th Avenue Eastbound and Westbound (E-17-IO & E-17-IN)

The cross section would remain unchanged along I-270 under the No Action Alternative. The No Action Alternative cross sections are shown on Figure 2 and Figure 3.

Figure 2. No Action Alternative (west of Vasquez Boulevard)

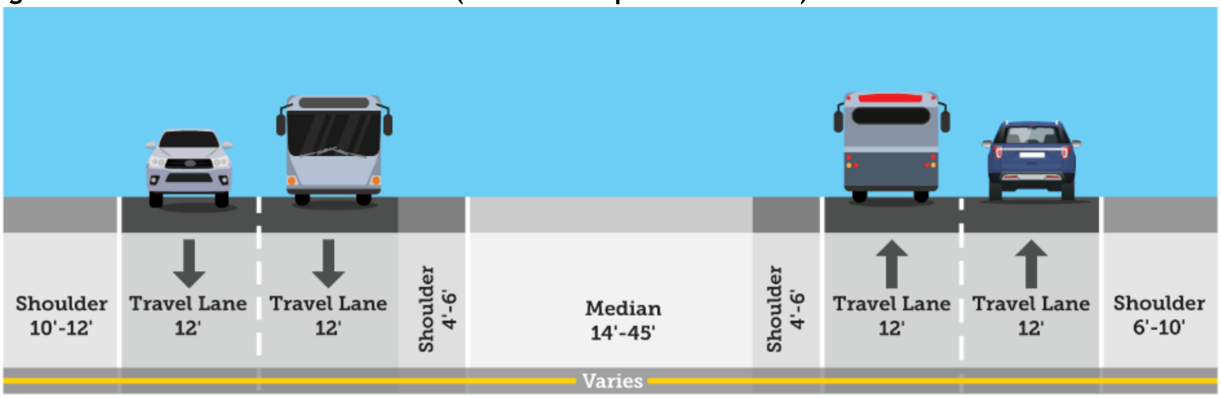
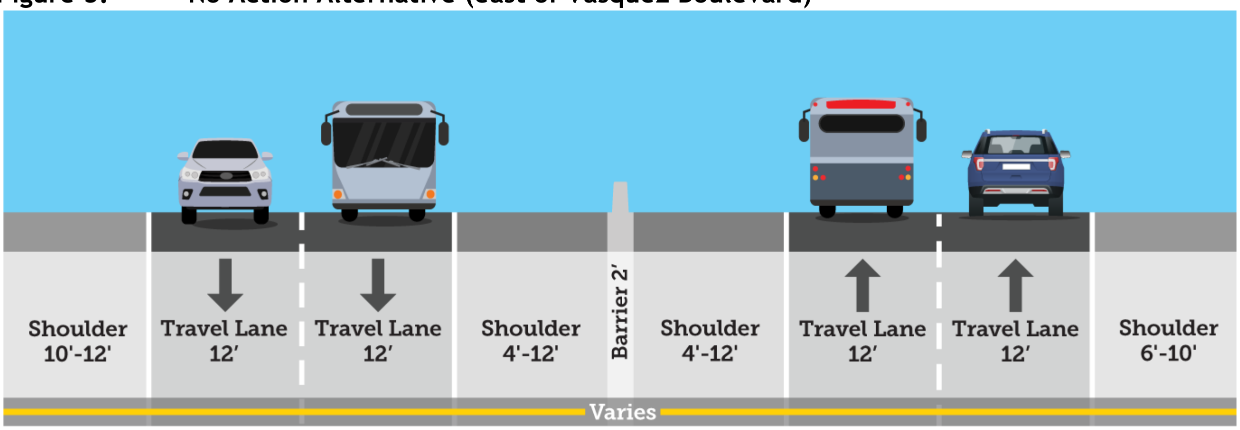


Figure 3. No Action Alternative (east of Vasquez Boulevard)



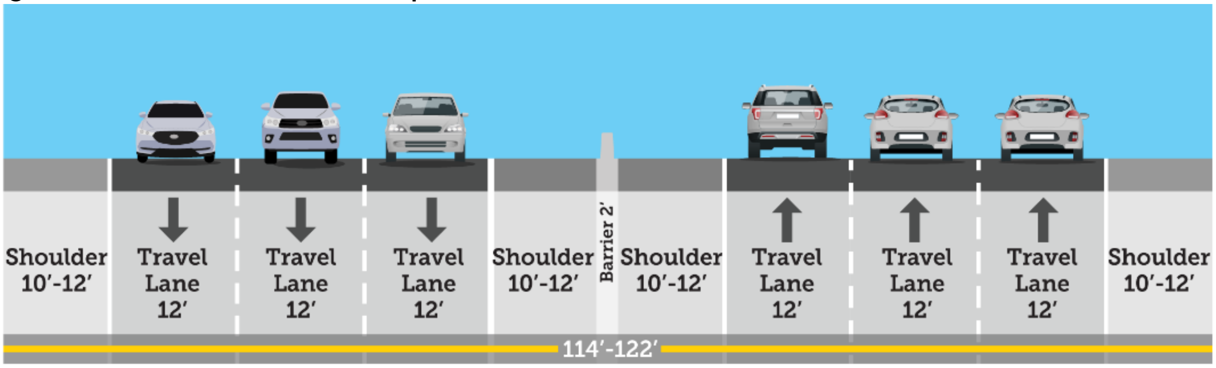
2.2 Build Alternatives

The build alternatives include improving the operational and physical conditions of the I-270 highway; reconfiguring interchanges and ramps; enhancing transit on the corridor; improving bicycle and pedestrian access across I-270; replacing deficient bridges and other infrastructure; and providing modern drainage, water quality, intelligent transportation systems, and other supporting infrastructure. Both add one new travel lane in each direction and have similar footprints, varying primarily how the additional travel operates.

2.2.1 Three General-Purpose Lanes Alternative

This alternative would reconstruct I-270 to provide three general-purpose lanes in each direction as shown in Figure 4.

Figure 4. Three General-Purpose Lanes Alternative



This alternative includes:

Mainline Improvements

- Providing three general-purpose lanes in each direction
- Widening shoulders to meet current standards
- Restriping of the westbound I-270 to northbound I-25 off-ramp to provide dual-exit lane capacity
- Adding emergency turnouts and turnaround
- Adding one continuous auxiliary lane in each direction between the I-76 and Vasquez Boulevard on-ramps and off-ramps

Interchange Improvements

- Adding an eastbound collector ramp to consolidate incoming movements from the I-76 on-ramps
- Separating the westbound I-270 York Street and I-76 off-ramps
- Improving the Vasquez Boulevard interchange design with improved westbound on-ramp acceleration lanes and the eastbound off-ramp deceleration lanes
- Improving the Quebec Street interchange ramp acceleration and deceleration lengths

Bridge Improvements

- Reconstructing bridges that are at, or will be reaching, the end of their useful life. Bridges carrying travel lanes on I-270 include widening to accommodate additional lanes
    - Replacing the existing York Street bridge over I-270 to meet current bridge standards, accommodate an additional travel lane in each direction on York Street, include a 10-foot multi-use path and a 5-foot sidewalk, and enhance lighting
    - Replacing the existing I-270 bridges over the South Platte River Trail to meet current bridge standards, accommodate this project's bicycle and pedestrian improvements on the South Platte River Trail, and enhance lighting
    - Replacing the existing I-270 bridges over the Burlington Ditch to meet current bridge standards, accommodate future bicycle and pedestrian improvements, and enhance lighting

- Replacing the existing I-270 bridges over Brighton Boulevard to meet current bridge standards, accommodate this project's bicycle and pedestrian improvements on Brighton Boulevard and future bicycle and pedestrian improvements by others, and enhance lighting
- Replacing the existing I-270 bridges over East 60th Avenue and the BNSF crossing to meet current bridge standards, accommodate future bicycle and pedestrian improvements, and enhance lighting
- Replacing the existing I-270 bridges over East 56th Avenue to meet current bridge standards, accommodate this project's bicycle and pedestrian improvements, and enhance lighting
- Replacing the existing Vasquez Boulevard bridge over Sand Creek to meet current bridge standards and accommodate this project's bicycle and pedestrian improvements

Bicycle and Pedestrian Improvements

- Improving the York Street I-270 ramp terminal intersections with crosswalks, curb ramps, and pedestrian indicators at the ramp terminal traffic signals
- Adding a new 5-foot sidewalk on the west side and reconstructing a 6-foot sidewalk on the east side of Brighton Boulevard under I-270
- Reconstructing East 56th Avenue under I-270 and adding an on-street bicycle lane, a 10-foot multi-use path, and 6-foot sidewalk connecting to existing sidewalks
- Improving the intersection at East 56th Avenue and South Sandcreek Drive to include curb ramps, crosswalks, and lighting that meet current standards
- Improving the intersection at East 56th Avenue and Eudora Street to include curb ramps, crosswalks, and lighting that meet current standards
- Adding attached sidewalks on the west side of South Sandcreek Drive. The new sidewalks would be 8 feet wide from Quebec Street to East 47th Avenue Drive and 6 feet wide from East 47th Avenue Drive to East 49th Avenue, with a pedestrian crosswalk across East 47th Avenue Drive connecting the two segments
- Improving wayfinding at key locations, guiding bicyclists and pedestrians to the nearest Regional Transportation District (RTD) bus stops, major road connections, or distances to the next trailhead to avoid out-of-direction travel

Trail Improvements

- Reconfiguring the South Platte River Trail crossing under I-270 to improve bicycle and pedestrian visibility around tight curves and increase vertical clearance from the I-270 overpass
- Improving bicycle and pedestrian visibility on the Sand Creek Trail by straightening out tight curves, adding a center stripe, and enhancing lighting at the Vasquez Boulevard bridge over the Sand Creek Trail
- Adding a multi-use path with bicycle and pedestrian underpasses crossing under two free-flow interchange ramps on the east side of Vasquez Boulevard through the interchange with enhanced lighting

- Adding a multi-use path on the east and west sides of the Vasquez Boulevard bridge over Sand Creek, connecting users from the East 56th Avenue and Vasquez Boulevard intersection to a new connection to the Sand Creek Trail
- Adding a multi-use trail spur, connecting the proposed north-south Vasquez Boulevard multi-use trail to the East 56th Avenue and South Sandcreek Drive intersection
- Adding a multi-use path in the southeast corner of East 56th Avenue and South Sandcreek Drive
- Adding a 10-foot-wide bicycle and pedestrian overpass over I-270 and South Sandcreek Drive approximately halfway between East 56th Avenue and Quebec Street

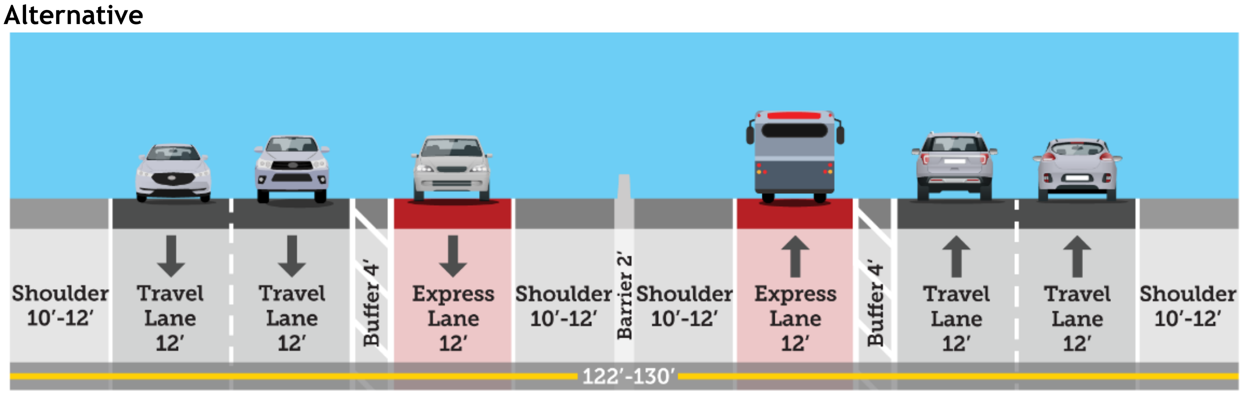
Transit Improvements

- Adding four new bus stops with connecting sidewalks and curb ramps on Quebec Street and South Sandcreek Drive near the I-270/Quebec Street interchange to improve access to RTD routes 88 and 37

2.2.2 Two General-Purpose Lanes and One Express Lane that Accommodates Transit Alternative

This alternative would reconstruct I-270 with two general-purpose lanes and one Express Lane in each direction as shown in Figure 5. Transit vehicles and high-occupancy vehicles (three or more people) could travel in the Express Lane free of charge. Other travelers, including freight trucks, who choose to pay a toll could also use the new Express Lane.

Figure 5. Two General-Purpose Lanes and One Express Lane that Accommodates Transit Alternative



This alternative includes:

Mainline Improvements

- Providing two general-purpose lanes and one Express Lane that accommodates transit in each direction
- Remainder of mainline improvements identified in the 3GPL Alternative

Interchange Improvements

This alternative includes the same interchange improvements identified in the 3GPL Alternative.

Bridge Improvements

This alternative includes the same bridge improvements identified in the 3GPL Alternative.

Bicycle, Pedestrian, Trail, and Transit Improvements

This alternative includes the same bicycle, pedestrian, trail, and transit enhancements identified in the 3GPL Alternative.

3.0 Regulatory Environment

State transportation GHG regulations include CDOT's GHG Transportation Planning Standard, issued by Colorado's Transportation Commission on December 16, 2021. Under this regulation, CDOT and the state's five Metropolitan Planning Organizations (MPOs) are required to achieve individually set GHG reduction levels at four time horizons: 2025, 2030, 2040, and 2050. To determine compliance with these reduction levels, agencies must model their existing transportation networks and all future Regionally Significant (RS) projects in their transportation planning documents using travel demand models (TDMs) and the U.S. Environmental Protection Agency (EPA) Motor Vehicle Emission Simulator (MOVES) model. Overall, the regulation encourages CDOT and MPOs to develop long range transportation plans that support travel choices that reduce GHG emissions.

The other key state transportation GHG regulation is Colorado Revised Statutes (CRS) 43-1-128 Section 4(a), which requires planned RS/Transportation Capacity (TC) projects to "(u)se Environmental Protection Agency Approved Models to determine air pollutant emissions for the planned project". An RS/TC project in the Denver Regional Council of Governments' (DRCOG) Regional Transportation Plan (RTP) is one that is already included in their comprehensive regional GHG analysis as part of the requirements for the GHG Transportation Planning Standard. However, the planning level analysis does not address the need to model emissions at the project level for NEPA to comply with CRS 43-1-128(4)(a). The I-270 Corridor Improvements project meets CDOT's established definition of an RS/TC project (CDOT 2022a), thus the quantitative analysis documented in this report was specifically conducted to meet the requirements of state law.

4.0 Affected Environment

GHGs are a class of gases that contribute to the planet's greenhouse effect, whereby gases in the atmosphere absorb and trap infrared radiation and heat from the sun. The primary GHGs are CO_2, CH_4, N_2O, fluorinated gases, and water vapor. There is unequivocal scientific evidence that over the last few centuries, the concentration of GHGs is increasing in the atmosphere (Cubash et. al. 2013). This increase in the concentration of atmospheric GHGs is increasing the amount of heat trapped in Earth's atmosphere, a phenomenon known as global warming. This observed increase in the concentration of GHG emissions is predominantly attributed to human activities, primarily fossil fuel use, land use changes, and agriculture (Cubash et. al. 2013).

This increased concentration of GHGs in the atmosphere and the subsequent warming of the planet is creating long-term shifts in the weather patterns that have come to define local, regional, and global areas - a phenomenon coined as climate change. Climate change will have copious detrimental environmental and societal consequences. Notably, GHGs mix evenly in the atmosphere, so the climate consequences for a geographic region are not directly attributed to the emissions that occur from that region.

CO_2 is the most predominant GHG, accounting for about 76% of global GHG emissions (Cubash et. al. 2013). Each GHG pollutant has a different GWP, a measure of how much heat one ton of gas can absorb over a given time frame. Further, each GHG has a different lifetime in the atmosphere. CO_2 has a lifetime of anywhere from 300 to 1,000 years (National Aeronautics and Space Administration 2019), CH_4 for 12.4 years, and N_2O for 121 years (Victor D.G. et. al. 2014). For ease of understanding, GHGs are often measured together as CO_2e, standardizing the warming effects of each gas relative to the most prevalent anthropogenic GHG, CO_2. For example, one ton of CH_4 is equivalent to 25 tons of CO_2 because it has a GWP 25 times greater than CO_2 based on the 100-year GWP (EPA 2024a).

4.1 GHGs and Transportation

GHG emissions from transportation sources include CO_2, CH_4, N_2O, and various hydrofluorocarbons (HFCs). CO_2, CH_4, and N_2O are all emitted through the combustion of fossil fuels, while HFC emissions are the result of leaks and end-of-life disposal from air conditioners used to cool people or freight (EPA 2024b). In the US, CO_2 accounts for 97.3% of the share of GHG emissions within the transportation sector. Thus, all transportation-sector GHGs are often measured together as CO_2e, standardizing the warming effects of each gas relative to the most prevalent anthropogenic GHG, CO_2. GHG emissions resulting from transportation projects have three sources: operational, construction, and maintenance.

Traditional transportation emissions analysis has only considered localized impacts of short-lived pollutants, e.g., hot-spot analysis in nonattainment or maintenance areas for criteria pollutants or air toxics analysis for populated areas. GHG impacts, unlike criteria pollutants and air toxics, are based on cumulative emissions, i.e., construction, operation, and maintenance emissions all have the same impact. Regardless of where they occur, emissions of GHGs impact atmospheric concentrations.

In Colorado, transportation sector emissions were the second largest source of GHG emissions in 2020, accounting for approximately 19.4% of Colorado's total GHG inventory, totaling 25.083 million metric tons (MMT) CO_2e (Colorado Department of Public Health and Environment [CDPHE] Air Pollution Control Division [APCD] 2023). In 2020, the electricity sector was the largest source of GHG emissions in the state. Notably, 2020 reflects travel behavior during the COVID-19 pandemic, when vehicle miles traveled (VMT) and resultant tailpipe emissions demonstrated a significant decrease. In the near future, it is expected that GHG inventories will show that transportation has become the largest source of GHG emissions in the state as the power grid increasingly transitions to clean energy and travel behavior returns to pre-pandemic conditions. Light duty vehicles, including passenger cars, light trucks, pickup trucks, vans, and sport utility vehicles, are the largest source of emissions within Colorado's transportation sector (CDPHE APCD 2021).

4.2 Factors that Affect Transportation GHGs

4.2.1 Operational

Operational GHG emissions result from vehicle travel on a transportation infrastructure project, such as the vehicles driving on the road or the trains on a track. According to the 2021 Colorado GHG Inventory, on-road transport accounted for 82% of transportation operational emissions in the state, which constitutes both passenger and freight travel. Notably, the operation of light-duty passenger vehicles is the largest contributor to transportation sector emissions. Off-road transport accounts for the other 18%, including aviation and rail (CDPHE APCD 2021).

Operational GHG emissions from CDOT projects are the motor vehicle tailpipe emissions increases or decreases that typically result from changes in vehicle speed related to congestion and added or avoided vehicle travel on the transportation network. Operational emissions are the largest share of transportation sector GHGs.

4.2.2 Construction

Construction GHG emissions are the result of construction processes such as the operation of construction equipment, the transportation emissions associated with fuel used to transport construction materials, and the embodied carbon resulting from the production of construction materials.

4.2.3 Maintenance

Maintenance GHG emissions result from the fuels used to maintain transportation facilities, such as snow removal, vegetation management, and other routine maintenance practices.

4.3 Trends in Transportation Emissions of GHGs

The *2023 Colorado Greenhouse Gas Inventory of Greenhouse Gas Emissions and Sinks* (CDPHE APCD 2024) provides the latest data by which to compare historical emission data trends with the state's GHG reduction targets. The 2023 inventory shows that transportation GHG emissions have decreased steadily between 2005 and 2020 (see Table 1), the latest year for which historic emissions have been analyzed. There was a significant drop between 2015 and 2020, due in large part to the Coronavirus Disease 2019 (COVID-19) pandemic. The 2023 inventory projects that transportation emissions will show slight increases between 2020 and

2025 and decreasing thereafter. The next statewide GHG inventory analysis, including transportation sector emissions, is anticipated to be published by APCD in December 2025.

Table 1. Colorado Transportation Emissions (MMT CO2e)

2005 Transportation Emissions	2010 Transportation Emissions	2015 Transportation Emissions	2020 Transportation Emissions
29.138	28.210	27.453	25.038

4.4 Climate Change Effects in Colorado

Colorado's climate is changing. The state has warmed 2.5 degrees Fahrenheit (°F) since the beginning of the 20th century, and temperatures have remained consistently higher than the long-term (1895-2020) average since 1998 (Frankson et. al. 2022). Future estimates predict an additional 2.5 °F to 5°F of warming in Colorado by 2050 (Colorado Water Conservation Board n.d.). Six of the eight warmest years on record for Colorado have occurred since 2012 (Frankson et. al. 2022). These changes to Colorado's climate from warming are causing increases in extreme temperatures, droughts, wildfires, and more frequent and severe floods.

While a natural part of Colorado's climate, the intensity of droughts has increased within the state. There are many river basins that originate in the state, and any changes in precipitation patterns pose enormous risks to water supplies for cities and farms across the region. Colorado has nearly constantly been in a drought since 2001, with three historic droughts occurring in 2002, 2012, and 2018 (Frankson et. al. 2022).

Higher temperatures and drought have increased the frequency, severity, and extent of wildfires. The 20 largest wildfires in Colorado history have all occurred in the last 20 years (Colorado Department of Public Safety [CDPS] n.d.). Before 2002, Colorado had never recorded a fire that burned more than 100,000 acres. By 2021, the state has experienced five such fires, four of which occurred after 2018 (CDPS n.d.). Colorado's five most destructive fires by homes lost have all occurred since 2012 (CDPS n.d.). With the exception of California, Colorado has the highest concentration of at-risk homes (332,716) and significant estimated reconstruction costs ($140.9 billion) (Corelogic 2023).

Emissions from transportation, when combined with ever hotter temperatures and summer days, are affecting Colorado's air quality, particularly in urban areas with high traffic volume. In addition to GHGs, many other air pollutants are also emitted from transportation. Pollutants emitted from vehicles, including particulate matter (PM), volatile organic compounds, and nitrogen oxides, have direct impacts on the health of Coloradans, with those who live closest to our busiest roads, often economically disadvantaged and minority populations (Boehmer et. al. 2013). Living in an area with high levels of air pollution is directly linked to higher rates of asthma, pulmonary disease, cardiovascular disease, reproductive complications, and mortality (Boehmer et. al. 2013). Reductions in GHG emissions from transportation also reduce many emissions of these other air pollutants that may lead to additional benefits to public health and the environment.

4.5 Climate Change Effects on Colorado's Transportation System

Colorado's transportation system is designed to withstand certain climate and weather-related stressors based on historical weather and climate conditions. However, climate change is creating long-term shifts in the weather patterns that have previously defined local, regional, and global areas, causing increased risk to Colorado's transportation infrastructure. It is critical to consider how future changes in climate will impact Colorado's existing and future planned transportation infrastructure and respond, design, and mitigate appropriately.

The following table was created with reports developed by the University of Colorado's Western Water Assessment program, in collaboration with the Colorado Water Conservation Board, which develops state-specific climate change information of both observed and anticipated changes to Colorado's climate (Bolinger et. al. 2024; Colorado Department of Agriculture et. al. 2015).

Table 2. Climate Change Impacts on Transportation Infrastructure

Projected Climate Change Effects	Potential Impacts on State Highways and Rail
Temperature Effects Higher average temperatures Increase in the intensity and duration of extreme heat events Drought and low stream and groundwater flow Substantially worsened wildfire risk	Increased thermal expansion of bridge joints and paved surfaces, which can cause buckling and degradation Impacts to roadway pavement integrity, increases in traffic-related rutting and migration of liquid asphalt, and greater need for maintenance Stress on bridge integrity due to temperature expansion of concrete joins, steel, asphalt, protective cladding, coats, and sealants High temperatures can force rails out of alignment, cause rail equipment to fail, and increase the risk of derailment Wetland mitigation site failure Increased noxious weeds, invasive plants Loss of roadside vegetation, leading to erosion and landslides, particularly in areas deforested by wildfires Increased frequency of dust storms

Precipitation Effects Increase in winter statewide precipitation Increased magnitudes of heavy and extreme precipitation events	Regional changes in snow and ice removal costs Increase in snow slides Increases in weather-related delays and traffic disruptions Increases in road washout, landslides, rock fall, and mudslides that damage roadways and affect traveler safety Drainage systems likely to be overloaded more frequently and severely Increased peak streamflow could affect scour rates and influence the size requirements for bridges and culverts

4.6 Measures Taken to Address Climate Change in Colorado

In 2019, Governor Jared Polis signed House Bill (HB) 19-1261, which set statewide GHG emission reduction targets and mandated new considerations for the Air Quality Control Commission. In 2023, Governor Polis signed Senate Bill 23-016, which updated and added additional GHG reduction targets. These targets include:

- Reduce 2025 GHG emissions by at least 26% of 2005 levels
- Reduce 2030 GHG emissions by at least 50% of 2005 levels
- Reduce 2035 GHG emissions by at least 65% of 2005 levels
- Reduce 2040 GHG emissions by at least 75% of 2005 levels
- Reduce 2045 GHG emissions by at least 90% of 2005 levels
- Achieve net zero GHG emissions by 2050

The Colorado Greenhouse Gas Pollution Reduction Roadmap (Roadmap) (Governor's Office 2024), published in early 2021 and updated in early 2024, identified distinct goals or actions for specific economic sectors to meet the GHG targets of HB 19-1261. The Roadmap reports that reducing growth in driving via transportation planning and infrastructure is a critical tool in the state's battle against climate change. The subsequent development and implementation of the GHG Transportation Planning Standard turned one of the recommendations from the Roadmap into a requirement and is a key element in Colorado's strategy for reducing emissions from the transportation sector. The GHG Transportation Planning Standard works alongside several other strategies identified in the Roadmap, including increasing Coloradans' access to electric vehicles (including trucks and buses), implementing a clean trucking strategy and fleet rules, reducing VMT, developing a Front Range Passenger Rail system, improving land use planning, and creating indirect source rules.

To address transportation construction emissions, HB 21-1303, the "Buy Clean Colorado Act", directed CDOT to establish policies to reduce GHG emissions over time by accounting for and limiting the GWP of key construction materials in state-funded building and transportation projects. The eligible construction materials include asphalt and asphalt mixtures, cement and concrete mixtures, and steel. On January 1, 2025, CDOT established a policy with GWP limits for each eligible material that will encourage manufacturers of construction projects to reduce their GHG emissions and require architects, engineers, and contractors to specify greener construction materials where those materials are practical and economically feasible.

4.6.1 CDOT GHG Reduction Targets

In December 2021, Colorado's Transportation Commission adopted the GHG Transportation Planning Standard with the goal of improving air quality, reducing smog, and providing more sustainable options for travelers across Colorado. The GHG Transportation Planning Standard (Governor's Office 2024) builds on the state's effort to rapidly deploy electric vehicles by encouraging a future transportation system that improves transit, biking and walking options. The rule focuses specifically on reducing VMT from mostly on-road passenger vehicles by increasing travel choice options.

The rule requires CDOT and the state's five MPOs to quantify the total GHG emissions expected from their updated transportation plans in 2025, 2030, 2040, and 2050 and show reductions in GHGs over time. The transportation plans must meet set GHG reduction amounts in the compliance years of 2025, 2030, 2040 and 2050 (see Table 3). These reduction levels are achieved relative to the baseline GHG emissions of the MPO's RTP or CDOT 10-Year Plan adopted as of January 2022 (CDOT 2022b). Agencies must use sophisticated travel models, alongside vehicle emissions models, to make this determination, with each emission reduction target differing for each agency and metropolitan region.

Table 3. GHG Transportation Planning Reduction Levels in MMT of CO2e

Regional Areas	2025 Reduction Level	2030 Reduction Level	2040 Reduction Level	2050 Reduction Level
DRCOG	0.27	0.82	0.63	0.37
North Front Range MPO	0.04	0.12	0.11	0.07
Pikes Peak Area Council of Governments	N/A	0.15	0.12	0.07
Grand Valley MPO	N/A	0.03	0.02	0.01
Pueblo Area Council of Governments	N/A	0.36	0.30	0.17
CDOT/Non-MPO	0.12	0.36	0.30	0.17
TOTAL	0.43	1.5	1.2	0.7

4.6.2 Local Climate Action Plans and Goals

In 2015, Adams County adopted the Sustainable Adams County 2030 Plan (Adams County 2021). While the plan does not have specific emission reduction targets for the county, the plan speaks broadly about the county's intention to support the statewide GHG targets established in HB 19-1261. However, the plan establishes goals in eight separate topic areas, including the transportation sector. Transportation sector goals include decreasing county fleet emissions through vehicle and operational efficiency and fuel switching, supporting EV mobility and infrastructure across all of Adams County, and supporting alternative modes of transportation and mobility for all Adams County residents.

In 2023, the City of Commerce City published its first Sustainability Action Plan. The plan highlights that the City of Commerce City is striving to achieve GHG reductions that align with the state level goals originally established in HB 19-1261. There are three transportation specific sustainability aspirations: support and promote equitable EV adoption, reduce idling by 20% by 2030 and 80% by 2050, and achieve a mode shift of 20% by 2030 and 50% by 2050 to multimodal options (City of Commerce City 2023).

The City and County of Denver has established specific climate goals, which include a 40% reduction in GHG emissions by 2025 from a 2019 baseline, 65% reduction by 2030, and a 100% reduction by 2040. These goals were adopted as part of the city's Climate Protection Fund Five-Year Plan (City and County of Denver 2021). The City and County of Denver has established goals to reduce driving by increasing transit, bicycling, walking, carpooling, and teleworking to 50% of workers by 2030.

5.0 Applicable Guidance

The methodology for the GHG analysis was conducted in accordance with all applicable state regulations and CDOT guidance. It was also informed by federal guidance from EPA and FHWA. The following relevant guidance was applied to the methodology for the analysis, where appropriate, as described in Section 7 and Appendix A:

- NEPA Manual, Version 7 (CDOT 2024a)
- Regionally Significant and Transportation Capacity Interpretation and Examples for CDOT Projects (CDOT 2022a)
- Interim Guidance for Project Level Compliance of CRS 43-1-128 (NEPA and Construction) DRAFT (CDOT 2023)
- Environmental Impacts of Capacity Projects–Additional Requirements–Legislative Declaration (CRS 2024)
- Air Quality Project-Level Analysis Guidance (AQ-PLAG), Version 1 (CDOT 2019)
- MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA 2023)
- MOVES Greenhouse Gas Guidance: Using MOVES for Estimating State and Local Inventories of Onroad Greenhouse Gas Emissions and Energy Consumption (EPA 2024)
- Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the

Social Cost of Methane and the Social Cost of Nitrous Oxide (Interagency Working Group on Social Cost of Greenhouse Gases [IWG SC-GHG] 2016)

6.0 Project Scoping and Interagency Consultation

6.1 Project Scoping

An environmental scoping meeting was held for the Project on September 20, 2023. FHWA, CDOT resource specialists and Project staff, and consultant team members were invited to the meeting. The meeting included the topics of Project overview and status; roles, responsibilities, and expectations; agency coordination; and a review of the environmental resources and scoping form. It was not determined that additional GHG scoping meetings were necessary at the meeting. However, it was determined that ongoing coordination was needed with CDOT's Air Quality and GHG Specialists.

6.2 Interagency Consultation

Working Group meetings were held throughout the Project to discuss the analysis needs, methods, and results. Nineteen meetings were held and included invitees from FHWA, EPA, CDOT, and the consultant team. A work plan for the GHG analysis (the Work Plan) was developed in coordination with the Working Group and was reviewed by FHWA, EPA, and CDOT. Consensus was reached among the Working Group participants to complete the final, approved Work Plan, which describes the GHG modeling and analysis approach and methods. The Work Plan was finalized on July 11, 2024, and is included in this report as Appendix A.

During the beginning of the consultation process, Working Group meetings were held weekly. After the analysis began, meetings were held as needed. Most of the meetings were held with CDOT and focused on obtaining Project-specific data for the GHG analysis. In addition, coordination occurred specifically with CDOT's Air Quality and GHG Specialists throughout the analysis process to ensure consistency with CDOT guidance.

Inputs to the various models for the GHG analysis were sent to the Working Group for review, and comments and questions were discussed in Working Group meetings. Inputs for the analysis, such as traffic information and construction durations, were revised as necessary prior to conducting the modeling and analysis. The modeling and technical analyses were then conducted using the final inputs. The modeling and analysis results were quality checked and presented to and discussed with the Working Group, then updated, as necessary, to address questions and comments.

7.0 Methodology

7.1 Overview

The GHG analysis conducted for the Project includes:

1. An assessment of lifetime operational emissions from vehicles using the Project corridor, for the No Action and build alternatives

2. An assessment of lifetime construction and maintenance emissions associated with the No Action and build alternatives
3. A cumulative assessment, considering direct emissions and associated indirect upstream emissions
4. Estimation of the SCC resulting from each Project alternative

This section of the report provides details of the methodology used for each of these elements of the analysis, and Section 8.0 summarizes the results of the analysis.

7.2 GHG Pollutants Considered

The analysis focuses on three GHGs: CO_2, CH_4, and N_2O. CO_2 is the most prevalent GHG, and the largest transportation-related source of this pollutant is motor vehicle exhaust. Production of materials used in roadway construction, such as concrete and steel, also results in CO_2 emissions. CH_4 and N_2O are emitted in smaller amounts, and vehicle exhaust is the main source of these pollutants in the transportation context.

Emissions of these three GHGs can be quantified as emissions of CO_2e, which represents the overall impact of GHG pollutants as if they were all emitted as CO_2. CO_2e is calculated by multiplying the amounts of CH_4 and N_2O by their 100-year GWP. The GWP of CH_4 used in this analysis is 25, meaning that one pound of methane emissions is 25 times as potent as one pound of CO_2 with respect to global warming. The GWP for N_2O used in this analysis is 298. These GWP values are embedded in the MOVES4 and ICE models used for modeling GHG emissions in the analysis.

7.3 Models Used

For the operational emissions analysis, a lookup table of emission factors for all GHGs listed above was generated by running the most recent version of EPA's MOVES[1] available when this analysis was conducted (i.e., MOVES4.0.1) for each analysis year (2023 and 2050). For each analysis scenario (i.e., Existing Conditions in 2023, No Action Alternative in 2050, and the two build alternatives in 2050), emission factors from the lookup table were then combined with link-level travel activity (traffic) and roadway type data to calculate the link-level emissions. The link-level emissions were then aggregated to the project level for each pollutant.

For the construction and maintenance analysis, FHWA's ICE tool[2] was used. Version 2.2.8 of this tool was the most recent available at the time of the analysis. ICE is a spreadsheet tool that estimates the lifecycle energy use and greenhouse gas emissions from the construction and maintenance of transportation facilities. The tool accounts for energy use and emissions associated with transportation infrastructure, including construction/rehabilitation activities and materials, traffic delay, routine maintenance, and facility use.

[1] EPA (2023) MOVES: MOVES4. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. August 2023. https://www.epa.gov/moves/moves-versions-limited-current-use.
[2] For more information, see https://www.dot.state.mn.us/sustainability/ghg-analysis.html.

7.4 Analysis Approach

7.4.1 MOVES Modeling for Operational Project Emissions

This section describes the approach for modeling operational emissions from motor vehicles using the MOVES model. This process involves setting up a run specification (RunSpec) for the MOVES model, entering Project data using a MOVES tool called the Project Data Manager, running MOVES, exporting the results as an emissions lookup table, and then using Project traffic data combined with the lookup table to calculate Project operating emissions for each year and Project alternative. These steps are described in more detail below.

7.4.1.1 Traffic Data

As described in the *I-270 Corridor Improvements Environmental Impact Statement Traffic Technical Report* (CDOT 2025c), the Project team selected the DRCOG Focus version 2.3.2 TDM and TransModeler 6.1 microsimulation software as the primary tools for the I-270 traffic analysis. These tools provide accurate traffic forecasts and detailed simulations, meeting the technical requirements established by CDOT and FHWA. The analysis uses the 2023 base year and 2050 horizon year TDMs from Focus version 2.3.2 for the existing and future traffic condition analyses.

The GHG emissions inventories were developed using lookup tables of emissions rates by vehicle type, road type, and speed (described below), and estimates of VMT and speeds by vehicle type from the traffic data. The traffic data provided estimates of traffic volume and speed for each modeled roadway segment (link); the traffic volume was combined with the length of each link in miles to estimate VMT. These calculations were performed separately for cars and trucks, as data for these two vehicle types were included in the summary traffic data.

The emissions inventory includes all roadway links involved in the Project, as well as adjacent roadway links where traffic is affected by the Project. These "non-Project" links were identified using the following criteria contained in FHWA's Mobile Source Air Toxics (MSAT) Frequently Asked Questions (FAQ)[3], which provide the only available recommendations for identifying links affected by a highway project:

- ± 5% or more change in annual average daily traffic (AADT) on congested highway links of level of service (LOS) D or worse
- ± 10% or more change in AADT on uncongested highway links of LOS C or better
- ± 10% or more change in travel time
- ± 10% or more change in intersection delay

These criteria were applied to roadway links within 500 meters of the Project to identify the Project and non-Project links included in the modeling of operational GHG emissions.

[3] Frequently Asked Questions (FAQ): FHWA Recommendations for Conducting Quantitative MSAT Analysis for FHWA NEPA Documents
https://www.fhwa.dot.gov/environMent/air_quality/air_toxics/policy_and_guidance/msat/fhwa_nepa_msat_faq_moves3_.pdf

Note that because the DRCOG TDM and the *Traffic Technical Report* findings are based on different modeling approaches (travel demand modeling versus microsimulation modeling) and slightly different roadway networks (the *Traffic Technical Report* includes the entire Project area, while the GHG analysis includes specific links selected using the criteria above), the two analyses reach different conclusions regarding the changes in VMT under the Project alternatives. The analysis of operational emissions documented in this report relies on the DRCOG TDM results for the modeled roadway links and, relative to the values in the traffic report, predicts higher VMT for the No Action and 3GPL Alternatives and slightly lower VMT for the 2GPL+1EL Alternative.

7.4.1.2 MOVES Runs – Overview of Approach

MOVES was run with the Project Scale setting to estimate running exhaust and crankcase running exhaust emissions for all pollutants. The MOVES runs produce emission factors for a lookup table, with emissions by road type, speed and vehicle type (car or truck). Data for Link inputs for MOVES were developed based on hypothetical link-level traffic and roadway data that cover the range of actual link-level traffic for all analysis scenarios, as described below. Link Source Type inputs for MOVES, which describe the mix of vehicle types on each link, were developed using data provided by CDPHE APCD.

Mainline and ramp roadway segments were modeled as urban restricted roadways. Other non-freeway roadways (i.e., arterials and collectors) were modeled as urban unrestricted roadways. Only on-road links were modeled; no "off-network" links were modeled. "Off-network" links reflect parking facilities, such as park and ride lots or truck stops, and no facilities of this type are affected by the Project. For each of the two road types, a series of hypothetical links with traffic volume of 1 vehicle per hour traveling one mile were created, with average vehicle speed ranging from 0 to 75 mph in 1 mph speed bins.[4] Emission factors were developed for both passenger ("non-truck") vehicle and truck vehicle categories, with appropriate mapping of MOVES source types to non-truck and truck categories.

Modeling was performed for a 2023 base year and a 2050 Project design year. For the analysis, the winter and summer seasons, represented by the months of January and July, respectively, were modeled using appropriate fuels inputs. This approach allows the modeling to capture wintertime conditions in Denver as well as the peak summertime period when warm-weather conditions impact vehicle air conditioning use.

Emission factors from the lookup table were applied (outside of MOVES) to Project-specific link-level traffic data in order to calculate link-level emissions, which were aggregated to the project level for each analysis scenario. The emission factors in the lookup table by vehicle type and speed (from the MOVES runs) were applied to the link-level traffic data to calculate the emissions for each link by traffic time period. The traffic data vary across three time periods during the day (Morning Peak, Afternoon Peak, and Evening).

[4] Note that only a single road grade (equal to 0%) was modeled in MOVES for the quantitative emissions inventory analysis, consistent with normal practices for emissions inventory development using the MOVES model.

7.4.1.3 RunSpec Inputs

MOVES RunSpecs were created to specify the parameter options for the MOVES model. Table 4 summarizes the MOVES inputs for the RunSpecs as defined in the navigation panel of the MOVES interface.

Table 4. MOVES RunSpec Selections

Navigation Panel	Model Selection
Scale	Project scale; inventory calculation type
Time Spans	Hour; weekdays; January/July; calendar years 2023 and 2050
Geographic Bounds	Adams County
Vehicles	All MOVES4 vehicle and fuel type combinations
Road Types	Urban restricted access, urban unrestricted access
Pollutants and Processes	GHGs listed in Section 7.2; running exhaust and crankcase running exhaust
General Output	Units of grams and miles
Output Emissions Detail	Road type

7.4.1.4 Project Data Manager Inputs

After the RunSpecs were created, an input database table for each run was created before running MOVES. This was done using the MOVES Project Data Manager to enter Project-specific data. Table 5 summarizes the MOVES Project Data Manager inputs, and they are discussed in more detail below.

Table 5. MOVES Project Data Manager Inputs

Project Data Manager Tab	Data Source
Meteorology Data	Provided by APCD
Age Distribution	Provided by APCD
Fuel	MOVES defaults; and AVFT[a] data provided by CDOT
Retrofit	No inputs (not applicable)
Inspection and Maintenance (I/M) Program	Provided by APCD
Link Source Type	Generated using traffic count data provided by APCD[b]
Links	Generic links designed to produce an emissions lookup table

[a] AVFT = Alternate Vehicle Fuel and Technology

[b] Note that the data provided by APCD are based on local Highway Performance Monitoring System traffic counts and reflect a statewide average for urban freeways, and are only used to define the vehicle type mix for separate "car" and "truck" input files for MOVES. The Project-specific fleet mix will be represented in the emissions analysis by the DRCOG TDM results for “car” and “truck” traffic volumes.

7.4.1.5 Meteorology Data

The meteorology data for this analysis were consistent with those used in the regional emissions analysis for transportation conformity and were provided by APCD. The relevant data provided by APCD for each modeled season were used to calculate average temperature and humidity for each traffic time period in the two seasons.

7.4.1.6 Vehicle Age Distribution

The vehicle age distribution input for the modeling, provided by APCD, is based on their latest available composite of vehicle registration data from seven Denver area counties (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, and Jefferson). These data were used to represent the age distribution in the analysis years (2023 and 2050).

7.4.1.7 Fuel Inputs

Consistent with APCD's standard practice, the default parameters in MOVES for fuel inputs were used, with the addition of AVFT data from CDOT to reflect the future zero emission vehicle fleet resulting from the state's adoption of the Colorado Clean Cars and Advanced Clean Trucks rules. The AVFT inputs define vehicle sales by fuel type and vehicle type in each past and future model year, and the CDOT-provided file reflects implementation of these Colorado rules.

7.4.1.8 I/M Parameters

Existing and anticipated future vehicle I/M program parameters for the Denver metropolitan area were provided by APCD.

7.4.1.9 Link Source Type

Link source type inputs were used to define the fraction of travel on each link by vehicle type. Two separate sets of MOVES runs were conducted, one for light-duty vehicles and one for (heavy-duty) trucks, such that two sets of link source type inputs were needed: one set with fractions for the four types of MOVES light-duty vehicles (MOVES sourcetypes 11, 21, 31, and 32), and one set with fractions for the nine types of heavy-duty vehicles, including buses (MOVES sourcetypes 41, 42, 43, 51, 52, 53, 54, 61, and 62).

For lanes in the build alternatives included in this analysis that will only permit usage by light-duty vehicles and buses, called Express Lanes, a third set of link source type fractions representing the Express Lane vehicle mix could be developed. However, this analysis included buses in the "truck" group, and did not model emissions for any buses in the Express Lanes because:

- Only one RTD bus route currently uses the corridor, and buses are a very small fraction of total travel.
- The travel activity data provided for this analysis only include traffic volumes for light-duty vehicles and trucks, and not separate traffic volumes for buses.

The vehicle mix used information was obtained from the travel demand modeling conducted for the Project, which provides light-duty and truck volumes for each link. The car/truck vehicle mix was further disaggregated to the 13 vehicle types in the MOVES model.

7.4.1.10 Links

A links input table was created that represents all possible combinations of road type (urban restricted and unrestricted access) and speed to generate the lookup table of emission factors applicable to any traffic link in the analysis scenarios.

7.4.2 ICE Modeling for Construction and Maintenance Emissions

As noted above, ICE is a spreadsheet tool that estimates the construction and maintenance emissions associated with highway projects. Multiple types of infrastructure were analyzed to capture the overall impact of the Project:

- Roadway construction, realignment, reconstruction, and resurfacing
- Bridges and overpasses
- Culverts
- Pathways (sidewalks and bicycle paths)
- Signs
- Lighting

CDOT developed an inventory of the amounts of each type of infrastructure associated with each alternative, and these were modeled using the ICE tool. Most analyses were conducted using ICE in Planning mode, but culverts were analyzed in ICE Project mode in order to better define the size of the planned culverts. Even the No Action Alternative includes some activities that generate emissions; the existing roadways need to be maintained, existing lighting consumes electricity, and some reconstruction and resurfacing is planned for the No Action Alternative, given the age and condition of the highway corridor. The only difference in infrastructure between the two build alternatives is the number of signs (the 2GPL+1EL Alternative requires additional signage).

ICE was also used to estimate the emissions impacts of construction delay. The tool uses travel speeds and national-average vehicle emissions rates to model the emissions impact of reduced speeds during the construction period (2026 through 2031). CDOT estimated the speed impacts of construction, and these were used along with the same traffic data supporting the GHG emissions inventory development to calculate daily average speeds with and without construction. The construction delay emissions are reported as part of the overall construction emissions associated with each build alternative.

7.4.3 Lifetime GHG Operational Emissions

MOVES GHG results for 2023 and 2050 were translated to lifetime emissions using interpolation to estimate emissions for each intervening calendar year. The interpolation method was based on the MOVES AVFT input table provided by CDOT along with the Colorado vehicle age distribution. The AVFT table contains electric vehicle sales by vehicle type and model year; the age distribution defines the rate of fleet turnover (what fraction of the overall vehicle fleet is represented by brand-new vehicles). A MOVES run was conducted for every calendar year between 2023 and 2050 using these two inputs, and the GHG trend in emissions over that time period was calculated using the GHG output from the model. This trend was then applied to the 2023 and 2050 emissions inventories to provide an estimate of GHG emissions by year.

The sum of emissions for each year between 2026 and 2050 represents the cumulative emissions from the Project over its lifetime. Lifetime emissions were calculated for each GHG pollutant and Project alternative.

7.4.4 Life Cycle Assessment and SCC

7.4.4.1 Life Cycle Assessment

This analysis considers both direct emissions from construction and operation of the Project alternatives, and the indirect or upstream emissions generated as part of these activities.

Upstream emissions from vehicle operation reflect “well-to-pump” emissions, or the emissions associated with producing the petroleum fuels or generating the electricity consumed by the vehicles using the Project. CDOT has developed a methodology for estimating these emissions as a function of VMT. For petroleum fuels (gasoline and diesel fuel), CDOT uses projections of fuel sales along with upstream emissions factors from the US Department of Energy’s *Greenhouse Gas and Regulated Emissions and Energy use in Transportation* model to estimate upstream emissions per year. To estimate electrical grid emissions from electricity consumed by electric vehicles, CDOT uses a detailed methodology that accounts for changes in electric vehicle usage, vehicle efficiency, and changes in the mix of sources powering the electrical grid to estimate upstream electricity-related emissions per year. Then, CDOT projections of VMT are used to calculate annual upstream emissions rates in units of kilograms CO_2e per mile driven.

ICE takes a lifecycle approach to account for GHG emissions. The lifecycle analysis for materials used in projects includes the embodied energy and emissions associated with the extraction, transportation, and production of materials. The construction analysis includes fuel use in construction and routine maintenance equipment, as well as fuel used to transport materials to the construction site. The lifecycle of infrastructure use includes vehicles delayed during construction while using the infrastructure, routine maintenance, rehabilitation and preventative maintenance, as well as ongoing electricity use in roadway lighting and the electrical generation emissions associated with that electricity use.[5]

7.4.4.2 SCC

This analysis included estimates of the SCC associated with the Project. The SCC is an estimate, in dollars, of the economic damage that would result from emitting each additional ton of CO_2 into the atmosphere. The SCC puts the effects of climate change into economic terms to help decision makers and the public understand the economic impacts of decisions that would increase or decrease emissions. In this analysis, SCC was calculated by year using annual estimates of vehicle operation, construction, and maintenance emissions, and then the SCC by year was summed to identify the total cost associated with each Project

[5] Infrastructure Carbon Estimator, version 2.2 Final Report and User’s Guide, May 2023, https://www.dot.state.mn.us/sustainability/ghg-analysis.html

alternative over the life of the Project. The costs are expressed in terms of calendar year 2020 US dollars.

The SCC values used in the analysis were published in 2021 by the federal IWG SC-GHG, in the document "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990." The social cost of CO_2 was applied to the CO_2e emissions totals for vehicle operation, construction, and maintenance, as well as the indirect effects, described above.

Because GHGs emitted today can cause climate effects many decades into the future, SCC analyses use discount rates to characterize the present-day value of these future impacts. Among other things, the SCC estimates can be used to compare the cost of emissions mitigation strategies to the value of the impacts avoided through mitigation. The first three values are based on the average SCC from three integrated assessment models, at discount rates of 5%, 3%, and 2.5%. SCC estimates are based on several discount rates because the literature shows that SCC is highly sensitive to the discount rate and because no consensus exists on the appropriate rate to use for analyses spanning multiple generations. In addition, there is extensive evidence in scientific and economic literature on the potential for lower-probability, but higher-impact outcomes from climate change, which would be particularly harmful to society. The fourth value, corresponding to the 95th percentile of the frequency distribution of SCC estimates based on a 3% discount rate is used to represent the damages associated with these lower-probability, higher-impact outcomes.[6]

8.0 Project-Level GHG Analysis Results

8.1 Direct Effects

Table 6 and Figure 6 summarize the lifetime (2026-2050) direct emissions associated with the Project alternatives. Emissions from initial construction, ongoing roadway maintenance, and vehicle operation are included. Emissions are in units of metric tons (MT) CO_2e.

[6] EPA Fact Sheet – Social Cost of Carbon, December 2016b: https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf

Table 6. Lifetime Direct GHG Emissions (MT CO2e over the Project lifetime)

Phase	No Action[1]	3GPL[2]	2GPL+EL[3]	D 3GPL[4]	D 2GPL+1EL[5]
Construction	11,656	50,831	50,875	+39,175 (+336%)	+39,219 (+336%)
Maintenance	4,382	4,995	4,995	+613 (+14%)	+613 (+14%)
Operational	2,555,968	2,719,578	2,613,050	+163,610 (+6%)	+57,082 (+2%)
Total Direct Emissions	2,572,006	2,775,403	2,668,919	+203,397 (+8%)	+96,913 (+4%)

[1] No Action Alternative

[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Figure 6. Lifetime Direct GHG Emissions (MT CO2e over the Project lifetime)

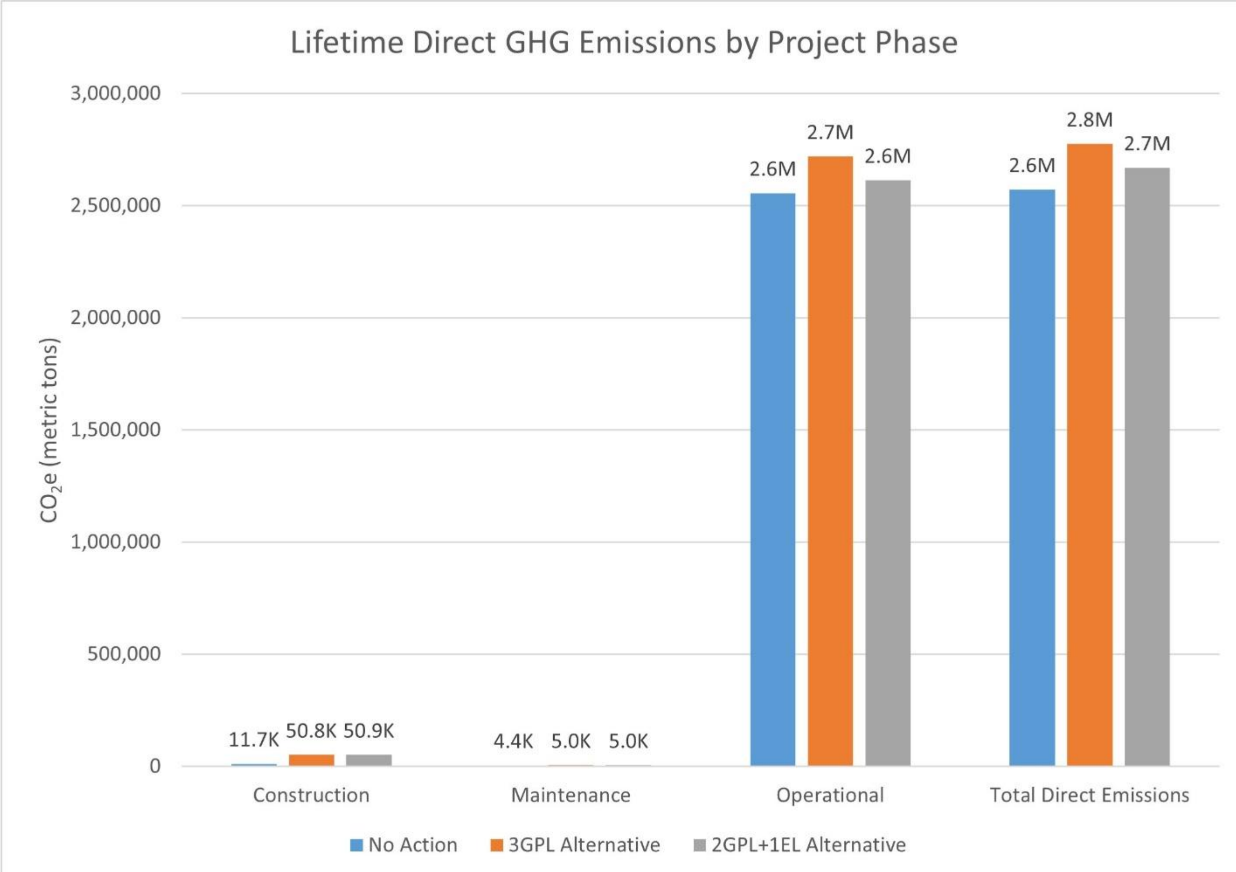
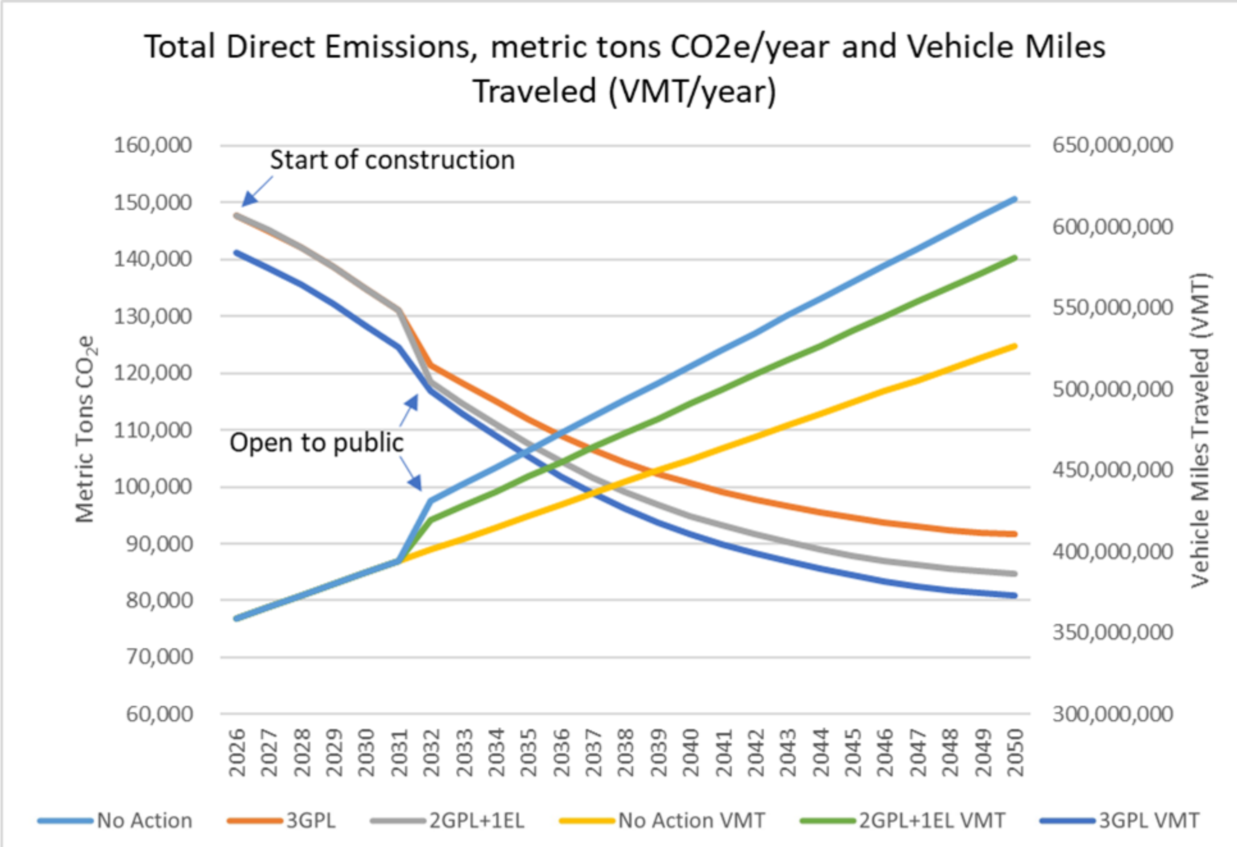


Figure 7 summarizes the *annual* direct emissions and VMT associated with the Project alternatives. Emissions from initial construction, ongoing roadway maintenance, and vehicle operation are included. Emissions are in units of MT CO_2e, and VMT is in units of miles.

Annual emissions (downward-sloping lines) are the same for all alternatives prior to construction and then increase when construction begins in 2026 (including the No Action Alternative, which involves some pavement resurfacing and reconstruction). The two build alternatives overlap because they have almost identical construction emissions. After construction is complete (2031), annual emissions decrease again, but each alternative has different emissions due to different levels of traffic (shown on the upward-sloping VMT lines).

Figure 7. Annual Direct GHG Emissions and VMT (MT CO2e and miles per year)



8.2 Indirect Effects

Figure 8 summarizes the annual indirect emissions for each of the Project alternatives. In this analysis, indirect emissions are the upstream emissions associated with producing fuel or electricity consumed vehicles as they use the Project infrastructure. Emissions are in units of MT CO_2e. Because this analysis uses a VMT-based emissions factor for upstream emissions, these emissions are projected to increase over time, unlike the direct operational emissions which decrease over time. Table 7 and Figure 9 summarize the lifetime indirect emissions with each of the Project alternatives.

Figure 8. Annual Indirect GHG Emissions (MT CO2e per year)

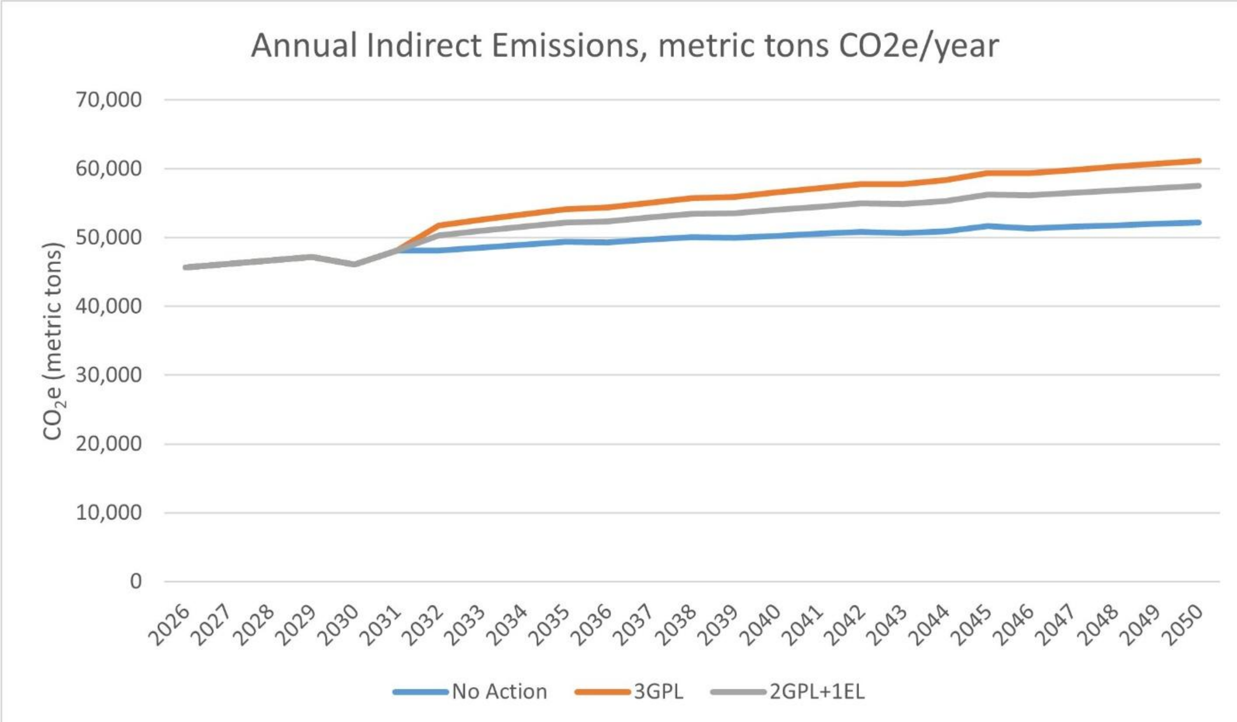


Table 7. Lifetime Indirect Emissions Associated with the Project Alternatives (MT CO2e)

	No Action[1]	3GPL[2]	2GPL+EL[3]	D 3GPL[4]	D 2GPL+1EL[5]
Upstream Fuel Cycle	1,237,616	1,361,059	1,311,242	+123,443 (+10%)	+73,626 (+6%)

[1] No Action Alternative

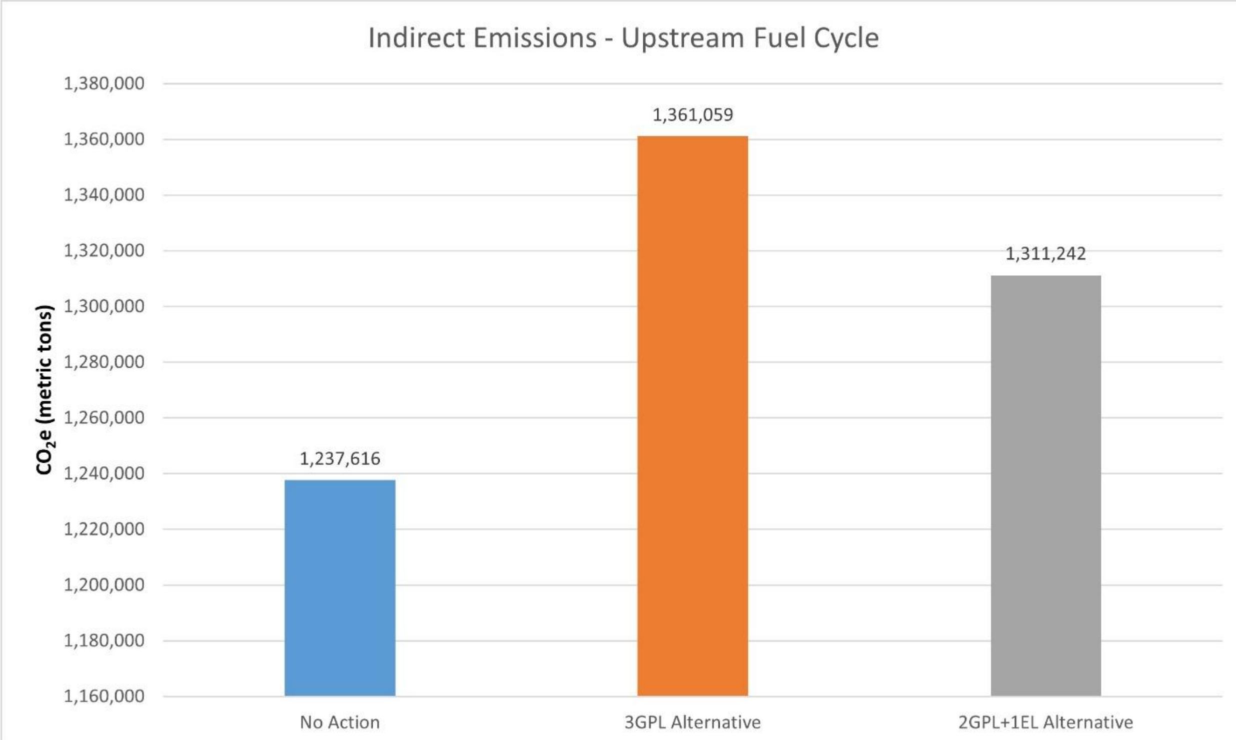
[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Figure 9. Lifetime Indirect GHG Emissions (MT CO2e over the Project lifetime)



8.2.1 Cumulative Effects

Table 8 summarizes the cumulative emissions (in units of MT of CO_2e) associated with the Project alternatives. Cumulative effects for the purpose of this analysis are the summation of direct and indirect effects. These are total emissions over the life of the Project, not estimates for individual calendar years.

Table 8. Cumulative GHG Emissions (MT CO2e)

	No Action[1]	3GPL[2]	2GPL+EL[3]	D 3GPL[4]	D 2GPL+1EL[5]
Direct Effects	2,572,006	2,775,403	2,668,919	+203,397 (+8%)	+96,913 (+4%)
Indirect Effects	1,237,616	1,361,059	1,311,242	+123,443 (+10%)	+73,626 (+6%)
Cumulative Effects	3,809,622	4,136,462	3,980,161	+326,840 (+9%)	+170,539 (+4%)

[1] No Action Alternative

[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

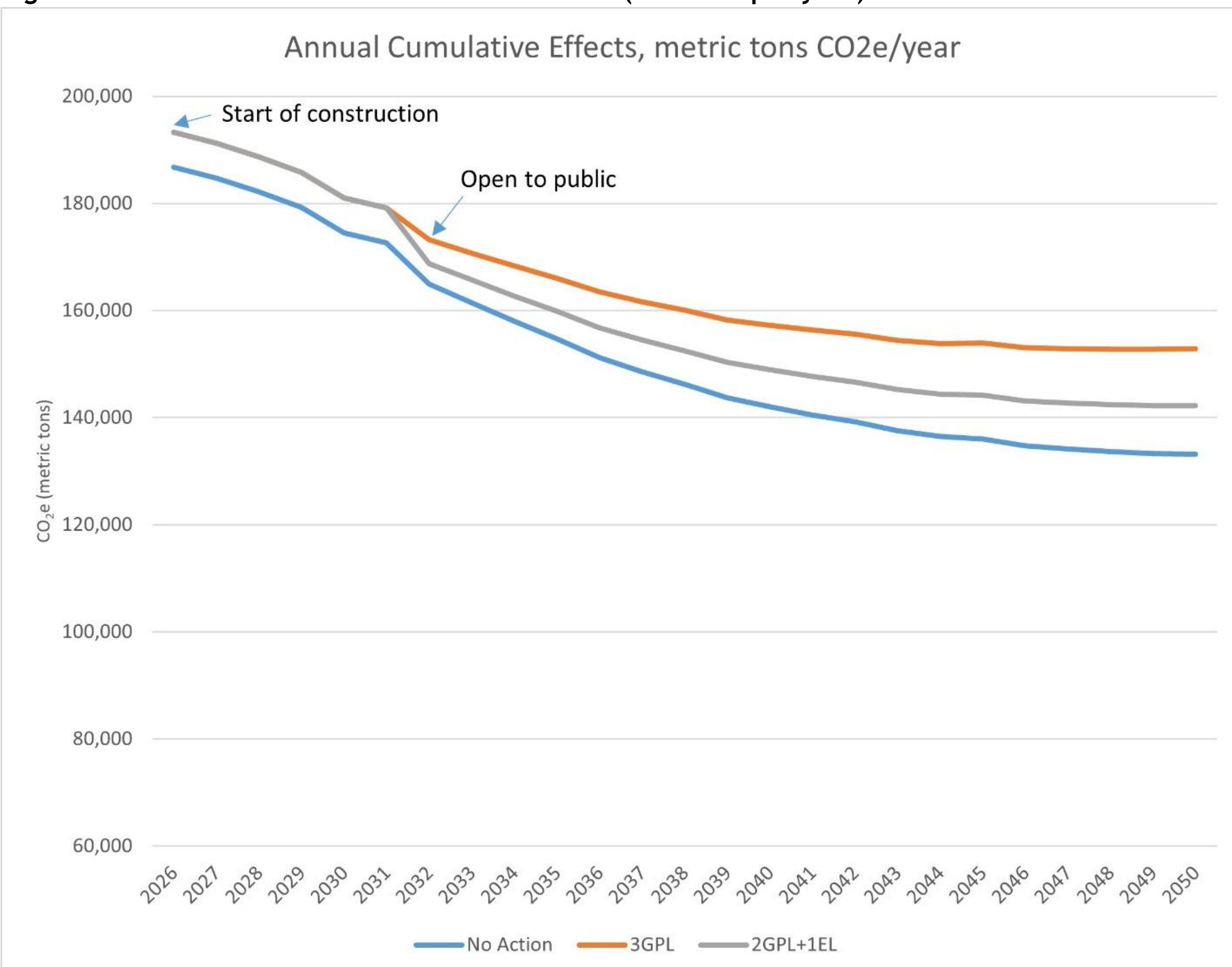
[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Figure 10 documents the annual cumulative emissions (Direct and Indirect) during the Project lifetime. As discussed in Section 7.1, annual emissions are the same for all alternatives prior to construction and then increase when construction begins (including the No Action Alternative, which involves some pavement resurfacing and reconstruction). After construction is complete, annual emissions decrease again, but each alternative has different emissions due to different levels of VMT (Figure 7).

GHG emissions associated with the Project decrease over time regardless of which alternative is selected, even though VMT is projected to nearly double in the corridor between 2023 and 2050. VMT increases under the build alternatives compared to the No Action Alternative due to the addition of a lane in each direction; the 3GPL Alternative results in a 17% increase in daily VMT compared to No Action in 2050, and the 2GPL+1EL Alternative results in a 10% increase in VMT.

Figure 10. Annual Cumulative GHG Emissions (MT CO2e per year)



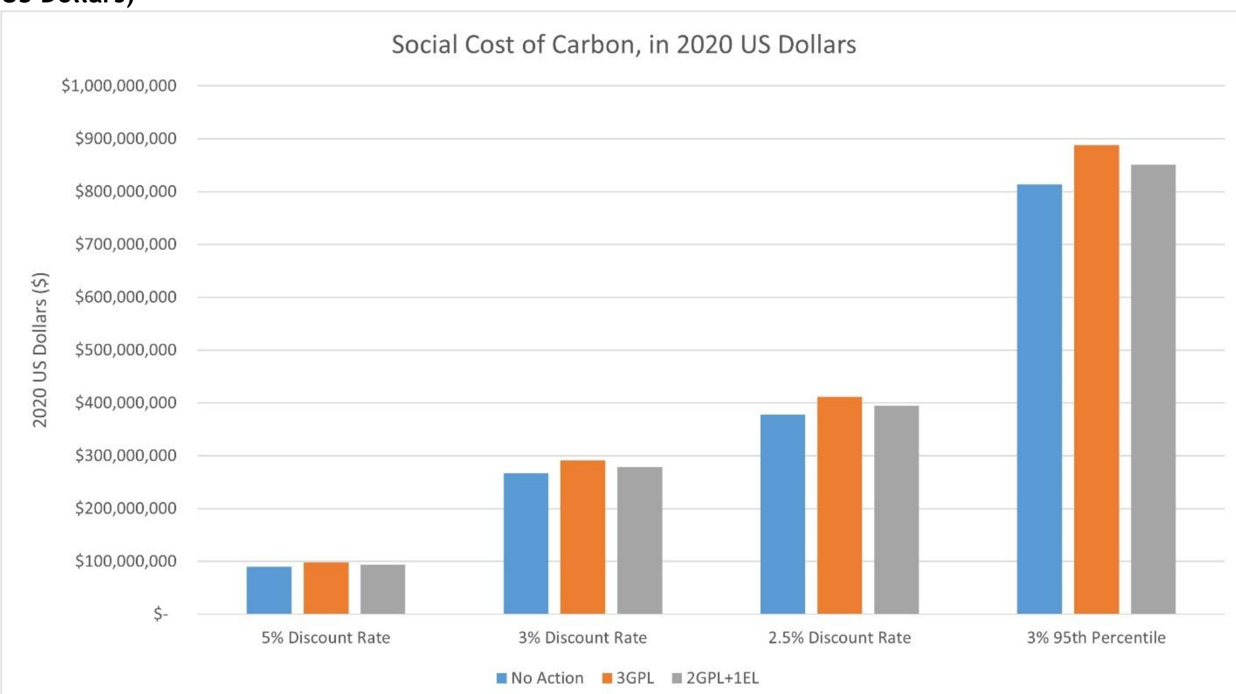
8.3 Social Cost of Carbon

Table 9 and Figure 10 summarize the SCC associated with each Project alternative. These estimates are in calendar year 2020 dollars and are based on the cumulative emissions from Table 8.

Table 9. Total Lifetime SCC (Calendar Year 2020 US Dollars)

	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
No Action Alternative	$90,185,273	$266,817,110	$377,866,099	$813,912,549
3GPL Alternative	$98,591,406	$290,972,797	$411,778,280	$887,828,806
3GPL Alternative SCC Relative to No Action Alternative	+$8,406,133	+$24,155,687	+$33,912,181	+$73,916,257
2GPL+1EL Alternative	$94,419,573	$279,135,337	$395,218,330	$851,543,127
2GPL+1EL Alternative SCC Relative to No Action Alternative	+$4,234,299	+$12,318,227	+$17,352,231	+$37,630,577

Figure 11. Total Lifetime SCC Grouped by Discount Rate and Alternative (Calendar Year 2020 US Dollars)



9.0 Project-Level GHG Effects

9.1 Project-Specific Impacts

It is likely that some of the modeled increase in VMT for the Project comes from existing vehicle trips that are currently using other routes under the No Action Alternative to avoid congestion on I-270, including longer and more circuitous route choices on I-70 and I-25. This analysis does not consider the potential reductions in VMT (and emissions) on those other roadways, some of which were excluded from the analysis as discussed in section 7.4.1. The alternative with the highest projected VMT per year (the 3GPL Alternative) has the highest emissions, and the alternative with the lowest projected VMT per year (No Action Alternative) has the lowest emissions.

On an individual vehicle basis, the operational gram CO_2e per mile emissions rates are 3 to 5% lower for the build alternatives compared to the No Action Alternative. Vehicles operate more efficiently due to the reduction in congestion under the build alternatives, reducing the amount of CO_2e emitted per mile driven.

It is typical when performing an emissions analysis for a highway expansion project to predict increases in VMT, and associated emissions, on the expanded roadway as it reduces congestion and makes this route more attractive than other more congested route choice options. The land use in the Project area is already developed with a mix of use types, therefore, the build alternatives are not likely to result in significant development or changes in the land use in the corridor resulting in redistribution of regional travel demand (see Section 11 for more information about travel demand and changes in VMT). It is unlikely the Project would result in lower density development in the future and the resultant associated longer and more frequent trips that could increase VMT and emissions in DRCOG's GHG compliance area. As noted, the project-level GHG analysis does not account for the VMT and GHG reductions associated with other, also now less congested routes in the region as more vehicles elect to travel on I-270 under either build alternative. Section 10.1 provides a discussion of DRCOG's planned actions, including the I-270 Project, to reduce GHG emissions within their region as a whole.

9.2 Related Projects with GHG Impacts

The Project build alternatives, alongside a host of separate but related projects in the area, contain several components which were not included in the GHG quantitative impact analysis but are expected to reduce GHG emissions in the form of transit accommodations and bicycle and pedestrian improvements. Currently, east-west local and regional connectivity is impeded in the Project area by I-270, Sand Creek, large scale industrial land uses, and substandard bicycle and pedestrian facilities. The lack of effective I-270 crossings creates inefficient transit routing, increases transit VMT, and precludes some trips from being made by bicycle or on-foot. The planned transit, bicycle, and pedestrian resources addressing these barriers are the same under the two build alternatives and are examined in this section. For further information, please see the *I-270 Corridor Improvements Environmental Impact Statement Transit, Bicycle, and Pedestrian Technical Report* (CDOT 2025d).

9.2.1 Transit Elements

Both build alternatives will reduce congestion on I-270, benefiting all interstate users, including buses. The Flatiron Flyer 5 route travels on I-270, regionally connecting Boulder to the Fitzsimons medical campus of Aurora. However, frequent congestion and variable travel speeds on I-270 have resulted in RTD publishing an official route deviation to this service, at the discretion of the bus operator; the deviation uses I-70 and I-25 instead of I-270. Mitigating this transit delay is identified as a need in the purpose and need. It is expected to provide GHG benefits in the form of decreased transit vehicle operational emissions. Additionally, the improved travel times anticipated with the build alternatives may entice more users to use transit rather than vehicles, further improving congestion on I-270 and positively impacting the community with improved travel time and reliability.

RTD coordination meetings were held to identify reroute opportunities that would provide riders with additional transit connections throughout the Denver metropolitan area. Existing RTD routes 37 and 88 currently do not cross I-270 at Quebec Street, and this presents an opportunity to optimize RTD bus route service. Four new proposed RTD bus stops and sidewalks at Quebec Street and South Sandcreek Drive included in the Project provide an opportunity for transfer between RTD routes 37 and 88, improving regional connectivity. Further, although buses do not currently use the I-270 and Vasquez Boulevard interchange as part of RTD's services, peak period queue jumps included in both build alternatives at the northbound Vasquez Boulevard to eastbound I-270 and southbound Vasquez Boulevard to westbound I-270 on-ramps planned for the Project provide the opportunity for future transit benefits, should RTD develop service requiring the interchange's use.

9.2.2 Bicycle and Pedestrian Elements

Currently, the Project area contains existing bicycle and pedestrian facilities in the form of sidewalks and both local and regional trails, but there are gaps between facilities, limiting bicyclists' and pedestrians' abilities to travel between neighborhoods, access other businesses or workplaces, or connect to the Sand Creek Regional Greenway (Sand Creek Trail) safely and efficiently. These gaps lead to more single-occupancy vehicle use, rather than promoting bicycle and pedestrian use, which increases GHG emissions. Additionally, there is only one designated on-street bike lane present within the Project area, further limiting opportunities to cross the I-270 corridor.

There are multiple municipal and community planned bicycle and pedestrian projects in the Project study area, all of which are in different phases of planning and design. The full list of planned future municipal and community planned bicycle and pedestrian projects can be found in Table 1 in the Transit, Bicycle, and Pedestrian Technical Report. Both build alternatives were designed not to impede these local projects, and in several cases support their development.

There are several Project elements which address the east-west connectivity gaps across I-270, identical in both build alternatives:

- Reconstructing the York Street bridge over I-270 with a 10-foot, multi-use path suitable for bicycles and pedestrians on the east side of York Street and a 5-foot sidewalk for pedestrians on the west side of York Street. These improvements will ultimately tie directly into the planned Adams County project north and south of the interstate, contributing to Adams County's long-term visions for a York Street bicycle and pedestrian connection extending from East 58th Avenue to 88th Avenue.
- The new I-270 bridge pier and abutment locations will allow for the future construction of the planned improvements identified in the City of Commerce City's 2012 Walk.Bike.Fit Plan, including a new greenway trail, off-street trails, on-street bike lanes, and improved sidewalks.

- The Project also constructs improvements on Vasquez Boulevard to allow for safety bicycle and pedestrian connectivity across I-270. The Project will construct a 10-foot, multi-use path on the east and west side of Vasquez Boulevard bridge over Sand Creek. It will connect bicycles and pedestrians from East 56th Avenue and Vasquez Boulevard intersection down to the Sand Creek Trail. The new east side trail will connect with a new east-west multi-use path between Vasquez Boulevard bridge and South Sandcreek Drive, with an ultimate connection to the Dahlia Trailhead. There will be a new north-south multi-use path beginning at the new east-west path mentioned above, crossing under the free-flow on-ramps.
- East 56th Avenue has been identified as a corridor that could benefit from bicycle and pedestrian improvements. The Project will construct a northbound on-street bike lane on East 56th Avenue under the new I-270 bridges and implement crosswalk improvements at the intersection of East 56th Avenue and South Sandcreek Drive, connecting to the new east-west trail across Vasquez described previously. A 10-foot attached sidewalk from the new east-west trail will be constructed, to the intersection of East 56th and Dahlia Street, transitioning to a 5-foot sidewalk on Dahlia Street north of the intersection. An east-west designated crosswalk will be constructed at the intersection of East 56th and Dahlia Street.
- Construction of a 10-foot-wide pedestrian overpass, approximately halfway between East 56th and Quebec Street. This overpass begins on the south side of I-270 connecting to the Sand Creek Trail, crosses over South Sandcreek Drive and I-270, and ties into North Sand Creek Drive at the intersection of East 53rd Way with a designated crosswalk. This improvement adds a grade separated bicycle and pedestrian connection for neighborhoods surrounding Leyden Park north of I-270 to the Sand Creek Trail, providing more regional connectivity for this neighborhood and surrounding businesses.
- In addition to the new transit stop improvements mentioned previously, an 8-foot, attached sidewalk is proposed for the Project between South Sandcreek Drive and East 47th Avenue Drive with a pedestrian crosswalk across East 47th Avenue Drive that connects to a proposed, 6-foot sidewalk between East 47th Avenue Drive and 49th Avenue. These pedestrian sidewalks provide connections from the new transit stops to existing RTD bus routes along East 49th Avenue.

All these bicycle and pedestrian improvements support mode shift into less carbon intensive forms of transportation by improving safety, connectivity, and new access.

10.0 Consideration of Indirect Effects

The key GHG analyses documented in this report include estimates of the lifetime vehicle emissions associated with the Project alternatives, the construction and ongoing maintenance emissions for each alternative, and the SCC for each alternative. The analysis did not consider some other possible indirect effects, including changes in land use that could generate additional vehicle travel; although some other effects of induced demand due to the availability of the additional highway infrastructure are considered: e.g., route choice, mode choice, and time of day travel choice. Since the Project corridor is largely fully developed, the potential for new development triggered by the availability of the additional roadway infrastructure is considered to be low. Some existing grass-covered right of way will be consumed by additional lane miles of roadway, reducing the potential carbon sequestration benefits of that right of way.

As noted in Section 6.6.4, the analysis uses a VMT-based upstream emissions factor to capture indirect emissions from the refining and electrical generation sectors. This approach assumes that each additional mile of travel will generate additional upstream emissions. However, because EPA emissions regulations are resulting in the sale of cleaner and more fuel-efficient vehicles, operational GHG emissions decrease over the life of the Project, even though VMT substantially increases between 2023 and 2050 (Figure 7). Since upstream emissions are directly related to operational energy consumption, these emissions will also likely decrease in the future to an unknown extent. In other words, the use of a VMT-based upstream emissions factor is a conservative approach.

The ICE tool used to estimate construction emissions considers both direct emissions and indirect emissions but does not report them separately. The direct emissions include CO_2e emissions from operating construction equipment. Sources of indirect emissions considered in ICE include the emissions associated with producing and transporting construction materials including steel, concrete and asphalt, and electrical generation emissions associated with roadway lighting. All of these emissions are reflected in this analysis.

11.0 VMT and Associated Emissions Changes on Other Alternate Routes

The project emissions study area was generally defined following existing project-level air quality analysis guidance for criteria pollutants. The purpose of project-level air quality analysis is to isolate the modified corridor to evaluate whether localized air quality impacts, e.g., elevated concentrations of traditional air pollutants, could result from a planned action as compared to the No Build Alternative. Under this guidance, the inclusion of roadways that are not proposed to be modified under an alternative are generally discouraged in an emissions analysis. Furthermore, the build alternative travel demand models used in the emissions analysis did not include planned, directly connected projects to I-25, US 36 and I-70 Express Lanes on either end of the corridor to provide a conservative estimate of emissions on I-270. These projects are included in DRCOG's 2050 RTP and are expected to eliminate bottlenecks at either end of the I-270 corridor that should result in smoother and less congested operations on the highway as well as likely associated emissions decreases. The I-270 Greenhouse Gas Analysis: Work Plan, located in Appendix A, provides additional detail on the methodology and inputs for the operational emissions analysis.

Figure 7 in Section 8.1 presented estimated annual direct emissions, including operational emissions, as well as VMT on roadways from the travel demand model for the Project alternatives within the defined emissions study area (see Figure 2 in the *State Air Quality Technical Report* for the I-270 Corridor Improvements Project [CDOT 2025b]). The emissions study area largely includes only project roadways except for smaller subsets of non-project roadways, also referred to as off-project links, close to where they physically interrelate with a project roadway. Please refer to the I-270 Air Quality Work Plan located in Appendix A of the *State Air Quality Technical Report* for detail on how roadways included in the operational emissions analysis were selected. As shown in Figure 7, corridor VMT is predicted to increase on these select roadways by 2050 for all project alternatives, reflecting anticipated regional population and employment growth incorporated into the model. Higher traffic volumes, increased daily VMT, and associated increases in operational emissions were projected for the Project build alternatives (3GPL and 2GPL+1EL) compared to the No Action Alternative due to the addition of a lane in both directions, which increases corridor capacity, albeit to different extents.

It is expected when conducting travel demand modeling for a highway expansion to predict increases in VMT and emissions on the expanded roadway compared to the No Action Alternative. The travel demand modeling data used in the operational emissions analysis focused on the project corridor independent of the broader regional network impacts, the project roadways. Added capacity on project roadways generally results in higher modeled VMT reported within the modified corridor as it reduces congestion on I-270 and increases its relative attractiveness for regional trips compared to other, more congested routes outside the area that was considered in the emissions analysis.

Some of this modeled increase in VMT reflects the reassignment of the No Action Alternative vehicle trips that use other routes to avoid congestion on I-270, including longer and more circuitous route choices on I-70 and I-25 as well as trips through local neighborhoods. The corridor level operational emissions analysis and results within this report do not account for the potential reductions in VMT and associated emissions on those other roadways, particularly I-70 and I-25, as drivers would elect to travel on less congested and more direct routes on I-270 under either build alternative.

Many roadways considered as alternate routes other than I-270 were not included in the project emissions study area as they are not proposed to be physically altered within the scope of project elements under an alternative. The exception is that subsections of some smaller roads associated with some alternate routes were included in the emissions study area, e.g., Vasquez Blvd. However, the geographic extents of these roads were highly constrained within the emissions study area to primarily focus on the direct influence of I-270 under an alternative(s). Thus, the project emissions study area does not capture the likely effects of travel and related emissions from these other alternate routes within the region.

To supplement the operational emissions analysis within the emissions study area and evaluate how travel behavior would likely change in a more regional manner under a given alternative, additional analysis was conducted on the alternate routes to evaluate changes in VMT and emissions from roadways that were not initially included in the emissions analysis. Consistent with the analysis conducted for the project emissions study area, the same regional travel demand modeling conducted for the project was used to represent likely travel behavior in 2050 for the No Action and 2GPL+1EL Alternatives for the following roadways that comprise some of the alternate routes near I-270, but were either fully (or partially) excluded from the project emissions study area:

- 38th Street
- 47th Avenue
- 56th Avenue
- Brighton Boulevard
- Central Park Boulevard

- Colorado Boulevard
- I-25
- I-270 Interchanges associated with I-25, I-70, I-76 and US 36
- I-70
- I-76
- Quebec Street
- Steele Street
- Vasquez Boulevard
- Washington Street
- York Street

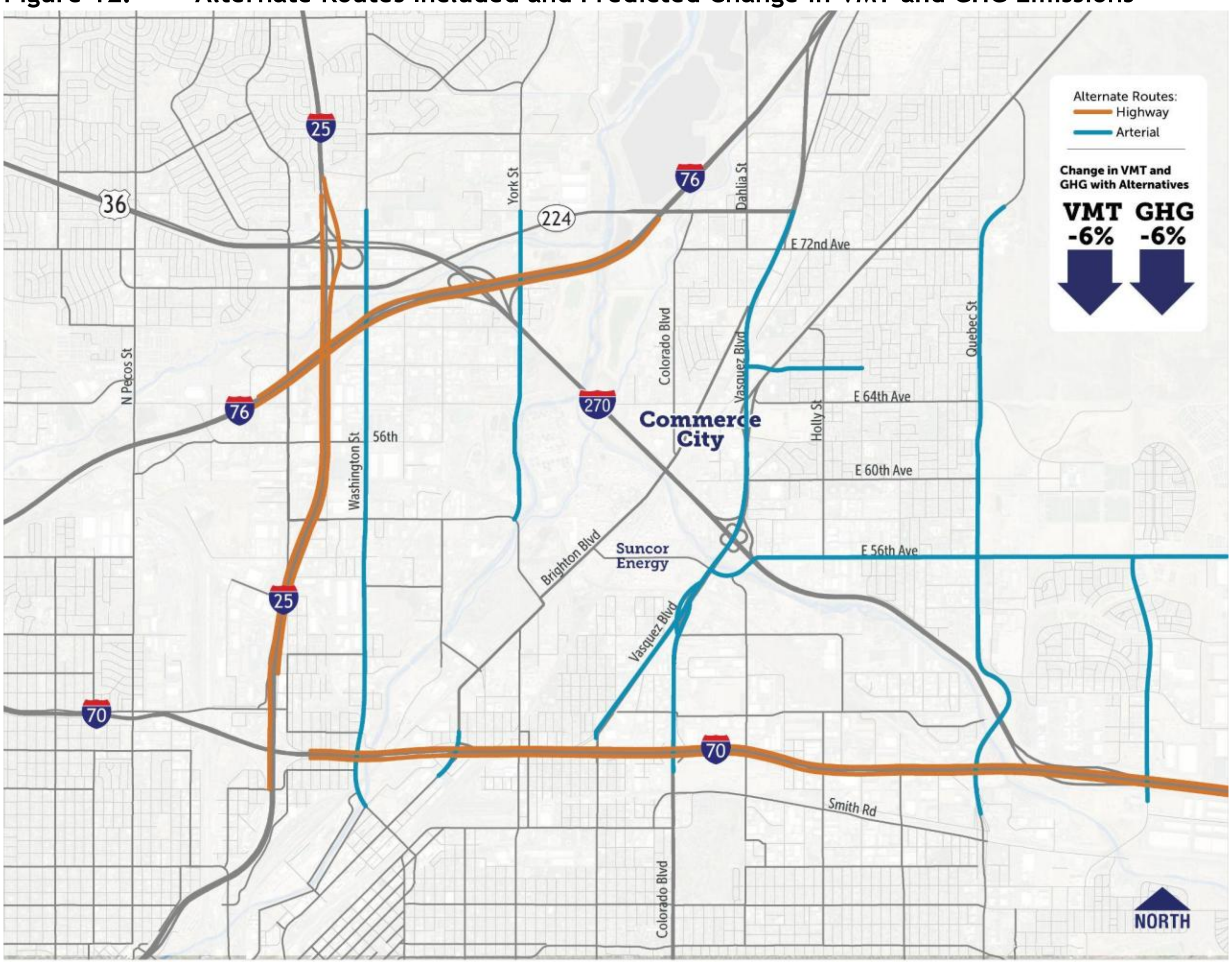
These roadways, which remain unaltered between alternatives, were extracted from the regional travel demand model and a qualitative analysis was conducted to compare the relative differences in VMT and emissions between the No Action and 2GPL+1EL Alternatives on the alternate routes in the region. The predicted travel behavior of these roadways was aggregated from the regional travel demand modeling for each alternative and emissions were analyzed in the same manner as is performed for the Transportation Commission's GHG Pollution Reduction Planning Standard. This methodology for analyzing emissions is aligned with the typical approach for a regional emissions analysis where localized impacts are not of concern. This is appropriate for GHGs that are global pollutants and are distinct from what was performed for the construction and operational emissions analysis in the project study area. However, the methodology for analyzing GHG emissions from the alternate routes is identical between the No Action and 2GPL+1EL Alternatives and was developed by CDPHE-APCD specifically for analysis of GHGs associated with on road mobile sources within a planning area.

The I-270 project is reflected in DRCOG's 2050 RTP and associated GHG compliance demonstration, but this analysis did not directly utilize DRCOG's travel modeling data associated with their 2050 RTP and should not be considered a subset of DRCOG's direct GHG emissions analysis for the purposes of demonstrating compliance with the GHG Standard. Notably, both build alternatives in this qualitative supplemental analysis do not include the planned, direct connect projects to I-25, US 36 and I-70 Express Lanes on either end of the corridor that are reflected in DRCOG's 2050 RTP. As directed by FHWA, these projects are included in the No Action model to reflect the most conservative air quality analysis results.

Direct Connects refer to Express Lane-to-Express Lane ramps between interstate facilities that provide regional Express Lane continuity. The I-270 Project 2GPL+1EL Alternative includes Express Lanes as part of the recommended improvements on I-270; however, it does not include the Express Lane Direct Connects to the I-25/US 36 and I-70 Express Lanes on the west and east ends of the corridor, respectively. The I-25/US 36 and I-70 Express Lane Direct Connect projects are included in the regional travel demand model as anticipated, stand-alone projects separate from the I-270 improvements project. The I-270 Express Lane benefits are projected to be maximized when coupled with the I-25/US 36 and I-70 Direct Connect projects, as these connections would allow for seamless Express Lane travel across multiple corridors in the regional network. Excluding the direct connects from the air quality analysis conservatively ensures that the potential emissions are not underestimated. The timing, funding and sequencing of these improvements relative to the I-270 Improvements Project are still under development at this time, therefore, these external improvements were conservatively excluded from this air quality analysis. As a result, the travel modeling of the build alternatives captures the projected increases in VMT associated with the added lanes in each alternative, and reduced corridor travel speeds compared to those anticipated to exist with the direct connections to the other routes.

Figure 12 shows the map of alternate routes that were included in the emissions analysis, as well as the total predicted change in VMT and GHG emissions in 2050 between the 2GP+1EL Alternative relative to the No Action on these roadways. VMT and emissions on these alternate routes are both predicted to decrease under the 2GP+1EL Alternative relative to the No Action Alternative by approximately 6%. This is due to more drivers choosing to travel on more direct routes with a less congested I-270 under the 2GP+1EL build alternative.

Figure 12. Alternate Routes Included and Predicted Change in VMT and GHG Emissions



The interstates associated with the alternate routes than I-270 in the region (shown in orange on Figure 12) are all predicted to have decreases in travel and VMT. The predicted reductions in VMT are also contributing to overall emissions reductions on these alternate routes.

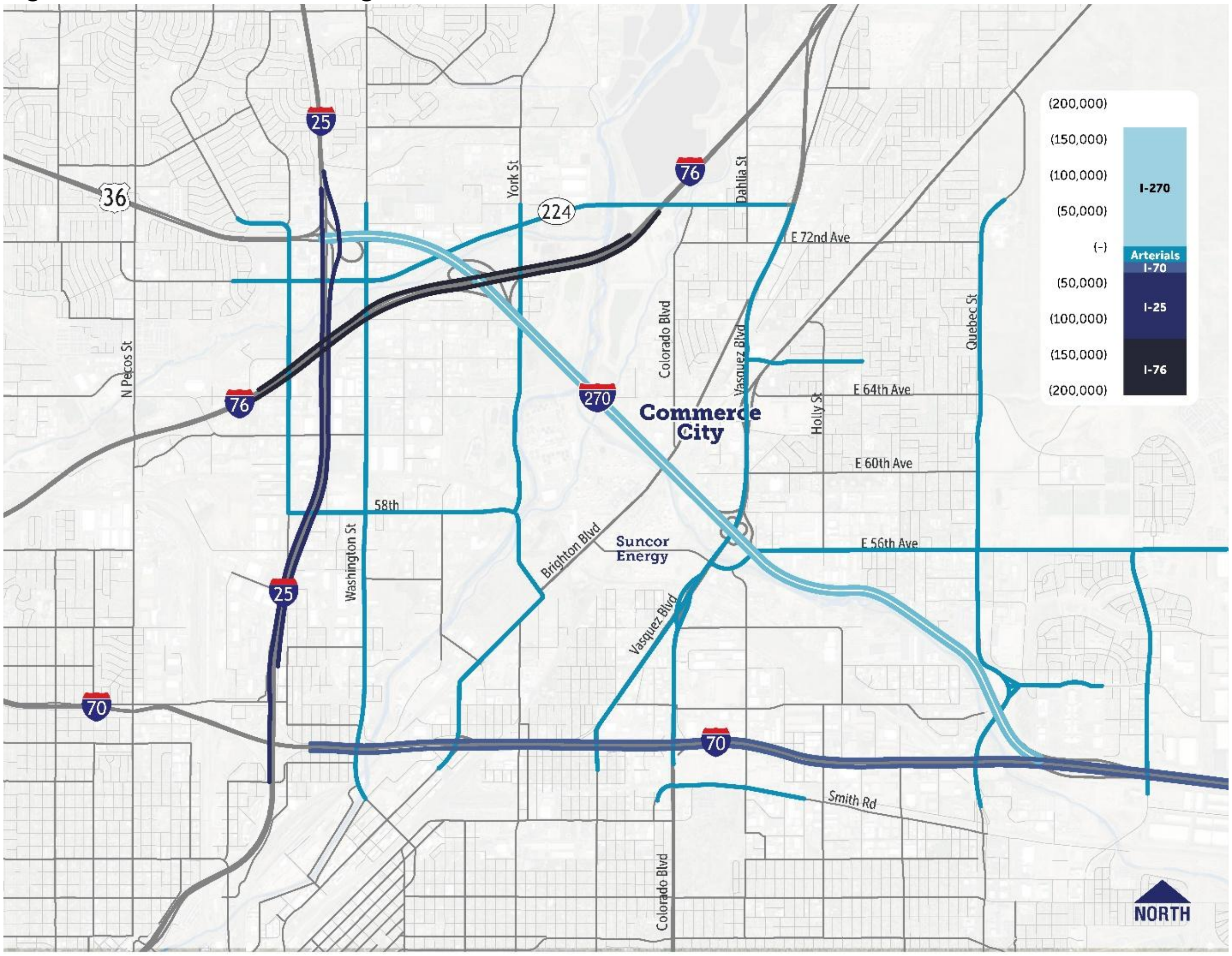
In addition to predicted decreases in VMT on alternate interstate routes other than I-270 in the region under the build alternatives, there is also a predicted decrease in vehicle travel on smaller arterial roads within the neighborhoods of the project area (shown in blue on Figure

12). This not only results in decreases in VMT and associated emissions, but it also provides a significant safety benefit to the public in the project area who will experience less traffic near locations such as residences and schools as drivers would elect to travel on the more efficient I-270 than local roads when traveling through the area. A reduction in commercial vehicles on these neighborhood streets is particularly beneficial in this regard.

The project corridor is largely built out with a mix of industrial, commercial, and residential land uses, so the proposed Build Alternatives are not expected to induce substantial new development or land-use changes that would generate additional long-term travel demand (often referred to as “induced demand”). Accordingly, it is important to interpret corridor-level VMT projections within the broader context of the regional transportation network and related projects. Although VMT is projected to increase on I-270 under both build alternatives relative to the No Action Alternative, this increase primarily represents a redistribution of regional travel demand rather than new, induced travel resulting from changes in land use or trip frequency.

Travel demand modeling for the No Action and 2GPL+1EL Alternatives was used to analyze predicted changes in VMT at the regional level; however, the forecasted changes in future VMT did not include the direct connects for the 2GPL+1EL which would provide a more accurate representation of likely future roadway conditions in and around the project area. Figure 13 presents the relative changes in VMT between the No Action and the 2GPL+1EL Alternatives for I-270, the surrounding interstates, and major local roads. Overall, the 2GPL+1EL alternative reduces VMT on the alternate routes to a greater extent than VMT is increased on I-270 under this alternative compared to the No Action Alternative. This demonstrates that VMT is not predicted to increase in the region as a direct result of the 2GPL+1EL build alternative indicating that the highway expansion is also not a significant source of regional induced demand as it relates to additional or more frequent trips, longer trips, and changes in land use.

Figure 13. Relative Changes in VMT between the No Action and 2GPL+1EL Alternatives



The *I-270 Corridor Improvements Environmental Impact Statement Traffic Technical Report* (CDOT 2025c) provides a comprehensive assessment of the corridors and overview of anticipated impacts to regional traffic operations. The analysis documented in the *Traffic Technical Report* includes results from the regional travel demand model as well as detailed microsimulation modeling that incorporates the planned direct connection improvements between I-270, I-25, US 36, and I-70. The travel modeling approach in the *Traffic Technical Report* is consistent with federal requirements for evaluating traffic impacts under NEPA and should be referred to for more accurately assessing likely future changes in travel behavior on the transportation network in the region. Similarly, the *Traffic Technical Report* demonstrates that the Build Alternatives are projected to increase VMT on I-270 relative to the No Action Alternative. These VMT increases on I-270, however, correspond with improved operational performance and reduced congestion throughout the broader regional system once the direct connections and improvements on I-270 are in place, as well as related decreases in VMT on other interstates and roadways in the region that connect to I-270.

12.0 GHG Commitment Considerations

For the purposes of CRS 43-1-128(4)(a), Colorado has not established a significance threshold for GHGs, thus GHG mitigation is not required. However, there are project-level mitigation measures occurring to address air quality that are likely to have GHG co-benefits. The mitigation measures listed for addressing the release of diesel emissions from construction equipment in Table 8 of the *I-270 Corridor Improvements Environmental Impact Statement Air Quality Technical Report* (CDOT 2025b) will also help to reduce GHG emissions from the construction of the Project. These measures include:

- Prohibition of unnecessary idling of construction equipment
- To the extent practical, use heavy construction equipment that has the cleanest available engines or that can be retrofitted with diesel particulate-control technology
- To the extent practical, use alternatives to diesel engines and/or diesel fuels, such as biodiesel, liquefied natural gas, compressed natural gas, fuel cells, and electric engines
- Install engine pre-heater devices to eliminate unnecessary idling for wintertime construction
- Prohibit tampering with equipment to increase horsepower or to defeat an emission control device's effectiveness
- Require construction vehicle engines to be properly tuned and maintained
- Use construction vehicles and equipment with the minimum practical engine size for the intended job

Project-level enhancements that CDOT commits to that could address operational GHG emissions or climate effects include:

- Provide funding for multimodal improvements on Colorado Highway 224, including sidewalks for safer pedestrian movement.
- Implement transportation demand management strategies via the local Transportation Management Organization, Northeast Transportation Connections (NETC). Examples of such management strategies employed by NETC include e-bike tax credits, free transit passes, and assistance with finding carpools or vanpools to join.
- Provide match funding for the Reconnecting Communities Planning Grant, which will improve multimodal connections along 60th Avenue between Brighton and Vasquez Boulevards.
- Assist with funding and coordinating the installation of landscaping and trees both within and beyond the Project limits. The installation of trees and landscaping can help absorb particulate matter and other pollutants.
- Collaborate with, participate in, and financially support local agency projects and other projects outside the I-270 limits that enhance community well-being by promoting improved safety, multimodal options, environmental and regional air quality improvements, community development, and/or alternative energy solutions to serve those most affected by the I-270 Project. This could include partnering with other agencies on regional air quality improvement projects or working with agencies to evaluate/prioritize route changes or other transit service on I-270.
- Implement enhanced measures beyond standard CDOT practices to improve safety, mobility, and incident response within the construction work zone. This could include implementing a tow truck patrol system to quickly clear crashes to reduce idling.

CDOT would use state funds to implement these enhancements that are identified through a community-driven process.

The GHG impacts associated with the Project are also being mitigated on the regional scale. The Project was analyzed as part of DRCOG's 2050 RTP to fulfill the requirements of the GHG Transportation Planning Standard when developing their 2050 RTP.

DRCOG completed a major update of the 2050 RTP in 2022 to initially comply with the GHG rule, which created the multi-strategy compliance framework that DRCOG has carried through in subsequent 2050 RTP amendments. This framework, as discussed in the GHG rule-required Transportation Greenhouse Gas Report, includes the following major strategies to help reduce GHG transportation emissions in the region:

- Reallocate $900 million within the 2050 RTP's financial plan towards additional and accelerated regional complete streets and other programmatic investments that support multimodal travel options.
- Modifying the scope of some roadway capacity projects to focus on multimodal, safety and complete streets investment elements and reduce the amount of increased roadway capacity.
- Investing over $1.34 billion in transportation associated GHG reduction benefits. These investments include active transportation, transit, and transportation demand management components associated with capital roadway and transit projects.
- Prioritizing measures to invest and accelerate multiple bus rapid transit projects along a system of corridors that can leverage federal funding opportunities, attract high volumes of ridership, are ready for implementation and reflect regional geographic variety; including socioeconomics and locational availability of transportation choices. These measures will also help maximize the region's current and planned investment in rail, bus rapid transit and other multimodal travel options. As the Denver region continues to grow, these proposed measures are intended to help accommodate some of that growth in strategic areas to reduce the frequency and length of auto trips.
- Increasing investments in DRCOG's Regional Traffic Operations Program above those already included in the 2050 RTP to retime and optimize an additional 50 signals per year beginning in 2025.
- Focus on voluntary local government actions related to parking management and rezoning in specific geographies (e.g., around rapid transit stations, vacant and underutilized land), as well as local adoptions of complete streets ordinances and associated standards application and project implementation. Note that while DRCOG's 2050 RTP accounts for GHG emissions benefits associated with these actions, the GHG emissions reductions associated with these actions, such as revising land use near rapid transit stations to increase travel choices, are not reflected within the associated travel behavior or emissions burden analysis under NEPA.

DRCOG's work to comply with the GHG Transportation Planning Standard is not just regulatory compliance but to encourage continued meaningful multimodal transportation planning within the region. The GHG reduction measures, as implemented over time, are intended to encourage and support multimodal travel options and the co-benefits that come with thoughtfully integrated land use and transportation planning that provides more people with more travel choices.

13.0 Resilience Considerations

Resiliency became a key priority for CDOT after the 2013 Front Range flooding event caused severe damage to the transportation system. The flood impacted roughly 500 miles of roads and 50 bridges and required more than $700 million in emergency repairs. CDOT, businesses, and the traveling public all felt the financial impact and inconvenience. Recognizing the importance of transportation resiliency, in 2018 the Transportation Commission adopted Policy Directive 1605, "Building Resilience into Transportation Infrastructure and Operations" (CDOT 2018). The Policy Directive directed CDOT to support state resilience goals by incorporating resilience in strategic decisions about transportation assets and operations and created the Risk and Resilience Program at the agency. The Risk and Resilience Program has created a suite of tools and processes by which resiliency can be integrated into project assessment, design, and decision making.

CDOT's formalized risk assessment process is described in the *Resilience Improvement Plan* (CDOT 2024b), which was approved by FHWA in January 2025. The risk assessment process was exercised on the I-270 Project area, and generally, the following steps were applied.

Resilience strategies can be physical or operational. To decide which strategies to implement, CDOT uses the tools detailed in the Resilience Improvement Plan to:

- Step 1. Threat Data Collection - Identify locations most at risk of hazards and determine the probability of this hazard/disaster occurring each year.
- Step 2. Asset Data Collection - Considering the condition of the asset, determine the likelihood that the asset will fail if a hazard/disaster were to occur.
- Step 3. Consequence Analysis - Calculate how much it would cost to repair.
- Step 4. Calculate the cost to travelers of delay/detour.
- Step 5. Vulnerability Analysis - Multiplying the cost of repairs by the probability of occurrence and the vulnerability of the asset, calculate the annual financial risk from hazards for CDOT and the traveling public.
- Step 6. Risk Assessment - Identify strategies and mitigation tools that can reduce the damage from the hazard or the chances it could occur.
- Step 7. Risk and Resilience Management - Implement the most cost-effective strategies.

As part of the risk assessment process, the I-270 corridor was assessed as high criticality. Criticality measures the importance of an asset to the overall transportation system and the success of CDOT to carry out its mission of delivering service to its travelers. Understanding relative criticality is necessary to evaluate risks for any asset and hazard in the context of CDOT's entire transportation network and mission. Criticality is based on six equally weighted criteria:

- the AADT, Association of American State Highway and Transportation Officials Roadway Classification
- freight value per ton at the county level
- tourism dollars generated at the county level
- social vulnerability index
- system redundancy

The I-270 Project was then screened for potential exposure to natural hazards, including the five natural hazards prioritized by CDOT (flood, snow/avalanche, geohazards, post-fire debris flow, and wildfire risk). CDOT's Asset Resiliency Mapping Application was used to collect data for the assessment. CDOT identified that the Project study area is in both a 100 year and 500 year floodplain.

The combination of the I-270 Project's high criticality and location in a floodplain led CDOT to explore whether there are any Project elements which could benefit from a future resilience analysis once the Project reaches a more mature design. Notably, given that the No Action Alternative contains several elements that would also be implemented through either build alternative, it is likely that implementing resilience considerations into Project elements do not differ between alternatives.

13.1 I-270 Mainline Bridges Crossing Floodplains

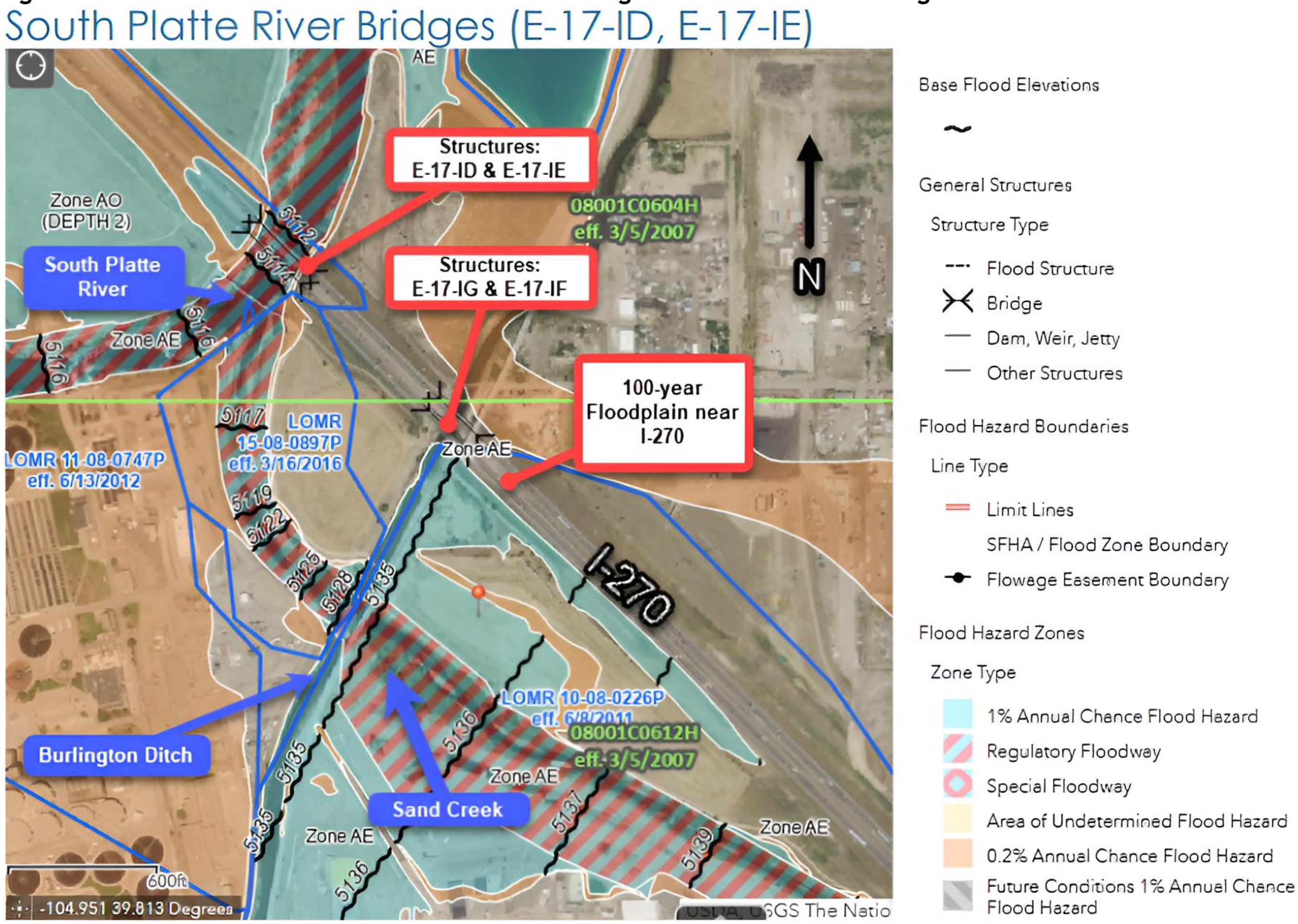
The two bridges for eastbound and westbound I-270 over the Burlington Ditch, structures E-17-IG and E-17-IF, were built in 1969 and are in poor condition according to CDOT's structures inventory. There is no mapped floodplain associated with Burlington Ditch, but Sand Creek and Burlington Ditch cross just south of I-270 as shown in Figure 12. If Sand Creek were to flood and back up the Burlington Ditch, it could pose a risk to these two bridges; however, the current bridges appear to adequately convey irrigation flows. See the *I-270 Corridor Improvements Environmental Impact Statement Floodplains Technical Report* (CDOT 2025e) for more information.

13.2 Parallel Roadway and Infrastructure

13.2.1 Roadside Upstream of Burlington Ditch Crossing

Based on current Federal Emergency Management Agency (FEMA) flood mapping shown in Figure 14, backwater from the Sand Creek and Burlington Ditch crossing (south of I-270) spreads the designated Zone AE, or 100 year floodplain near the eastbound I-270 roadway embankment. In this area the adjacent roadway has a threat of flood rise in the existing and future climate informed science scenarios. See the *I-270 Corridor Improvements Environmental Impact Statement Floodplains Technical Report* (CDOT 2025e) for more information.

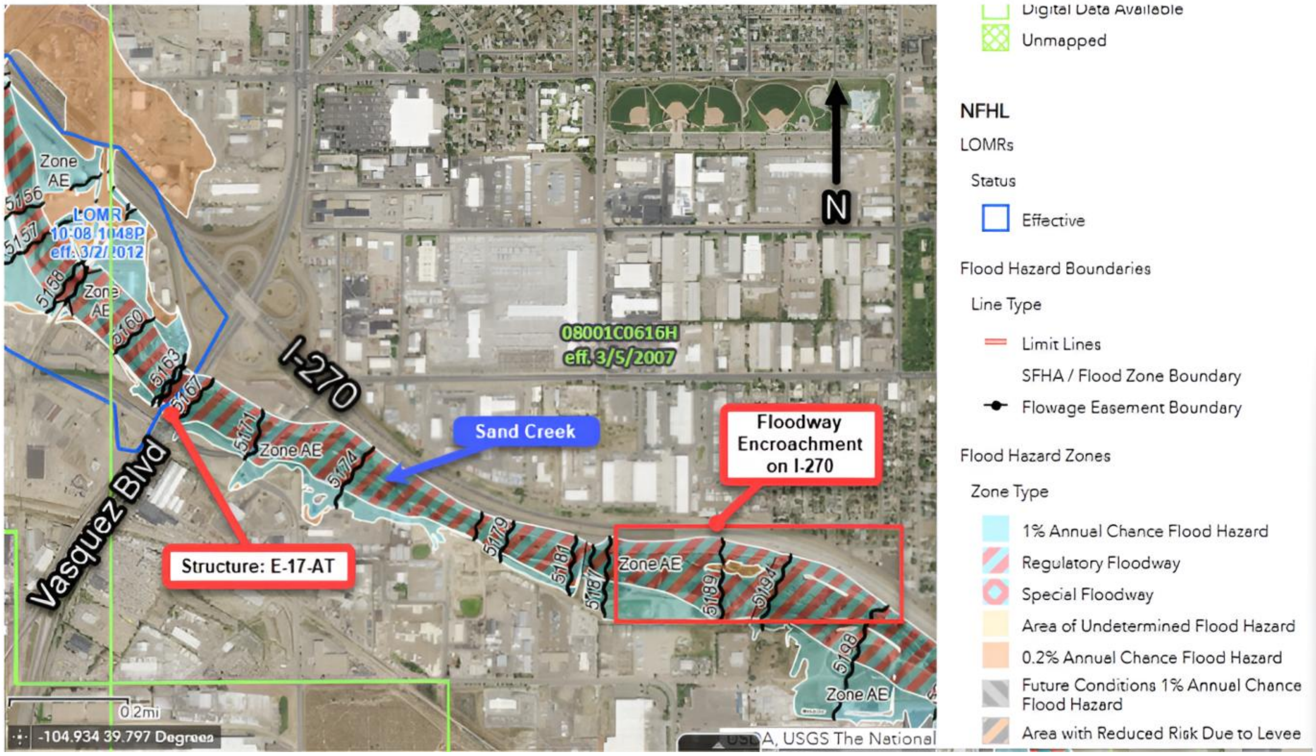
Figure 14. FEMA Flood Hazard Schematic Burlington Ditch and I-270 Bridges



13.2.2 Vasquez Boulevard and Sand Creek Bridge Adjacent to I-270

Figure 15 shows the current FEMA flood mapping along I-270 near the Vasquez Boulevard interchange. Sand Creek runs along a 1.5-mile section of eastbound I-270 in this location. Aerial imagery with a flood mapping layer shows several locations where the regulatory floodway encroaches the I-270 eastbound shoulder and potentially two locations of the regulatory floodway where a threat of flooding could occur on the travel way for I-270 eastbound. Future conditions based on climate-informed science could increase the likelihood of flooding events. The proximity of Sand Creek to I-270 causes vulnerability to a flood event. See the *I-270 Corridor Improvements Environmental Impact Statement Floodplains Technical Report* (CDOT 2025e) for more information.

Figure 15. FEMA Flood Hazard Schematic I-270 and Vasquez Blvd



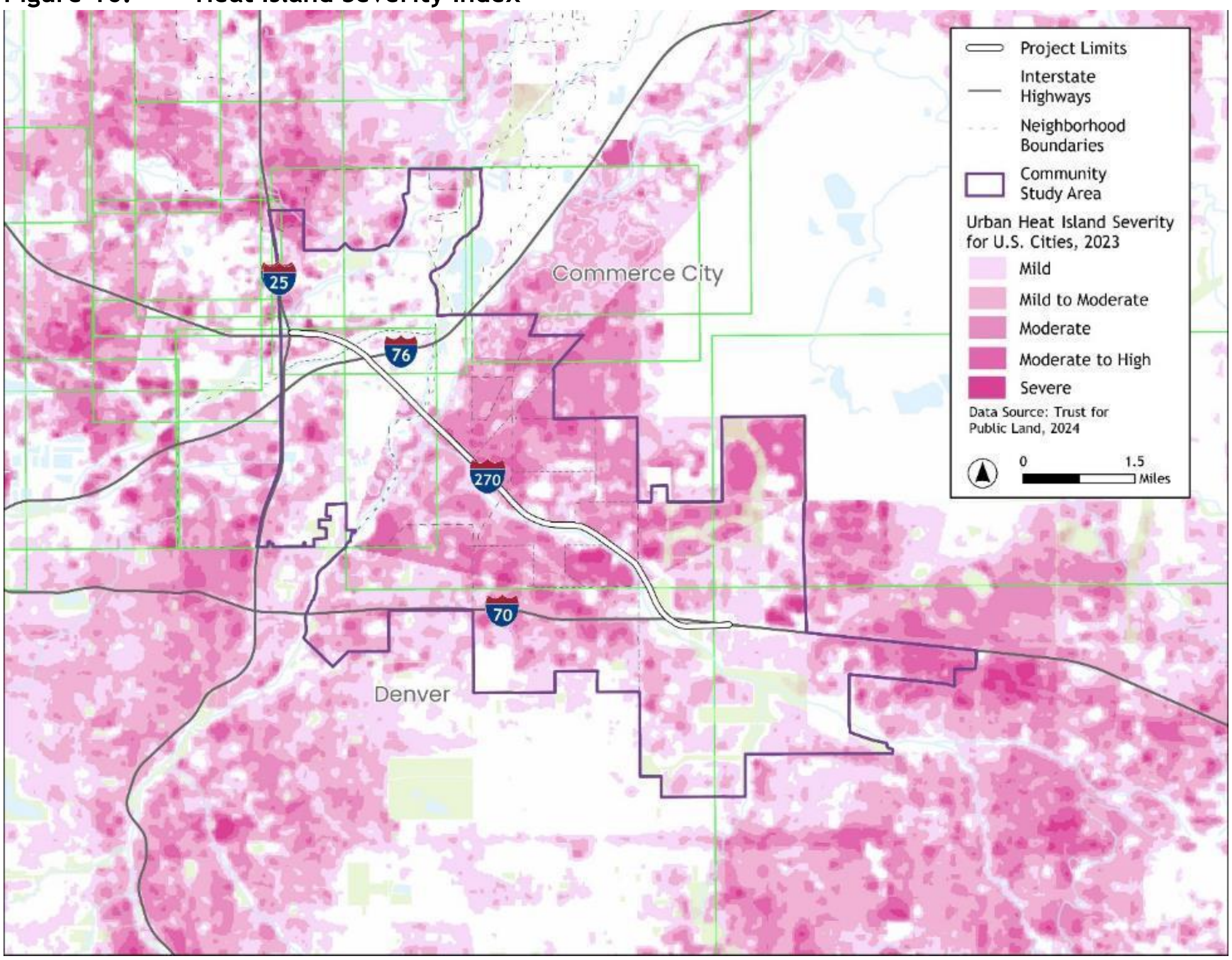
14.0 Community Impact Considerations

Components of Colorado Senate Bill 21-260, *The Sustainability of the Transportation System*, now codified as CRS 43-1-128, requires certain projects to use enhanced engagement methods with Disproportionately Impacted Communities (DI Communities) throughout the planning, environmental study, and project delivery phase. The requirement to work with and evaluate effects to DI Communities only applies if the project is an RS/TC project. As an RS/TC project, the I-270 Corridor Improvements Project was required to undergo additional analysis and consideration for DI Communities.

To fulfill these state requirements, a community analysis for the I-270 Corridor Improvements Project was also conducted in parallel with the NEPA process. As documented in Figure 3 and Table 1 of the *I-270 Corridor Improvements Project Community Analysis Technical Report* (CDOT 2025f), DI Communities are present in this study corridor. Section 4.0 of the *Community Analysis Technical Report* describes the outreach and engagement efforts conducted by CDOT in the community study area (CSA). During these public engagement efforts, CDOT received comments and questions related to air quality, GHGs, and climate change. Many stakeholders expressed concern that adding lanes will increase emissions and worsen climate impacts. Some stakeholders requested that the Project strive to improve air quality and contribute to the state's GHG reduction goals, with recommendations to consult the EPA, accurately measure VMT and GHG impacts, and implement mitigation measures if emissions increase.

There is one particular climate vulnerability within the community study area relates to the "heat island" effect. Heat islands are urbanized areas that experience higher temperatures than outlying areas. These higher temperatures result in increased energy consumption, elevated emissions of air pollutants and GHGs, and compromised human health and comfort (Santamouris, 2020). Climate change is expected to intensify these heat island impacts. Trust for Public Land developed and mapped an index that measures heat island severity nationally. Severity is measured on a scale of 1 to 5, with 1 being a relatively mild heat area (slightly above the mean for the city), and 5 being a severe heat area (significantly above the mean for the city) (Trust for Public Land 2023). Figure 16 shows that much of the CSA has a high or severe heat severity index.

Figure 16. Heat Island Severity Index



15.0 Conclusion

As documented in Section 8.0 of this technical report, the analysis predicts that annual GHG emissions decline over the life of the Project regardless of alternative, even though VMT increases over time. The 3GPL Alternative would produce cumulative GHG emissions (lifetime direct and indirect emissions combined) that are 8% higher than the No Action Alternative; the 2GPL+1EL Alternative would produce emissions 4% higher than the No Action Alternative. There would be a temporary increase in emissions between 2026 and 2031 as a result of Project construction, and then emissions decrease each year after that.

For over 25 years, DRCOG has been actively involved in efforts to reduce the amount of motor fuel burned, VMT, and associated GHG emissions. The task continues to be challenging due to the region's growth. However, DRCOG has remained strongly committed to efforts to reduce GHG emissions through its planning work and project funding allocations. As part of their efforts to reduce emissions of GHGs from transportation in the region, DRCOG has reduced and limited the number of planned roadway expansion projects that were included in previously approved regional planning documents, and furthermore, has formally incorporated these actions into their current long-range planning process through inclusion in their 2050 RTP and GHG Transportation Report.

The I-270 Corridor Improvements project is included in DRCOG's 2050 RTP and is analyzed as part of the associated GHG Transportation Report. DRCOG's GHG Transportation Report demonstrates a significant regional reduction in GHGs and satisfies the requirements of the GHG Transportation Planning Standard for all compliance demonstration years. It is important to note that the GHG Transportation Planning Standard addresses regional emissions reductions of GHGs from the transportation network as a whole, and not on an individual project-by-project basis. This is appropriate given that individual and commercial travel behavior is highly dynamic with high levels of traveler variability, such as route and mode choice, given the day-to-day conditions of the transportation network in the region. Furthermore, unlike criteria pollutants, GHGs are global pollutants that do not have regional or localized impacts near the source of their emissions. Therefore, it is important to consider each corridor's context within a region, as well as how it relates to a planning area's commitments to reduce GHG emissions as a whole within their transportation network rather than to solely focus on a single action. Although emissions of GHGs may increase through implementation of either build alternative in comparison to the No Action Alternative at the corridor level, when considered as part of a holistic transportation plan, the Project does not adversely impact DRCOG's regional GHG emissions reduction efforts or compromise the agency's ability to comply with the GHG Transportation Planning Standard.

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Appendix A. Greenhouse Gas Analysis Work Plan

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The Greenhouse Gas Analysis Work Plan is included here.

I-270 Corridor Improvements

Greenhouse Gas Analysis: Work Plan

July 11, 2024

Federal Project No.
STU 2706-046

CDOT Project Code
25611

Acronyms and Abbreviations

Acronym/Abbrev.	Definition
APCD	Air Pollution Control Division
AQ-PLAG	Air Quality Project-Level Analysis Guidance
ATR	Automated Traffic Recorder
AVFT	Alternate Vehicle Fuel and Technology
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CH4	methane
CO	carbon monoxide
CO2	carbon dioxide
CO2e	CO2-equivalent
C.R.S	Colorado Revised Statutes
DRCOG	Denver Regional Council of Governments
EF	emission factor
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
HPMS	Highway Performance Monitoring System
I-270	Interstate 270
I/M	inspection and maintenance
ICE	Infrastructure Carbon Estimator
LCA	life cycle assessment
MOVES	Mobile Source Vehicle Emissions Simulator
mph	miles per hour
N2O	nitrous oxide
NEPA	National Environmental Policy Act
RS/TC	regionally significant transportation capacity
RTD	Regional Transportation District
RunSpecs	run specifications
SB	Senate Bill
SIP	State Implementation Plan
TDM	travel demand model
TP	time period
VMT	vehicle miles traveled
ZEV	zero emission vehicle

1.0 Introduction

The Colorado Department of Transportation (CDOT) and Federal Highway Administration (FHWA) are preparing an Environmental Impact Statement (EIS) for the Interstate 270 (I-270) Corridor Improvements project (the Project).[7] This document provides a brief overview of the regulatory context for the greenhouse gas (GHG) analysis (**Section 2**); describes the proposed elements and methodology of the GHG analysis (**Section 3**); and discusses plans for technical reporting of the analysis (**Section 4**).

The proposed GHG analysis is a quantitative analysis of GHG emissions, based on a life cycle assessment (LCA) approach, and the social cost of carbon (SCC) due to GHG emissions over the lifetime of the Project. The analysis will be conducted to account for energy use and GHG emissions associated with construction and maintenance for the Project for a No Action Alternative in 2050 (horizon year) and selected Build Alternatives in 2050, and cumulative emissions from opening of the Project through the horizon year.

2.0 Regulatory Context for the GHG Analysis

The purpose of the GHG analysis is to evaluate potential impacts associated with the Project in accordance with applicable state requirements and guidance. These are described in the subsections below and include the following:

- Colorado Revised Statutes (C.R.S.) 43-1-128(4)(a)
- CDOT Interim Guidance for Project Level Compliance of CRS 43-1-128 (National Environmental Policy Act [NEPA] and Construction) DRAFT (CDOT 2023a)
- CDOT Regionally Significant and Transportation Capacity Interpretation and Examples for CDOT Projects (CDOT 2022a)

C.R.S. 43-1-128 requires an enhanced level of modeling and analysis of GHG emissions from regionally significant transportation capacity (RS/TC) projects. The Project is considered regionally significant by the Denver Regional Council of Governments (DRCOG)[8] and is considered a planned RS/TC project for CDOT purposes, as it is contained in the CDOT 10-year plan (CDOT 2022b). The RS/TC determination for the Project is based on the following definition in CDOT guidance (CDOT 2022a): "A roadway-widening project (via construction or restriping) adding at least one general purpose through lane of one lane-mile or more in length (or two miles in length if in a Rural area with a [volume to capacity] V/C ratio less than 85%)."

[7] The purpose of the Project is to implement transportation solutions that modernize the I-270 corridor to accommodate existing and forecasted transportation demands. While addressing the needs of traveler safety, travel time and reliability, transit on the corridor, bicycle and pedestrian connectivity across I-270, and freight operations, a key goal of the Project is to minimize resulting environmental and community impacts.

[8] DRCOG is the federally designated metropolitan planning organization (MPO) responsible for transportation planning for the Denver metropolitan region, where the Project is located.

To meet the state requirements, GHG emissions will be quantified over the Project lifetime for the No Action Alternative and the selected Build Alternatives. The Project lifetime is defined as the period beginning with the commencement of construction through the Project horizon year. The GHGs from on-road mobile sources that will be quantified in the analysis include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and CO_2-equivalent (CO_2e). The LCA-based analysis provides an estimate of cumulative CO_2e emissions over the lifetime of the Project, including (1) operational emissions of vehicles traveling on the Project once opened, (2) emissions from the upstream creation of fuel for those vehicles, and (3) construction and maintenance for the Project.

3.0 Analysis Methods

The methodology for the proposed analysis will be conducted in accordance with all applicable state regulations, and it will be based upon guidance from the U.S. Environmental Protection Agency (EPA) and CDOT. The following relevant guidance will be applied to the methodology for each element of the proposed analysis, where appropriate, as described in this section of the work plan and agreed upon by CDOT and FHWA:

- NEPA Manual, Version 7 (CDOT 2023b)
- Interim Guidance for Project Level Compliance of CRS 43-1-128 (NEPA and Construction) DRAFT (CDOT 2023a)
- Air Quality Project-Level Analysis Guidance (AQ-PLAG), Version 1 (CDOT 2019)
- MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA 2023)
- MOVES Greenhouse Gas Guidance: Using MOVES for Estimating State and Local Inventories of Onroad Greenhouse Gas Emissions and Energy Consumption (EPA 2024)

3.1 Operational Emissions

For the proposed quantitative project-level analysis of GHG emissions, a lookup table of EFs for all GHGs listed in **Section 2** will be generated by running the most recent version of EPA's Motor Vehicle Emissions Simulator (MOVES) available when this work plan was prepared (i.e., MOVES4.0.1) for each analysis year[9] Before its subsequent use in calculating project-level emissions for the analysis, CDOT and FHWA will review the lookup table, along with the underlying MOVES input/output files. EPA will be provided the run specifications (RunSpecs) and input/output databases for the MOVES modeling to review. For each analysis scenario (i.e., Existing Conditions in 2023, No Action Alternative in 2050, and the selected Build Alternatives in 2050), EFs from the lookup table will be combined with link-level travel activity (traffic) and roadway-type data to calculate the link-level emissions, which will be aggregated to the Project level for each pollutant. The methodology details for this process are described below.

[9] Note that using MOVES to generate a project-scale lookup table of EFs eliminates the need to use project-specific traffic data as part of the MOVES inputs and adds flexibility to the analysis. If traffic data change or new links are later added to the analysis, updated emissions can be calculated without needing to revise MOVES inputs and re-run the MOVES model.

3.1.1 MOVES Runs – Overview of Approach

MOVES will be run with the Project Scale setting to estimate running exhaust and crankcase running exhaust emissions for all GHGs. The MOVES runs will produce EFs for the lookup table. Data for Links input for MOVES will be developed based on hypothetical link-level traffic and roadway data that will cover the range of actual link-level traffic for all analysis scenarios. Link Source Types input for MOVES will be provided by the Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division (APCD) or CDOT.

Mainline and ramp roadway segments will be modeled as urban restricted roadways. Other nonfreeway roadways (e.g., arterials and collectors) will be modeled as urban unrestricted roadways. Only on-road links will be modeled (no "off-network" links will be modeled). For each of the two road types, a series of hypothetical links with traffic volume of 1 vehicle per hour traveling one mile will be created, with average vehicle speed ranging from 0-75 miles per hour (mph) in 1-mph speed bins.[10] Emission factors will be developed for both passenger ("non-truck") vehicle and truck vehicle categories, with appropriate mapping of MOVES source types to non-truck and truck categories.

For the proposed analysis, the winter and summer seasons, represented by the months of January and July, respectively, will be modeled using appropriate fuels inputs for each season. This approach allows for modeling of typical "worst-case" wintertime air quality in Denver as well as the peak summertime period when warm-weather conditions can adversely influence air quality.

Emission factors from the lookup table will be applied (outside of MOVES) to Project-specific link-level traffic data in order to calculate link-level emissions, which will be aggregated to the project level for each analysis scenario. The EFs in the lookup table by vehicle type and speed (from the MOVES runs) will be applied to the link-level traffic data to calculate the emissions for each link by traffic time period. The traffic data are anticipated to vary across four time periods during the day (i.e., AM Peak, Midday, PM Peak, and Evening).

3.1.2 MOVES Run Specification Inputs

MOVES RunSpecs will be created to specify the parameter options for the MOVES model. Table 1 summarizes the MOVES inputs for the RunSpecs as defined in the navigation panel of the MOVES interface. The following subsections describe input options needed for the RunSpecs.

[10] Note that only a single road grade (equal to 0%) will be modeled in MOVES for the proposed analysis, consistent with normal practices for quantitative emissions analyses using the MOVES model.

Table 1. MOVES RunSpec options

Navigation Panel	Model Selection
Scale	Project scale; inventory calculation type
Time Spans	Hour; weekdays; January/July; calendar years 2023 and 2050
Geographic Bounds	Adams County
Vehicles	All MOVES4 vehicle and fuel type combinations
Road Types	Urban restricted access, urban unrestricted access
Pollutants and Processes	GHGs listed in Section 2; running exhaust and crankcase running exhaust
General Output	Units of grams and miles
Output Emissions Detail	Road type

3.1.3 MOVES Project Data Manager Inputs

After the RunSpecs are created, an input database table must be created before running MOVES. This process is done using the Project Data Manager to enter project-specific data. Table 2 summarizes the MOVES Project Data Manager inputs, and these inputs are discussed in more detail below.

Table 2. MOVES Project Data Manager inputs

Project Data Manager Tab	Data Source
Meteorology Data	Provided by APCD
Age Distribution	Provided by APCD
Fuel	MOVES defaults; and AVFT[a] data provided by CDOT
Retrofit	No inputs (not applicable)
Inspection and Maintenance (I/M) Program	Provided by APCD
Link Source Type	Generated by the Air Quality Consultant using traffic count data provided by APCD[b]
Links	Generated by the Air Quality Consultant

[a] AVFT = Alternate Vehicle Fuel and Technology

[b] Note that the data provided by APCD are based on local Highway Performance Monitoring System (HPMS) traffic counts and reflect a statewide average for urban freeways and are only used to define the vehicle type mix for separate "car" and "truck" input files for MOVES. The project-specific fleet mix will be represented in the emissions analysis by the Denver Regional Council of Governments (DRCOG) TDM results for “car” and “truck” traffic volumes.

3.1.3.1 Meteorology Data

The meteorology data for this analysis will be consistent with those used in the regional emissions analysis for transportation conformity and will be provided by APCD. The relevant data provided by APCD for each modeled season will be used to calculate average temperature and humidity for each traffic time period in the two seasons.

3.1.3.2 Vehicle Age Distribution

The vehicle age distribution input for the modeling, which will be provided by APCD, is expected to be based on their latest available composite of vehicle registration data from seven Denver area counties (i.e., Adams, Arapaho, Boulder, Broomfield, Denver, Douglas, and Jefferson). These data will be used to represent the age distribution in the analysis years (2023 and 2050).

3.1.3.3 Fuel

Consistent with APCD's standard practice, the default parameters in MOVES for fuel inputs will be used with the addition of AVFT data from CDOT to reflect the future zero emission vehicle (ZEV) fleet resulting from the state's adoption of the Colorado Clean Cars and Advanced Clean Trucks rules that can be accommodated in MOVES4.

3.1.3.4 Inspection and Maintenance Parameters

Existing and anticipated future vehicle inspection and maintenance (I/M) program parameters for the Denver metropolitan area will be provided by APCD.

3.1.3.5 Link Source Type

Link source type inputs are used to define the fraction of travel on each link by vehicle type. Two separate sets of MOVES runs will be conducted, one for light-duty vehicles and one for heavy-duty trucks, such that two sets of link source type inputs will be needed: one set with fractions for the four types of MOVES light-duty vehicles (MOVES sourcetypes 11, 21, 31, and 32), and one set with fractions for the nine types of heavy-duty vehicles, including buses (MOVES sourcetypes 41, 42, 43, 51, 52, 53, 54, 61, and 62).

For lanes in the Project Build Alternatives included in this analysis that will only permit usage by light-duty vehicles and buses, called Express Lanes, a third set of link source type fractions representing the Express Lane vehicle mix could be developed. However, including buses in the "truck" group, and not modeling emissions for any buses in the Express Lanes, is planned for three reasons:

- Only one Regional Transportation District (RTD) bus route currently uses the corridor, and buses are a very small fraction of total travel.
- The travel activity data provided for this analysis only include traffic volumes for light-duty vehicles and trucks, not separate traffic volumes for buses.

Automated Traffic Recorder (ATR) data by HPMS class (if available) for representative freeway and arterial segments, provided by APCD, will be used, along with MOVES default estimates by vehicle miles traveled (VMT) by source type, to develop link source type inputs for the two groups of vehicles.

3.1.3.6 Links

A links input table will be created that represents all possible combinations of road type (urban restricted and unrestricted access) and speed to generate the lookup table of EFs applicable to any traffic link in the analysis scenarios.

3.1.4 Calculation of Project-Level Emissions

The project-level emissions for each pollutant and season in all four analysis scenarios will be calculated from the link-level traffic data for each scenario and appropriate EFs from the lookup table developed using MOVES. The calculation will be performed as follows. First, the link-level emissions will be calculated for each traffic time period as the product (multiplication) of VMT by all vehicles, number of hours, and applicable fleet-average total EF based on the fleet mix (i.e., the fraction of passenger and truck vehicles) and average speed in each traffic time period:

$$E_{link}^{TP} = VMT_{link}^{TP} \times hrs \times \left(f_t^{TP} \times EF_t(v^{TP}) + (1 - f_t^{TP}) \times EF_{pass}(v^{TP}) \right) \quad \textbf{Equation 1}$$

where

$$E_{link}^{TP} = link - level\ emissions\ for\ a\ single\ time\ period\ (TP)$$

$$VMT_{link}^{TP} = L_{link} \times V_{tot}^{TP}$$

$$L_{link} = link\ length\ (miles)$$

$$V_{tot}^{TP} = V_{pass}^{TP} + V_t^{TP} = total\ vehicle\ volume\ in\ the\ TP$$

$$V_{pass}^{TP} = passenger\ vehicle\ volume\ in\ the\ TP$$

$$V_t^{TP} = truck\ vehicle\ volume\ in\ the\ TP$$

$$hrs = number\ of\ hours\ in\ the\ TP$$

$$f_t^{TP} = \frac{V_t^{TP}}{V_{tot}^{TP}} = truck\ fraction\ of\ V_{tot}^{TP}$$

$$EF_{\mathrm{t}}(v^{TP}) = \text{emission factor for truck vehicles as a function of average speed, v, for the TP (g/mile)}$$

$$EF_{\mathrm{pass}}(v^{TP}) = \text{emission factor for passenger vehicles as a function of speed, v, for the TP (g/mile)}$$

Note that the EFs by vehicle type and speed in **Equation 1** represent the sum over the emission processes modeled in MOVES (i.e., running exhaust and crankcase running exhaust for all GHGs analyzed) based on analysis season. For each traffic link, the average speed for each time period and the road type will be used as keys to identify the applicable EFs for passenger and truck vehicles in the lookup table. As the Project traffic volumes represent annual average volumes, CDOT monthly ATR summary data will be used to develop seasonal traffic adjustments.

After the link-level emissions by time period for each link have been calculated, the total link-level emissions will be calculated as the summation of **Equation 1** over all time periods. Finally, the project-level emissions will be calculated by summing the total link-level emission for each link over all links in the traffic data. The project-level GHG emissions will be used to calculate operational emissions for the LCA-based analysis.

3.2 Quantitative Life Cycle Assessment of GHGs and Social Cost of Carbon

The quantitative LCA-based analysis of GHGs and SCC will account for the operational GHG emissions described in Section 3.1, the GHG emissions associated with construction and maintenance activities of the selected Project Build Alternatives, and upstream GHG emissions associated with vehicle operation. Construction and maintenance emissions will be calculated using the most recent version of FHWA's Infrastructure Carbon Estimator (ICE) tool when this work plan was prepared (version 2.2.8). ICE applies an LCA approach to account for energy use and emissions associated with transportation infrastructure, including construction/rehabilitation activities, traffic delay, routine maintenance, and facility use. The upstream GHG emissions associated with vehicle operation reflect "well-to-pump" emissions, or the emissions associated with producing the petroleum fuels or generating the electricity consumed by the vehicles using the Project. CDOT will provide emission rates in units of kg CO_2e per mile driven. The cumulative GHG emissions from the lifetime of the Project will then be calculated as the sum of estimated emissions from these sources beginning with the start of construction and ending with the horizon year for the Project. The SCC from the Project will be calculated using the estimated cumulative GHG emissions and dollar values per metric ton of GHG at a discount rate of 2.5%, per the requirements of 43-1-128(4)(a) (CDOT 2023a), as well as 5%, 3%, and 3% at the 95th percentile.

4.0 Reporting

After completion of the proposed GHG analysis described in this work plan, a GHG technical report will be prepared to document the results, along with the analysis methodology, input data, and key assumptions used for each element of the analysis. This report will include a discussion of the relevant regulations, GHGs, and climate change concerns, as well as GHG commitment, resilience, and community impact considerations. Aspects of the report aside from the modeling and analyses described in this Work Plan will be documented by CDOT or other consultants for the Project.

5.0 References

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U.S. Environmental Protection Agency (EPA). 2024. *MOVES Greenhouse Gas Guidance: Using MOVES for Estimating State and Local Inventories of Onroad Greenhouse Gas Emissions and Energy Consumption*. June. EPA-420-B-24-023.

U.S. Environmental Protection Agency (EPA). 2023. *MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity*. August. EPA-420-B-23-011.

Appendix B: Supplemental Tables

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This appendix includes additional summary tables providing more detail on the results of the GHG analysis.

Table A1 summarizes the vehicle operating emissions associated with the project alternatives. Emissions are in units of metric tons per day.

Table A1. Greenhouse Gas Emissions from Vehicle Operation (MT/day)

GHG	Baseline (2023)	No Action[1] (2050)	3GPL[2] (2050)	D 3GPL[3] (2050)	2GPL+1EL[4] (2050)	D 2GPL+1EL[5] (2050)
CO_2	389.595	216.218	244.932	28.714	226.376	10.158
CH_4	0.016	0.011	0.012	0.001	0.011	0.000
N_2O	0.009	0.017	0.019	0.002	0.017	0.000
Total CO_2e	392.715	221.417	250.762	29.345	231.655	10.238

[1] No Action Alternative

[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Table A2 summarizes the estimated annual VMT, by project alternative.

Table A2. VMT by Alternative (miles per year)

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2023	338,353,180	338,353,180	338,353,180
2024	345,329,109	345,329,109	345,329,109
2025	352,305,037	352,305,037	352,305,037
2026	359,280,965	359,280,965	359,280,965
2027	366,256,894	366,256,894	366,256,894

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2028	373,232,822	373,232,822	373,232,822
2029	380,208,750	380,208,750	380,208,750
2030	387,184,679	387,184,679	387,184,679
2031	394,160,607	394,160,607	394,160,607
2032	401,136,535	431,435,186	419,207,661
2033	408,112,464	441,777,631	428,191,492
2034	415,088,392	452,120,077	437,175,323
2035	422,064,320	462,462,522	446,159,154
2036	429,040,248	472,804,967	455,142,986
2037	436,016,177	483,147,412	464,126,817
2038	442,992,105	493,489,857	473,110,648
2039	449,968,033	503,832,302	482,094,479
2040	456,943,962	514,174,747	491,078,310
2041	463,919,890	524,517,192	500,062,141
2042	470,895,818	534,859,637	509,045,972
2043	477,871,747	545,202,082	518,029,804
2044	484,847,675	555,544,528	527,013,635
2045	491,823,603	565,886,973	535,997,466
2046	498,799,532	576,229,418	544,981,297
2047	505,775,460	586,571,863	553,965,128
2048	512,751,388	596,914,308	562,948,959
2049	519,727,317	607,256,753	571,932,791
2050	526,703,245	617,599,198	580,916,622

Table A3 summarizes the total construction emissions associated with each of the project alternatives. Table A4 summarizes the lifetime (2023-2050) maintenance emissions associated with each of the project alternatives. Emissions are in units of metric tons. Emissions estimates are provided only for CO_2e, because this is the only pollutant reported by the Infrastructure Carbon Estimator (ICE) tool.

Table A3. Lifetime Construction Emissions Associated with the Project Alternatives (MT)

	No Action[1]	3GPL[2]	D 3GPL[3]	2GPL+1EL[4]	D 2GPL+1EL[5]
Total CO_2e	11,656	50,831	+39,175	50,875	+39,219

[1] No Action Alternative

[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Table A4. Lifetime Maintenance Emissions Associated with the Project Alternatives (MT)

	No Action[1]	3GPL[2]	D 3GPL[3]	2GPL+1EL[4]	D 2GPL+1EL[5]
Total CO_2e	4382	3943	439	3943	439

[1] No Action Alternative

[2] 3GPL Alternative

[3] 2GPL+1EL Alternative

[4] Difference between the No Action Alternative and the 3GPL Alternative (3GPL-No Action) as the absolute change or (in parentheses) the percentage change

[5] Difference between the No Action Alternative and the 2GPL+EL Alternative (2GPL+1EL-No Action) as the absolute change or (in parentheses) the percentage change

Table A5 provides estimates of annual direct emissions. This includes emissions from vehicle operation, construction (for calendar years 2026 through 2031 when construction occurs), and maintenance.

Table A5. Annual Direct CO_2e Emissions Associated with the Project Alternatives (MT/year)

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2026	141,098	147,627	147,635
2027	138,588	145,117	145,125
2028	135,552	142,081	142,088
2029	132,108	138,637	138,644
2030	128,395	134,924	134,931
2031	124,504	131,033	131,040
2032	116,837	121,440	118,464
2033	112,847	118,133	114,712
2034	109,037	114,976	111,130
2035	105,348	111,919	107,661

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2036	101,894	109,056	104,414
2037	98,865	106,546	101,566
2038	96,137	104,286	99,001
2039	93,779	102,332	96,784
2040	91,787	100,681	94,911
2041	89,938	99,149	93,172
2042	88,330	97,816	91,661
2043	86,904	96,634	90,320
2044	85,581	95,539	89,076
2045	84,382	94,545	87,949
2046	83,353	93,692	86,981
2047	82,571	93,044	86,246
2048	81,848	92,445	85,566
2049	81,333	92,018	85,082
2050	80,992	91,736	84,762

Table A6 provides estimates of annual cumulative emissions. This includes the emissions from vehicle operation, construction and maintenance included in Table A5, plus indirect (upstream) emissions.

Table A6. Annual Cumulative CO_2e Emissions Associated with the Project Alternatives (MT/year)

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2026	186,727	193,256	193,263
2027	184,737	191,266	191,273
2028	182,206	188,735	188,742
2029	179,254	185,783	185,790
2030	174,470	180,999	181,006
2031	172,591	179,120	179,128
2032	164,973	173,212	168,769
2033	161,412	170,705	165,667
2034	158,017	168,326	162,716
2035	154,729	166,027	159,862

Year	No Action Alternative	3GPL Alternative	2GPL+1EL Alternative
2036	151,233	163,429	156,755
2037	148,571	161,625	154,476
2038	146,196	160,051	152,463
2039	143,726	158,257	150,297
2040	142,051	157,240	148,929
2041	140,505	156,321	147,679
2042	139,187	155,581	146,638
2043	137,558	154,426	145,231
2044	136,490	153,871	144,413
2045	136,024	153,963	144,229
2046	134,729	153,044	143,114
2047	134,160	152,874	142,750
2048	133,636	152,733	142,424
2049	133,306	152,743	142,275
2050	133,136	152,878	142,272

Table A7 provides the SCC values used in the analysis, by discount rate and calendar year. The SCC values used in the analysis were published in 2021 by the federal Interagency Working Group on Social Cost of Greenhouse Gases, in the document "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990."

Table A7. Annual Social Cost of Carbon values (calendar year 2020 dollars per MT)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2020	14	51	76	152
2021	15	52	78	155
2022	15	53	79	159
2023	16	54	80	162
2024	16	55	82	166
2025	17	56	83	169
2026	17	57	84	173
2027	18	59	86	176
2028	18	60	87	180
2029	19	61	88	183

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2030	19	62	89	187
2031	20	63	91	191
2032	21	64	92	194
2033	21	65	94	198
2034	22	66	95	202
2035	22	67	96	206
2036	23	69	98	210
2037	23	70	99	213
2038	24	71	100	217
2039	25	72	102	221
2040	25	73	103	225
2041	26	74	104	228
2042	26	75	106	232
2043	27	77	107	235
2044	28	78	108	239
2045	28	79	110	242
2046	29	80	111	246
2047	30	81	112	249
2048	30	82	114	253
2049	31	84	115	256
2050	32	85	116	260

Tables A8 through A10 provide the SCC estimates by alternative and calendar year, calculated using the cumulative CO_2e emissions by alternative and year (Table A6) and SCC values by year (Table A7).

Table A8. Annual SCC Estimates for the No Action Alternative (calendar year 2020 dollars per year)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2026	$3,174,355	$10,643,426	$15,685,049	$32,303,731
2027	$3,325,259	$10,899,461	$15,887,349	$32,513,645
2028	$3,279,705	$10,932,349	$15,851,906	$32,797,047
2029	$3,405,818	$10,934,470	$15,774,317	$32,803,409
2030	$3,314,925	$10,817,123	$15,527,805	$32,625,838
2031	$3,451,823	$10,873,241	$15,705,793	$32,964,906

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2032	$3,464,437	$10,558,285	$15,177,535	$32,004,802
2033	$3,389,654	$10,491,788	$15,172,739	$31,959,599
2034	$3,476,374	$10,429,122	$15,011,616	$31,919,435
2035	$3,404,040	$10,366,849	$14,853,992	$31,874,191
2036	$3,478,367	$10,435,101	$14,820,868	$31,759,002
2037	$3,417,126	$10,399,948	$14,708,498	$31,645,557
2038	$3,508,693	$10,379,884	$14,619,555	$31,724,434
2039	$3,593,146	$10,348,260	$14,660,034	$31,763,408
2040	$3,551,263	$10,369,689	$14,631,205	$31,961,370
2041	$3,653,128	$10,397,364	$14,612,512	$32,035,121
2042	$3,618,858	$10,439,013	$14,753,805	$32,291,347
2043	$3,714,068	$10,591,970	$14,718,712	$32,326,143
2044	$3,821,731	$10,646,250	$14,740,962	$32,621,203
2045	$3,808,664	$10,745,872	$14,962,607	$32,917,736
2046	$3,907,155	$10,778,359	$14,954,973	$33,143,454
2047	$4,024,793	$10,866,941	$15,025,893	$33,405,780
2048	$4,009,070	$10,958,125	$15,234,466	$33,809,823
2049	$4,132,473	$11,197,668	$15,330,140	$34,126,225
2050	$4,260,350	$11,316,554	$15,443,767	$34,615,341
Total	$90,185,273	$266,817,110	$377,866,099	$813,912,549

Table A9. Annual SCC Estimates for the 3GPL Alternative (calendar year 2020 dollars per year)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2026	$3,285,350	$11,015,587	$16,233,496	$33,433,272
2027	$3,442,784	$11,284,680	$16,448,855	$33,662,773
2028	$3,397,229	$11,324,097	$16,419,941	$33,972,292
2029	$3,529,872	$11,332,747	$16,348,881	$33,998,241
2030	$3,438,978	$11,221,929	$16,108,899	$33,846,787

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2031	$3,582,405	$11,284,577	$16,299,944	$34,211,971
2032	$3,637,447	$11,085,553	$15,935,483	$33,603,084
2033	$3,584,795	$11,095,795	$16,046,227	$33,799,500
2034	$3,703,166	$11,109,499	$15,990,945	$34,001,800
2035	$3,652,586	$11,123,785	$15,938,557	$34,201,487
2036	$3,758,865	$11,276,596	$16,016,035	$34,320,076
2037	$3,717,379	$11,313,762	$16,000,893	$34,426,163
2038	$3,841,213	$11,363,590	$16,005,056	$34,730,971
2039	$3,956,437	$11,394,539	$16,142,263	$34,974,904
2040	$3,931,000	$11,478,521	$16,195,721	$35,379,003
2041	$4,064,343	$11,567,745	$16,257,371	$35,641,161
2042	$4,045,111	$11,668,589	$16,491,605	$36,094,834
2043	$4,169,493	$11,890,778	$16,523,548	$36,290,036
2044	$4,308,379	$12,001,914	$16,618,034	$36,775,095
2045	$4,310,962	$12,163,070	$16,935,921	$37,259,026
2046	$4,438,265	$12,243,490	$16,987,842	$37,648,731
2047	$4,586,217	$12,382,786	$17,121,876	$38,065,600
2048	$4,581,986	$12,524,095	$17,411,546	$38,641,414
2049	$4,735,047	$12,830,451	$17,565,499	$39,102,328
2050	$4,892,093	$12,994,623	$17,733,838	$39,748,259
Total	$98,591,406	$290,972,797	$411,778,280	$887,828,806

Table A10. Annual SCC Estimates for the 2GPL+1EL Alternative (calendar year 2020 dollars per year)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2026	$3,285,475	$11,016,005	$16,234,112	$33,434,541
2027	$3,442,916	$11,285,112	$16,449,486	$33,664,064
2028	$3,397,361	$11,324,537	$16,420,579	$33,973,612

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate	3% Discount Rate 95th Percentile
2029	$3,530,011	$11,333,194	$16,349,526	$33,999,583
2030	$3,439,118	$11,222,384	$16,109,551	$33,848,159
2031	$3,582,552	$11,285,039	$16,300,612	$34,213,372
2032	$3,544,140	$10,801,190	$15,526,710	$32,741,106
2033	$3,479,004	$10,768,345	$15,572,684	$32,802,037
2034	$3,579,759	$10,739,277	$15,458,051	$32,868,697
2035	$3,516,958	$10,710,736	$15,346,726	$32,931,516
2036	$3,605,368	$10,816,105	$15,362,004	$32,918,579
2037	$3,552,955	$10,813,342	$15,293,155	$32,903,455
2038	$3,659,111	$10,824,871	$15,246,297	$33,084,465
2039	$3,757,421	$10,821,372	$15,330,277	$33,215,599
2040	$3,723,234	$10,871,845	$15,339,726	$33,509,110
2041	$3,839,654	$10,928,246	$15,358,617	$33,670,814
2042	$3,812,581	$10,997,829	$15,543,599	$34,019,952
2043	$3,921,230	$11,182,766	$15,539,688	$34,129,222
2044	$4,043,557	$11,264,196	$15,596,579	$34,514,651
2045	$4,038,400	$11,394,058	$15,865,144	$34,903,317
2046	$4,150,316	$11,449,147	$15,885,692	$35,206,128
2047	$4,282,500	$11,562,750	$15,988,001	$35,544,751
2048	$4,272,712	$11,678,746	$16,236,305	$36,033,203
2049	$4,410,525	$11,951,100	$16,361,625	$36,422,399
2050	$4,552,713	$12,093,144	$16,503,585	$36,990,795
Total	$94,419,573	$279,135,337	$395,218,330	$851,543,127