Boulder County Transportation Master Plan Emissions Reduction Modeling Report

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FOX TUTTLE

LOTUS
Engineering & Sustainability

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Key Takeaways

Project Background

Reducing vehicle miles traveled (VMT) from fossil fuel vehicles is a vital step in combatting climate change. Sixty-two proposed projects from Boulder County's Transportation Master Plan (TMP) were evaluated to understand their potential for VMT and greenhouse gas (GHG) emissions reductions. TMP projects were analyzed in two ways. First, the VMT and emissions reductions were calculated through 2040 assuming all projects were completed in 2022. This shows the potential cumulative impact of each project on the same timeline. Second, VMT and GHG reductions were calculated through 2040 based on the estimated implementation date of each project. This analysis allows Boulder County to understand how progress in project implementation will affect overall VMT and GHG reductions through 2040.

Within each analysis, projects were split into five project categories: Road projects, trail projects, multi-use path projects, transit service projects, and fare free transit projects. VMT and GHG emissions reductions were summarized for all projects and split by project category. The impact of Boulder County's investment into these projects was also evaluated for each project category. Key findings from each analysis, and by project category are discussed below. Boulder County can use this analysis to identify projects with the greatest impact on VMT and GHG emissions and monitor emissions reductions as projects are implemented.

Key Findings for All TMP Projects (Implementation Date Not Considered: 2022 – 2040):

- Cumulatively, if all 62 evaluated TMP projects were to be implemented in 2022, 477,053 mt CO_2e (metric tons of CO_2e) would be avoided by 2040. This reduction is equivalent to removing 5,711 gasoline powered passenger vehicles from the road.
- Based on total leveraged cost of all evaluated TMP projects, Boulder County avoids one mt CO_2e for every $1,767 invested and every $1 million invested by Boulder County avoids 566 mt CO_2e.
- Implementation of these TMP projects is a step forward towards Boulder County's overall emissions reduction goal and are an integral part of County climate action.
    - By 2040, the TMP projects contribute a 0.5 percent reduction in total Countywide emissions from a 2005 baseline.
- By 2040, the TMP projects are modeled to reduce Boulder County VMT per capita by 308 miles per capita (from 6,816 VMT per capita without the TMP projects to 6,508 VMT per capita with the projects).

- The TMP projects have environmental co-benefits outside of GHG emissions reductions including air quality improvements and bettering the quality of life in the County.

Key Findings for All TMP Projects (Implementation Date Considered: Implementation Date – 2040)

- The actual benefit of the county's TMP on GHG emissions depends on how much progress the county can make on implementing these projects.
- Assuming all the projects are implemented on the forecasted timeline, the TMP projects listed in this report would avoid 262,841 mt CO_2e by 2040 for a total cost of $3.9 billion. This reduction is equivalent to removing 3,146 gasoline powered passenger vehicles from the road.
- Every $1 million invested by Boulder County into the analyzed TMP projects will avoid 312 mt CO_2e.
- In 2040, all the TMP projects together would reduce emissions by 23,169 mt CO_2e that year. This equates to a 2.6 percent reduction in emissions from Boulder County's 2019 on-road transportation emissions (891,538 mt CO_2e).

Key Findings by Project Category

- If all the projects were to be implemented, **transit projects** (transit service and fare free projects together) would provide Boulder County with the greatest reduction in emissions, avoiding 220,899 mt CO_2e cumulatively.
- **Transit service projects** are the costliest and require the most investment to realize VMT and GHG reductions compared with other project types (i.e., it takes more money for a transit project to avoid one mt CO_2e than any other project type).
- **Fare-free transit projects** require the least amount of investment for the greatest VMT and GHG reductions.
- **Multi-use path projects** have high potential for VMT and GHG reductions and require less investment to realize those reductions than all other project types except fare-free transit projects. Multi-Use path projects avoid 183,724 mt CO_2e cumulatively from 2022 through 2040.
- While **multi-use path projects** have high investment impact, these projects tend to be used for shorter trips, are more weather dependent, and are less available for general commuting trips.
- **Road and trail projects** have the lowest total impact on VMT reductions and GHG emissions than the other project categories.

- The Colorado 7 Bus Rapid Transit, Intersection Safety, and Commuter Bikeway ($435 million) and the Boulder to Longmont Multi-use Path ($40 million) projects are expected to have the most emissions reductions out of all projects.

Introduction

Background

In 2019, Boulder County adopted an updated version of the County's Transportation Master Plan (TMP). The purpose of the updated TMP is to aid in implementing "…high quality, safe, sustainable, and environmentally responsible transportation infrastructure and services across all modes, to meet the mobility and access needs of all users".[1] Part of the TMP vision is to minimize the environmental impacts of the transportation system, including greenhouse gas (GHG) emissions and Vehicle Miles Traveled (VMT). Additionally, Boulder County has a goal to reduce GHG emissions by 45 percent by 2030 (compared to a 2005) baseline. Fox Tuttle Transportation Group and Lotus Engineering and Sustainability (Lotus) were hired to assess the VMT and GHG emissions reduction impacts of projects planned through the TMP. Sixty-two projects from the TMP anticipated to have an impact on VMT and GHG emissions were selected for this analysis. Fox Tuttle analyzed the selected TMP projects to assess projected VMT reductions from each project. Lotus used the VMT reduction estimates provided by Fox Tuttle to calculate GHG emissions reduction from each of the 62 TMP projects.

Project Objective

The purpose of this project is to quantify the GHG emissions reduction potential of the transportation projects included in the updated TMP. Fox Tuttle and Lotus developed an Excel-based tool that models GHG emissions reduction potential for the selected projects. Projects were evaluated by assessing emissions reductions based on current traffic conditions (2022) and traffic conditions in 2040. Lotus evaluated avoided emissions in two ways. First, Lotus calculated emissions reductions for all projects assuming they were all to be implemented in 2022. This allows for a direct comparison of potential project impacts, regardless of project cost which needs to be considered as well. Second, Lotus incorporated estimated project implementation dates to provide a more realistic view of potential avoided emissions from TMP projects once implemented. Key takeaways from both analyses can be found below.

The analysis will provide Boulder County with the tools to understand the impact of each TMP project on GHG emissions and track avoided emissions from projects as they are implemented

[1] Boulder County Transportation Master Plan Summary: https://assets.bouldercounty.org/wp-content/uploads/2020/02/transportation-master-plan-tmp-update-summary-document-final.pdf

and when combined with cost analysis, come up with an effective implementation plan that incorporates both VMT and greenhouse gas impacts. Fox Tuttle and Lotus hope that this work aids the Boulder County Transportation Department in monitoring progress toward reaching the TMP's goal of minimizing environmental impact.

Results

The following assumptions should be noted before interpreting the results below:

- This analysis assumes that all 62 projects are implemented between now and 2040. These projects have a total cost of $3.9 billion dollars. The analysis assumes that Boulder County would be responsible for paying $843 million of those costs and additional funds would come from other local, regional, state and federal sources.
- Boulder County does not currently have the funding to implement all projects by 2040. Additional funding sources would be needed to complete all projects in this timeframe. This analysis presents results in an assumed scenario where all projects can be funded by 2040.
- Each of the project categories include a different number of projects and varying amounts of project costs. The impacts of each project category are compared within the context of all TMP projects, not as representations of the effectiveness of a specific project type (i.e., results from each project category only reflect the impacts of the specific TMP projects within that category. They may not reflect the impacts of a project of that type outside of the contexts of the TMP). Project categories that contain more projects may have greater GHG emissions reductions than other categories with fewer projects. See the investment impact results for a normalized comparison across project categories.

VMT Reductions

In current traffic conditions with all projects implemented, Boulder County would reduce on-road VMT by 93,699,917 miles per year. Based on estimated traffic conditions in 2040, all projects would reduce on-road VMT by 114,559,414 miles per year.

The seventeen transit service projects in the analysis have the largest impact on VMT, with an annual reduction of 46,626,878 miles driven based on current traffic conditions and 57,834,544 miles driven in 2040 traffic conditions. All for a cost of $1.8 billion, with $360 million coming from the county. While transit projects reduce VMT by single-occupancy vehicles, they also increase

miles traveled by buses through new or extended routes. Transit projects would increase annual VMT by 3,314,119 miles. Including additional bus VMT, transit service projects would have a net VMT reduction of 43,312,759 miles in 2022 and 54,520,425 miles in 2040 (See Figure 1). The seven fare free transit projects are treated separately as it is assumed that they will not cause any changes in service and lead to increased VMT.

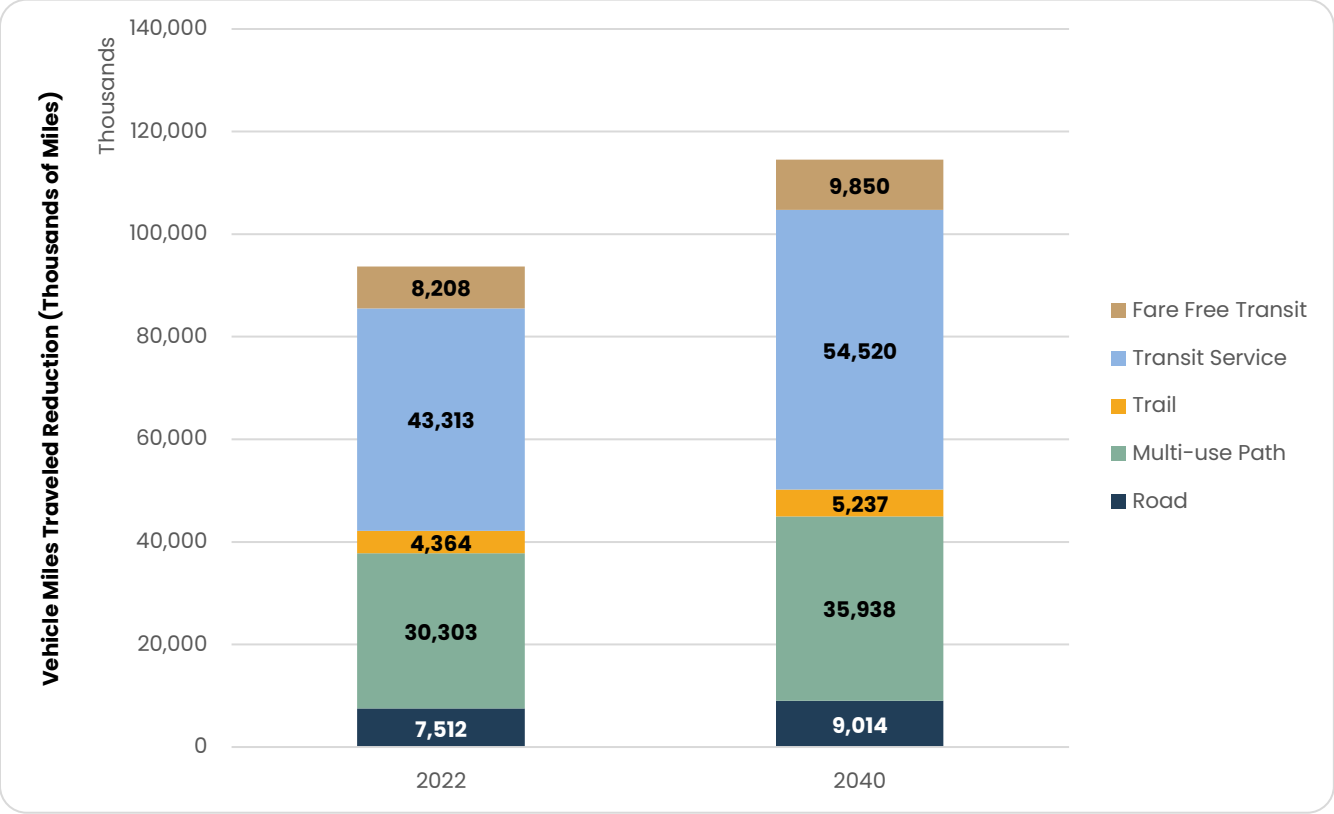

Figure 1. 2022 and 2040 VMT reduction by project category.

The 35 non-transit projects, if fully implemented for a total cost of $521 million, would reduce VMT by an estimated 50,188,900 VMT in 2040.

The $174 million in multi-use path projects have the largest impact on VMT for all non-transit projects, reducing VMT by 30,303,250 miles driven in 2022 and 35,938,300 miles driven in 2040. These multi-use path projects also have the biggest impact of each dollar spent with an estimated 112,000-mile reduction in annual VMT per $1.0 million spent on these projects.

When project implementation dates are considered, the TMP projects would reduce VMT by 1.2 billion miles cumulatively by 2040. In 2040, projects would lead to 117.8 million miles in VMT reductions, a 5.3 percent reduction from 2019 VMT levels (Figure 2).

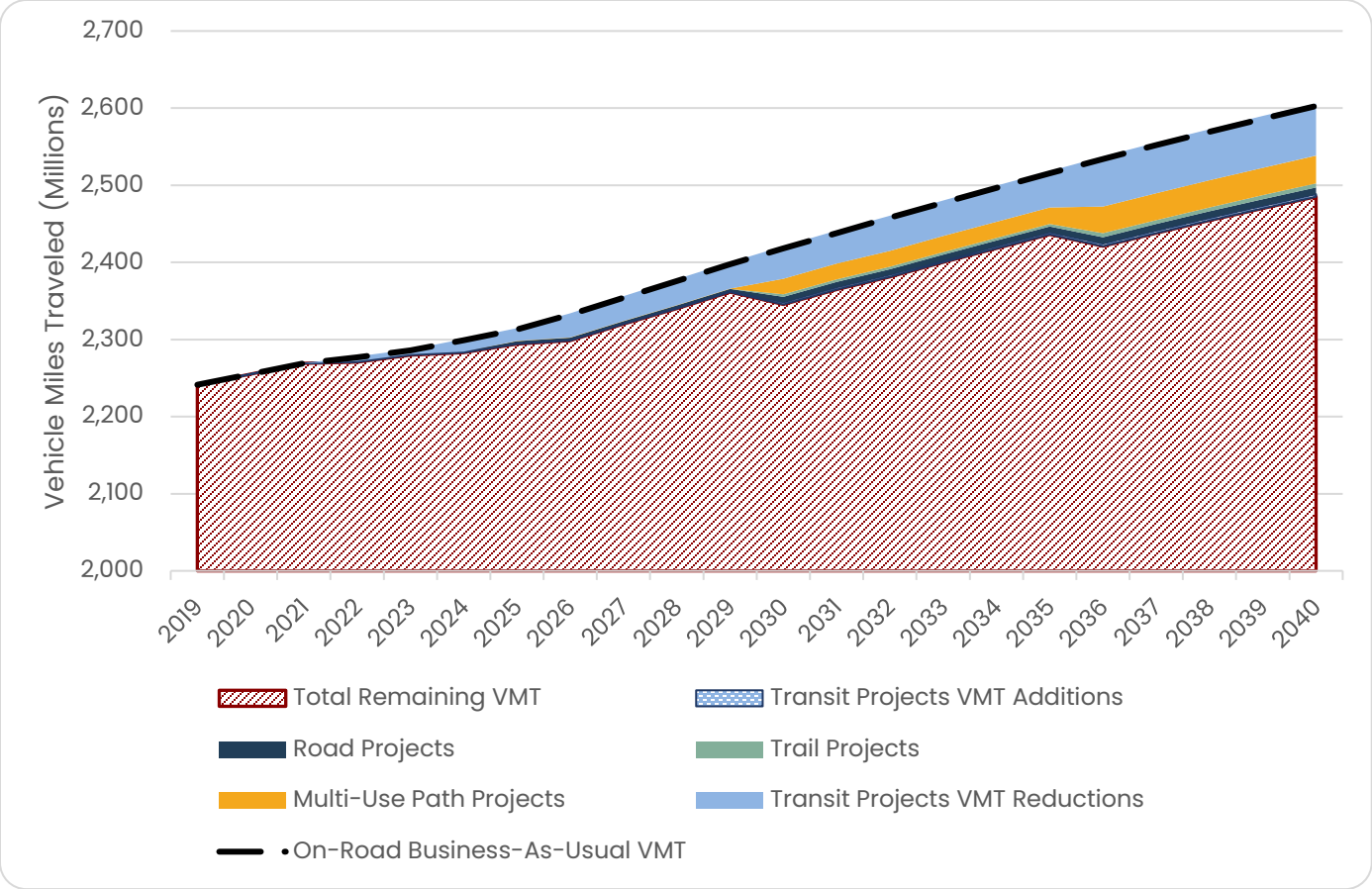

Figure 2. Year-to-year VMT reductions by project category compared to Boulder County's Business-As-Usual VMT.

This reduction equates to a decrease in VMT per capita of 308 miles in 2040, from 6,816 VMT per capita without the TMP projects to 6,508 VMT per capita with the TMP projects. VMT per capita was calculated based on only the Boulder County resident population. Individuals who live outside of Boulder County but are employed within the county also contribute to total VMT. Data on the number of people who live outside Boulder County but commute to the county was unavailable.

Emission Reductions

Emission reductions from TMP projects are presented in two ways. First, emissions reductions are summarized for projects as if all projects were to be implemented in 2022. This allows emission reductions to be compared across the same timeline and for the most impactful projects to be identified. Second, emissions reductions calculated for all projects based on an estimated project implementation year are presented. This method only calculates emissions reductions from project implementation years through 2040 and is useful for monitoring actual

expected emissions reductions. The investment impact of TMP project leveraged costs is presented for each emissions reduction calculation method.

Note that the tool used to calculate these results is interactive and users can change various inputs used in emissions reduction calculations. Changing the inputs may cause the results from the tool to not align with this report.

Emissions Reductions without Project Implementation Dates

Emissions Reductions

The emissions reductions calculated for each project without considering the implementation year allows Boulder County to prioritize projects with the greatest potential VMT and emissions reductions. The results in this section evaluate project impact on the same timeline (2022 through 2040) and are not meant to convey actual expected emissions reductions. Results are displayed below for 2022, 2040, and cumulatively from 2022 through 2040.

All 62 projects included in the analysis, if implemented in 2022, would avoid 29,277 metric tons (mt) of CO_2e in their first year.

In 2040, annual emissions reductions for all projects would be 23,169 mt CO_2e, a decrease from 2022 annual reductions. This decrease in 2040 does not mean that projects are less effective at reducing VMT and emissions in 2040, but that emissions reductions are also occurring at the vehicle level rather than entirely coming from the individual projects. The VMT reduction results from Fox Tuttle show an increase in VMT reductions between 2022 and 2040 (97,014,036 VMT in 2022 and 117,873,533 in 2040, excluding additional VMT from transit). While VMT reductions increase, more EVs on the road, a cleaner electric grid, and improvements in fuel efficiency reduce the emissions intensity of on-road VMT by 2040.

Multi-use path projects avoid the most emissions of all project categories and are estimated to avoid 111,094 mt CO_2e in 2022 and 8,962 mt CO_2e in 2040 (See Figure 3).

Transit service projects have slightly lower avoided emissions than multi-use path projects. Transit service projects have the greatest impact on VMT but additional emissions from buses or rail on new or extended routes reduce the net avoided emissions from transit service projects. Fare free transit projects are treated as a different project category from other transit service projects as they are based on existing routes and do not produce additional emissions. VMT reductions for transit service projects increased from 42,403,243 miles to 53,610,909 from 2022 to 2040. Emissions reductions are lower in 2040 than in 2022 despite an increase in VMT reductions due to the reasons mentioned above.

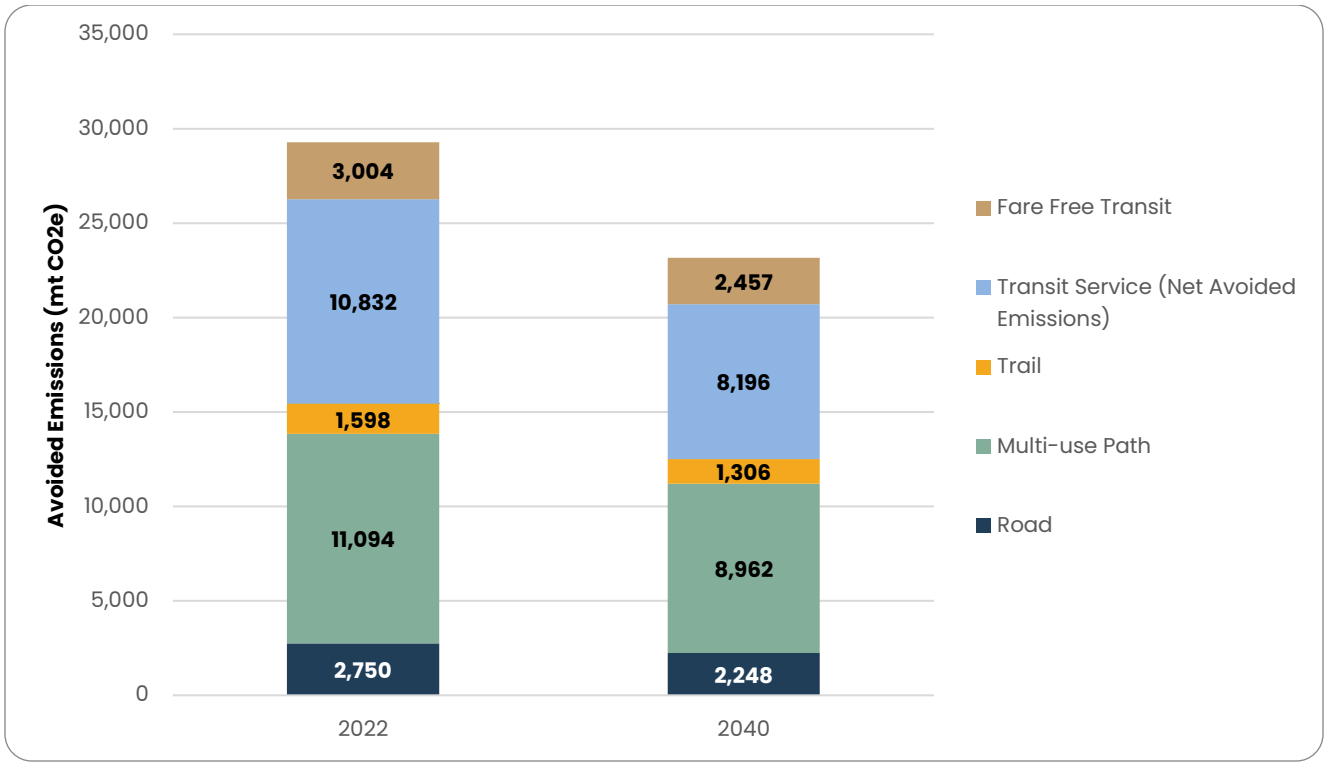

Figure 3. 2022 and 2040 annual emissions reductions by project category.

Cumulatively, if implemented in 2022 all projects would avoid 477,053 mt CO_2e by 2040. This reduction is equivalent to removing 5,711 gasoline passenger vehicles from the road. Transit service and fare free transit projects account for 46 percent of cumulative avoided emissions from 2022 through 2040 (See Figure 4). Road and trail projects have less total impact on VMT and GHG emissions reductions than the other project categories.

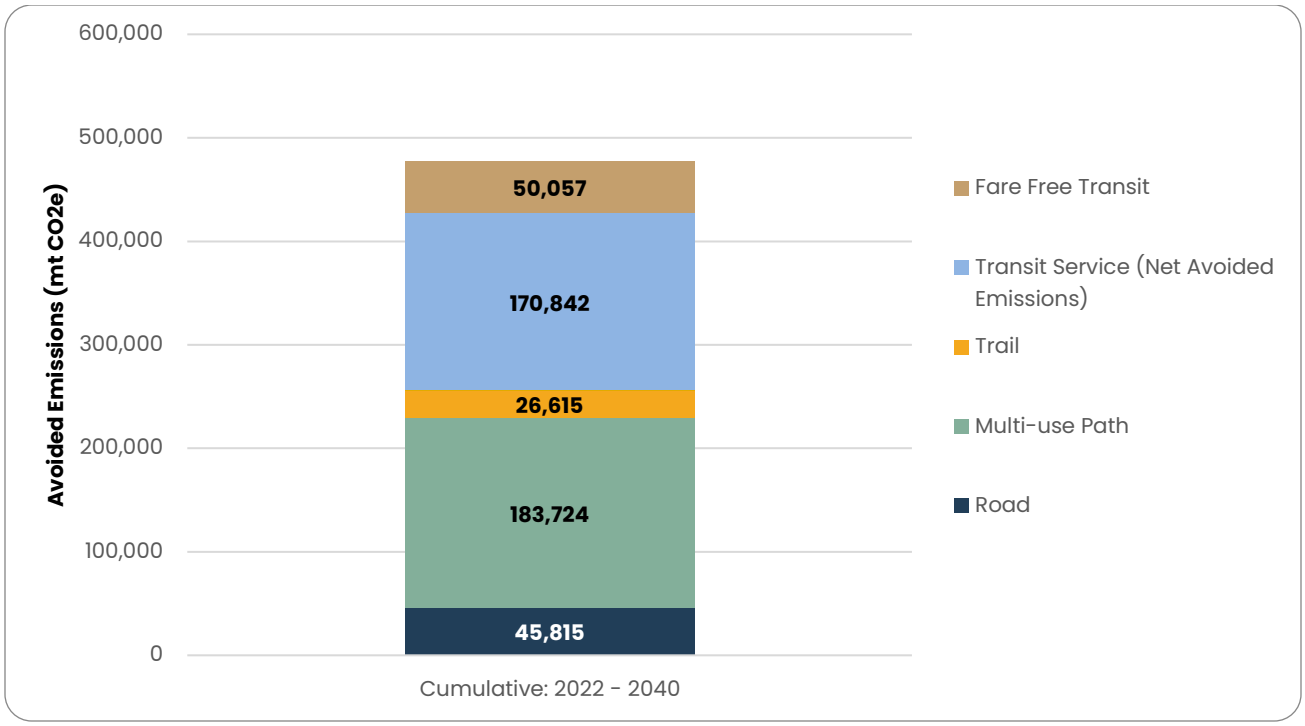

Figure 4. Cumulative emissions reductions from 2022 through 2040 by project category.

Table 1 shows the five TMP projects projected to avoid the most emissions. The Colorado 7 Bus Rapid Transit, Intersection Safety, and Commuter Bikeway would avoid the most emissions of all projects included in this analysis. If implemented in 2022, this project would avoid 81,364 mt CO_2e by 2040. The Boulder to Longmont Multi-use Path project would provide the greatest emissions reductions for all non-transit projects. All but one of the projects selected for this analysis had a net positive impact on GHG reductions. See Appendix E for a full list of cumulative emissions reductions by project.

Table 1. Five TMP projects projected to have the highest cumulative emissions reductions from 2022 through 2040.

Project Name	Project Type	2022 Avoided Emissions (mt CO_2e)	2040 Avoided Emissions (mt CO_2e)	Cumulative Avoided Emissions (mt CO_2e)	Estimated Total Project Costs
Colorado 7 Bus Rapid Transit, Intersection Safety and Commuter Bikeway	Transit Service	4,765	4,096	81,364	$435 M
Boulder to Longmont Multi-Use Path	Multi-Use Path	2,900	2,370	48,305	$40 M
Highway 93 Multi-Use Path – Hwy 170 south to Jefferson County	Multi-use Path	2,226	1,713	35,982	$4.2 M
Northwest Corridor Commuter Rail – Denver to Longmont	Transit Service	2,275	1,535	33,738	$1.5 B
US 287 Bikeway – Hwy 66 to Larimer County Line	Multi-use Path	2,021	1,652	33,667	$2.3 M

Investment Impact

Emissions reductions without considering project implementation dates were normalized by Boulder County's investment into the TMP projects (leveraged project costs). This allows Boulder County to understand the impacts of their investments on emissions reductions. The total leveraged cost of all 62 projects evaluated in this analysis is $842,732,078. With cumulative emissions reductions from all evaluated TMP projects expected to be 477,053 mt CO_2e by 2040, every $1,767 dollars invested in these projects by Boulder County is expected to reduce 1 mt CO_2e. Every $1 million in investment by Boulder County is expected to reduce 566 mt CO_2e between 2022 – 2040.

Figure 5 and Figure 6 show the emissions impact of Boulder County's investment into the TMP projects by project category. Fare free transit projects have the greatest investment impact on emissions reductions with every $1 million in investment into these types of projects reducing 14,628 mt CO_2e and every $68 in investment reducing 1 mt CO_2e. The costs associated with fare free projects assume that no additional transit service is needed to accommodate new ridership from fare free routes. Additional service would increase the cost of implementing these projects and reduce investment impact. The fare free projects considered in this analysis

can accommodate a significant increase in ridership before additional service would be needed.[2]

Multi-use path projects have the greatest investment impact on emissions reductions after fare free projects with every $1 million in investment into these types of projects reducing 6,661 mt CO_2e and every $150 in investment reducing 1 mt CO_2e. Transit service projects are modeled to have the most emissions reductions out of all project categories but have the greatest costs to realize those reductions. Transit service projects require $4,048 in investment to reduce 1 mt CO_2e, and only reduce 247 mt CO_2e per $1 million invested.

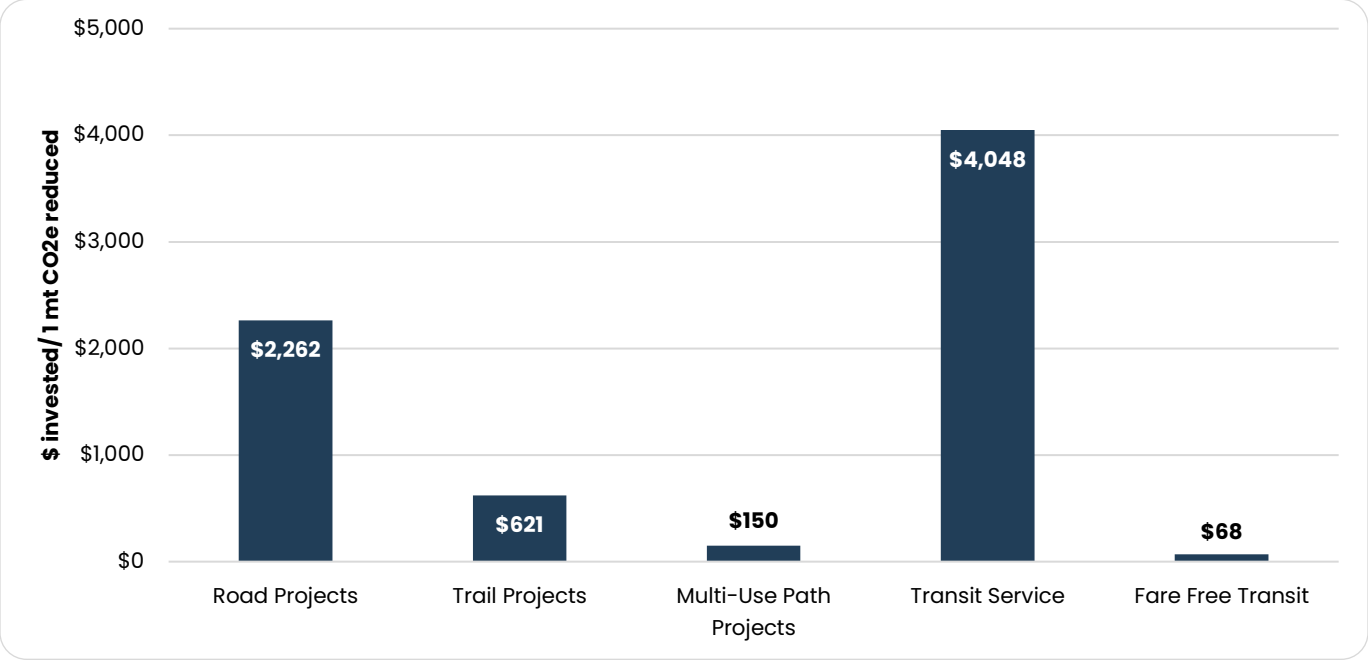

Figure 5. Boulder County dollars invested to reduce 1 mt CO_2e by project category without considering project implementation dates.

[2] See Table A 2. The VMT reduction analysis assumes that the transit routes that will be converted to fare free can accommodate an additional 2,260 riders per day without an increase in service.

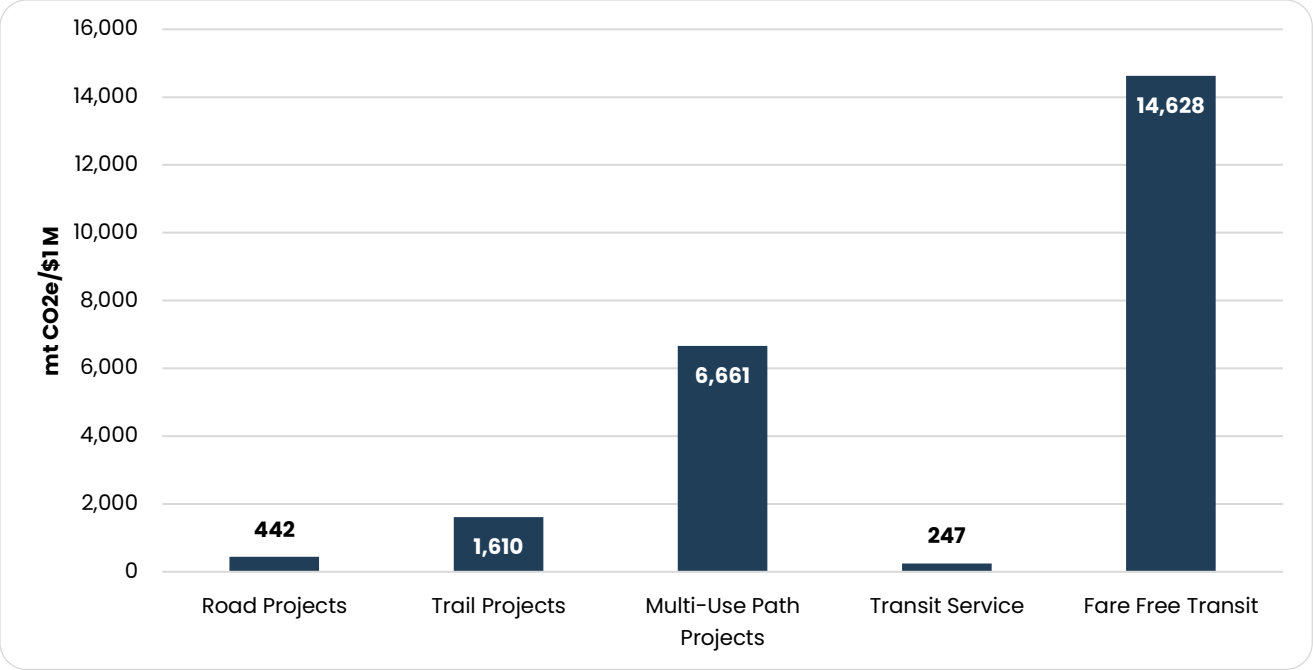

Figure 6. Mt CO_2e reduced per $1 million of investment into TMP projects by Boulder County without considering project implementation dates.

Emissions Reductions Including Project Implementation Dates

Emissions Reductions

While the emissions reductions without considering the implementation date are useful for direct comparison of project impact, including the implementation date allows emissions reduction progress to be accurately monitored. The implementation year can significantly affect the cumulative avoided emissions potential for projects. While this analysis does not calculate emissions reductions past 2040, projects would continue to have emissions reductions beyond 2040 as long as the projects reduce automobile VMT.

The implementation years provided by Boulder County were used to estimate avoided emissions year by year from each project's implementation year out to 2040. Implementation years were provided as ranges for each project so the mid-point year within the range was used. Compared to the avoided emissions calculated without the implementation years, avoided emissions inclusive of the implementation year are significantly lower. This is expected as the project implementation dates provided for each project range from 2025 through 2036.

When considering the project implementation year, all projects would avoid 262,841 mt CO_2e cumulatively, by 2040. This reduction is equivalent to removing 3,146 gasoline passenger vehicles from the road. Figure 7 shows the expected reductions in emissions over time from the

TMP projects compared to the 2019 baseline and the Business-As-Usual (BAU) model. The black dotted line indicates where emissions are expected to be each year in a BAU scenario. The solid-colored sections indicate the reductions from the TMP projects, split by category. The dashed red section shows the total remaining emissions after reductions from the projects are subtracted. The BAU model decreases over time in addition to the reductions provided by the TMP projects due to EV adoption and fuel efficiency improvements.

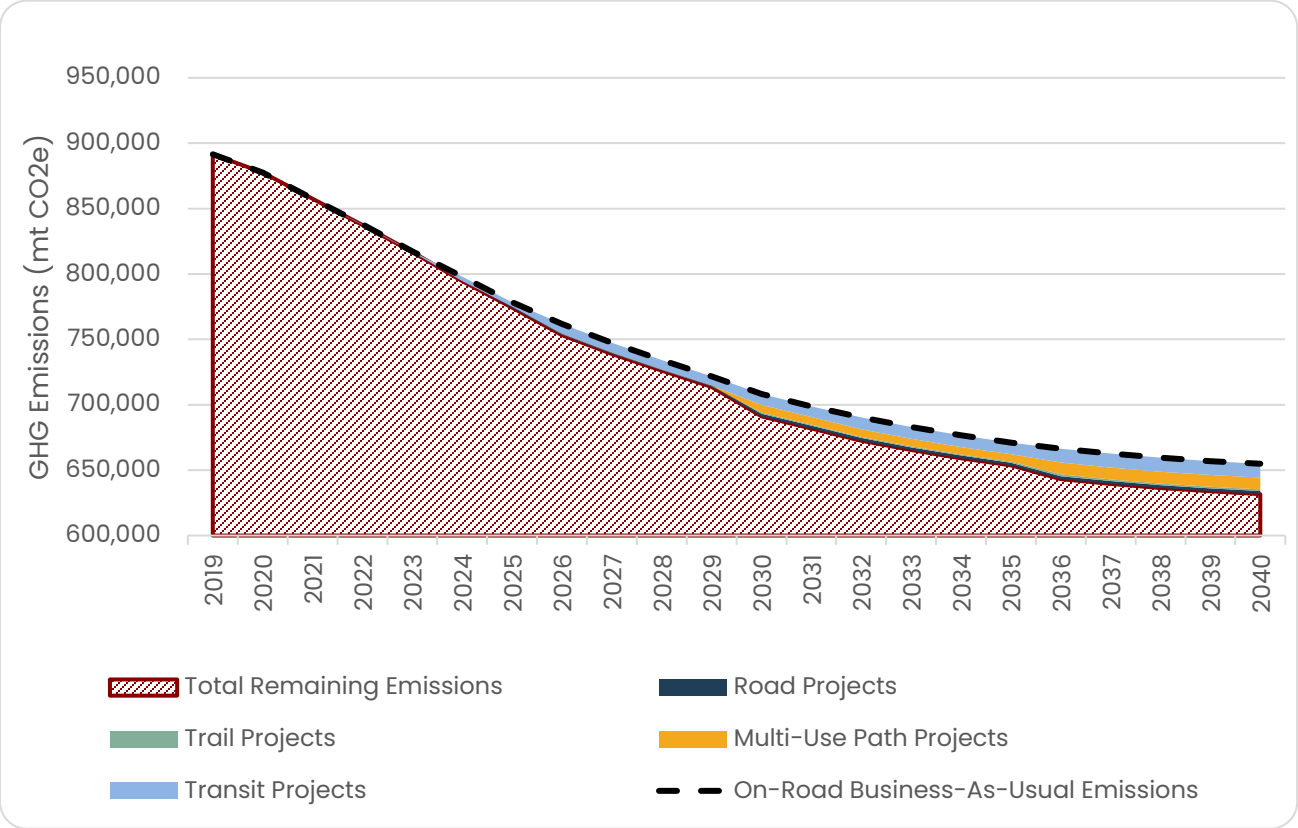

Figure 7. Year-to-year emissions reductions by project category compared to Boulder County's Business-As-Usual transportation emissions model.

In 2040, compared to the BAU modeled emissions, the TMP projects are expected to avoid 23,169 mt CO_2e, resulting in 631,736 mt CO_2e remaining transportation emissions. Without the TMP projects, 2040 Boulder County on-road transportation emissions would total 654,905 mt CO_2e. Compared to the 2019 baseline, this reduction in 2040 equates to a 2.6 percent reduction in Boulder County's on-road transportation emissions.

Transit Service and multi-use path projects would provide the greatest reductions in emissions by 2040 (143,323 mt CO_2e and 80,521 mt CO_2e respectively). From least to most, trail projects, road projects, and fare free transit projects avoid the remaining emissions (See Figure 8).

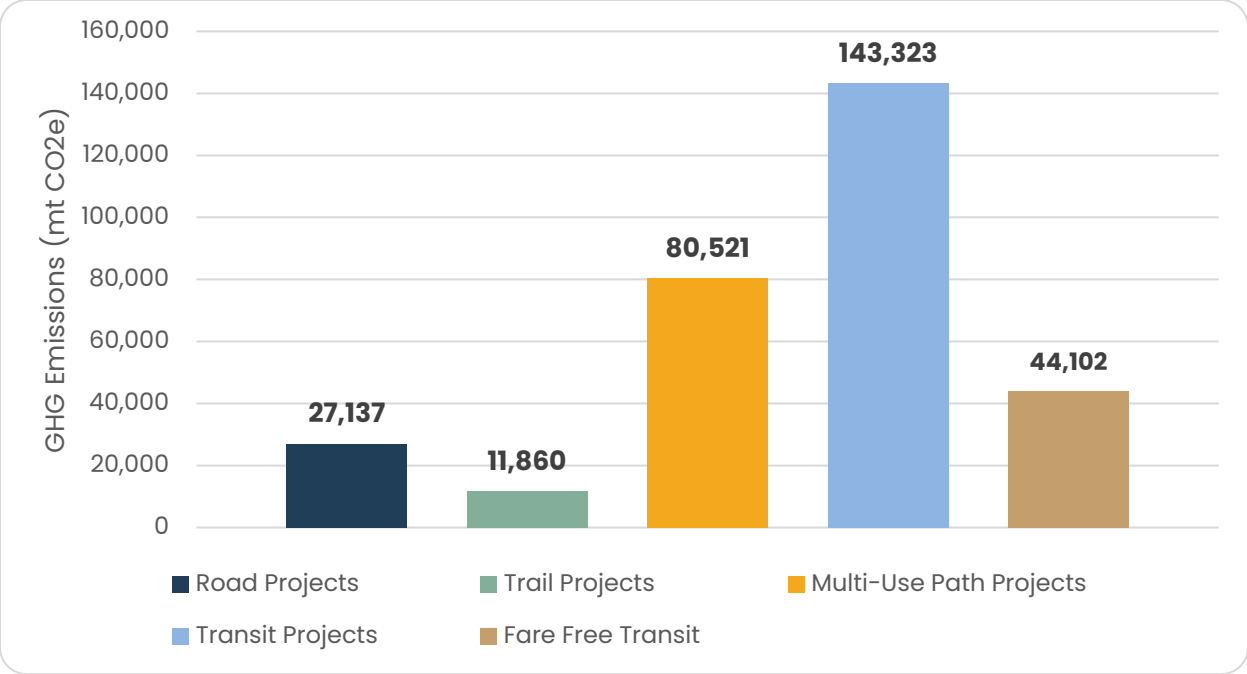

Figure 8. Cumulative emissions reductions from project implementation date through 2040 by project category.

The three projects modeled to have the highest emission reductions when considering the implementation year are transit service and multi-use path projects (Table 2). The projects that would provide the fourth and fifth most emissions reductions are fare-free transit projects. These project, when considered without the implementation date, would not be within the top ten most impactful projects. However, as they have early implementation years compared to other projects with greater infrastructural changes needed, emissions reductions build up for these projects over time. See Appendix E for a full list of cumulative emissions by project with the implementation date considered.

Table 2. Five TMP projects projected to have the highest cumulative emissions reductions from project implementation year through 2040 (Fare free option projects do not have cost data).

Project Name	Project Category	Estimated Construction Year	Cumulative Avoided Emissions (mt CO_2e)	Estimated Total Project Cost
Colorado 7 Bus Rapid Transit, Intersection Safety and Commuter Bikeway	Transit Service	2026	62,742	$435 M
Boulder to Longmont Multiuse Path	Multi-use Path	2030	26,559	$40 M
Highway 7 Multiuse Path - 119th Street to East County Line	Multi-use Path	2030	11,401	$2.05 M
Fare Free Option - DASH	Fare Free	2024	10,531	$672,437
Fare Free Option – JUMP	Fare Free	2024	9,760	$578,678

Investment Impact

When project implementation dates are considered in emissions calculations, the investment impact on emissions reductions through 2040 is smaller compared to when projects are assumed to start at the same time. This is expected as emissions reductions do not occur for some projects until later in the evaluated time frame. When implementation dates are considered, every $3,206 invested by Boulder County would reduce 1 mt CO_2e through 2040 and every $1 million in investment would reduce 312 mt CO_2e. Emissions reductions from projects after 2040 are not considered in this analysis so the long-term impacts of projects implemented closer to 2040 are not accounted for in the investment impact calculations.

Fare free transit projects still have the greatest investment impact on emissions out of all project categories when project implementation dates are considered (Figure 9 and Figure 10). The costs to reduce 1 mt CO_2e increase significantly for all project categories compared to when project implementation dates are not considered. Transit service projects still require the greatest investment to reduce 1 mt CO_2e.

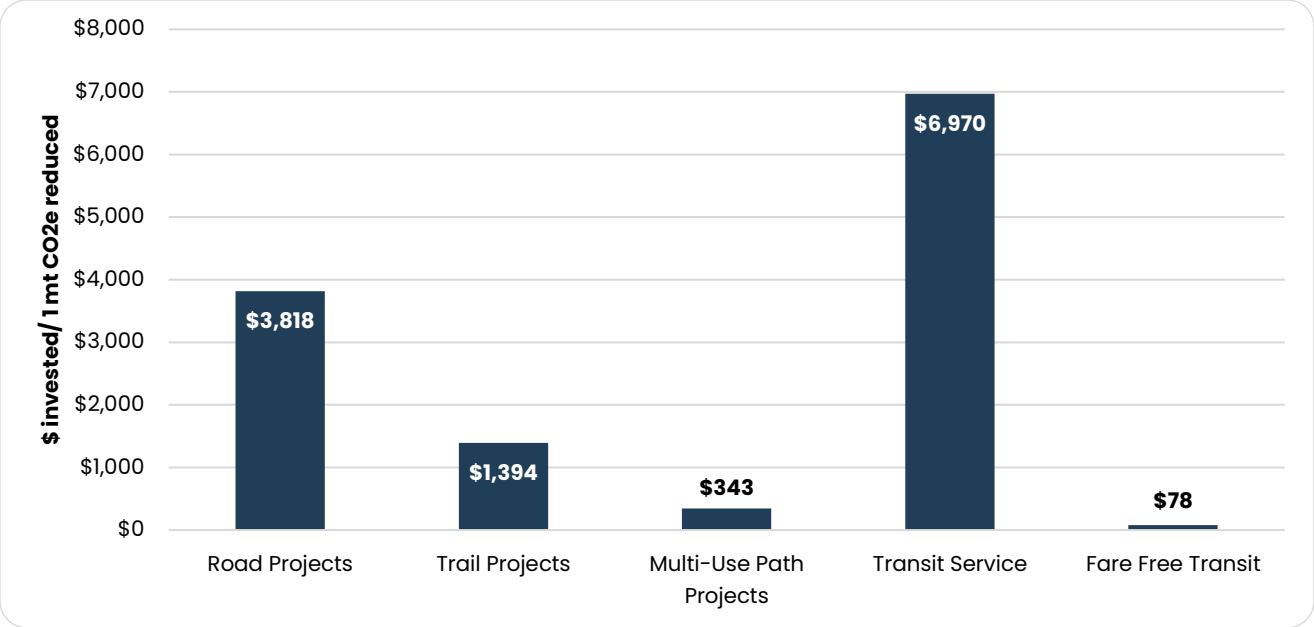

Figure 9. Boulder County dollars invested to reduce 1 mt CO_2e by project category considering project implementation dates.

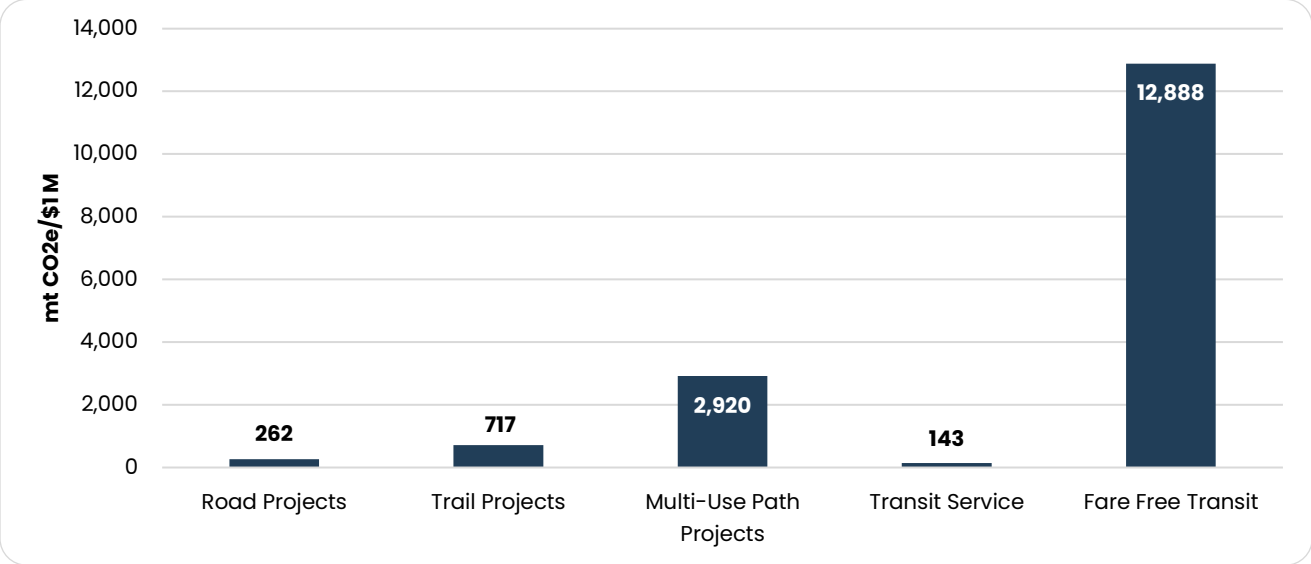

Figure 10. Mt CO_2e reduced per $1 million invested into TMP projects by Boulder County considering project implementation dates.

Analysis Comparison

In conjunction, the two analyses described above allow Boulder County to identify the most impactful projects overall and understand emissions reductions when project feasibility and timelines are considered. When project timelines are not considered, multi-use path projects are modeled to reduce emissions more than any other project category. When implementation

dates are considered, transit projects are modeled to have the greatest emissions reductions (See Figure 11). This difference is due to multi-use path projects having later implementation dates on average than transit projects. All seven fare free transit projects could be implemented sooner than any of the multi-use path projects.

The Colorado 7 Bus Rapid Transit, Intersection Safety, and Commuter Bikeway project, both with and without the consideration of the project implementation date, is estimated to have the highest emissions reductions out of all TMP projects (81,364 mt CO_2e avoided without implementation date and 62,742 mt CO_2e avoided with implementation date). The Boulder to Longmont Multi-Use Path project is modeled to have the second most emissions reductions both exclusive (48,305 mt CO_2e) and inclusive (26,559 mt CO_2e) of the implementation date.

Figure 11. Cumulative emissions reductions by project category compared between the analysis excluding project implementation dates and the analysis including project implementation dates.

When project implementation dates are considered, the impact of Boulder County's investment decreases compared to when projects are evaluated from 2022 – 2040 (Figure 12). As project implementation dates are closer to 2040, cumulative GHG emissions reduction by 2040 are lower. TMP projects will lead to GHG emissions reductions after 2040, but these reductions are not considered in this analysis.

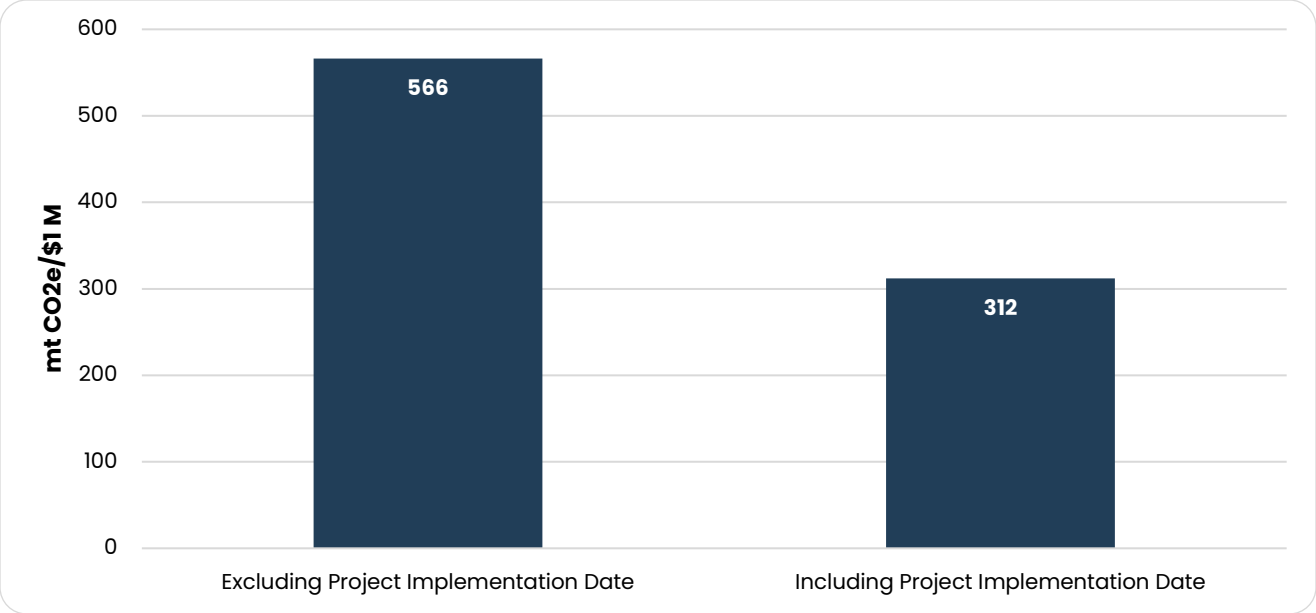

Figure 12. MT CO_2e reduced per $1 million invested into TMP projects by Boulder County excluding project implementation dates and including project implementation dates.

High-Level Review of Methodology

VMT Reduction Calculations

The subsections below provide a summary of the methods used in the VMT reduction analysis. For a detailed methodology see Appendix A.

Boulder County provided a list of over 100 TMP projects to consider for this analysis. To evaluate vehicle miles traveled (VMT) and GHG emissions reductions Fox Tuttle identified 62 projects where VMT impacts could be calculated (See Appendix A for a description of the projects not included):

- 38 road, regional trail, or multi-use path projects with a specific location and length that would result in more bicycle or pedestrian travel in a particular corridor and a reduction in automobile VMT (See Appendix F Table VMT1).

- 24 transit projects with specific routes and enough information to estimate transit ridership increases and the resultant decrease in automobile VMT. (See Appendix F Table VMT2).

Existing and Projected Automobile Traffic

Current and projected traffic volumes were taken from the Boulder County traffic volume map, Colorado Department of Transportation's (CDOT) traffic count database, and Denver Regional Council of Government's (DRCOG) traffic count map. Most counts were taken before the influence of COVID-19 and therefore were considered appropriate estimates of existing conditions. 20-year traffic growth factors from CDOT were used to calculate future growth in automobile traffic. Where CDOT information was unavailable a 20-year growth factor of 1.2 was assumed. Traffic volumes and 20-year growth factors were used to estimate the amount of traffic along a particular corridor that could be shifted away from automobile travel due to the TMP projects in 2022 and 2040.

Intercity Automobile Travel Patterns and Distances in Boulder County

An understanding of intercity and regional travel patterns in Boulder County is needed to estimate shifts in VMT. Estimated travel patterns between communities within Boulder County and other parts of the Denver and North Front Range Regions were taken from the updated TMP[3] (See Table A 1). Appendix A Table A 1 lists the estimated daily trips between subareas and includes an estimate of the travel distance between the approximate centers of any two subareas. This information was then considered when estimating the potential mode shift effect of the various TMP projects under consideration.

Transit Related Travel Mode Assumptions and VMT Reduction Estimation

Current daily transit ridership and projected 20-year ridership was provided by Boulder County staff or taken from transit-related studies (i.e., NAMS). An auto occupancy factor of 1.15 was used to convert transit ridership to automobile trips. Ridership was multiplied by 250 to estimate weekday annual ridership.

The average length of a transit trip for each route was estimated based on the average bus trip length along each route. It was not assumed that the average transit trip was as long as

[3] See Figure 15 on page 30 of Boulder County's Transportation Master Plan: https://assets.bouldercounty.org/wp-content/uploads/2020/02/transportation-master-plan-tmp-update-technical-document-final.pdf

the entire transit route under consideration. Ridership and route length was then used to calculate VMT reductions from transit projects. VMT reductions were calculated for 2022 and 2040, using the 20-year growth factors. See Appendix A for detail on how this information was applied to specific projects and project types.

Information to estimate the impacts of converting a transit route to a "fare-free" service was taken from the CDOT's Policy Directive Development – GHG Mitigation Measures[4].

Bicycle Related Travel Mode Assumptions and VMT Reduction Estimation

Many of the identified projects in the TMP will provide improved facilities for travel by bicycle. Project types include bikeable shoulders, buffered shoulders, gravel multiuse paths, and paved multiuse paths. Reduction in automobile travel was estimated based on the area type (suburban or rural) and the type of new bicycle facility. Appendix A Table A 3 includes the projected increase in bicycle travel or reduction in automobile travel for each facility and area type combination. This projected travel mode shift from automobile to bicycle travel was assumed to be in addition to the existing county-wide travel mode information summarized in the TMP.

The calculation methodology considered the amount of automobile travel in the most appropriate parallel travel corridor, and the estimated average trip length in that area of the County. The mode shift assumption from Appendix A Table A 3 was then applied to the travel being considered, and the daily travel was expanded to annual travel using a 250-day per year factor. Lastly, 20-year traffic growth factors were applied to account for increased travel over time within the County and estimate VMT reductions in 2040.

Any of the key assumptions that were used in calculating automobile VMT reduction for each project can be adjusted in Appendix F Tables VMT1 or VMT2 to update VMT reductions for each project.

Emissions Reduction Calculations

Baseline and Business-As-Usual Model

Lotus calculated a 2019 baseline for Boulder County's transportation emissions as a foundation with which to compare the emissions reductions from the TMP projects. 2019 was selected as

[4] CDOT's Policy Directive Development – GHG Mitigation Measures: https://www.codot.gov/programs/environmental/greenhousegas/assets/pd-1610-ghg-mitigation-measures-may-19-2022-signed.pdf

the baseline to avoid including the impacts of the COVID-19 pandemic in the calculations. The 2019 baseline includes emissions from on-road vehicles and public transit. Other sources of transportation emissions (e.g., air travel and off-road vehicle use) were excluded as these sources would not be impacted by the TMP projects.

The baseline 2019 emissions were used as the foundation for projecting Boulder County's Business-As-Usual (BAU) transportation emissions to 2040. The BAU projects emissions out to a future year assuming no interventions are taken by the community to reduce emissions. This BAU model is used to compare TMP project emissions reductions on a year-to-year basis out to 2040. Additionally, assumptions used in the BAU regarding electric vehicles (EVs), fuel efficiency, and other changes over time are used for modeling year-to-year emissions reductions from TMP projects.

For detailed documentation of the methods used to calculate the 2019 baseline and the BAU model, see Appendices Appendix B and Appendix C.

Emissions reductions

Each project included in the VMT reduction analysis was assigned one of four project categories: road, trail, multi-use path, and transit. These categories were included for each project in the TMP project data provided by Boulder County. Emissions reductions were calculated for road, trail, and multi-use path projects separately from transit project emissions reductions. Transit emissions reductions are calculated separately as additional emissions from new or augmented bus activity were included in the analysis.

Road, Trail, and Multi-Use Path Projects

Avoided emissions for all non-transit projects from the TMP were calculated based on the 2022 and 2040 estimated VMT reductions, provided by Fox Tuttle. To give a year-to-year view of emissions reductions, Lotus assumed a linear change between 2022 and 2040 VMT reduction values.

To calculate emissions reductions for each year, the annual VMT reduction estimates were split by fuel type (gasoline, ethanol, diesel, and electricity). The proportion of VMT from each fuel type as estimated in the BAU (see Appendix C for more detail) for each year was used to split total VMT reductions between the different fuel types. For example, total VMT reductions in 2022 for a project are now split into gasoline, diesel, ethanol, and electric VMT reduction for that project. This is repeated for every project and every year from 2022 through 2040. The BAU includes estimates for increased EV adoption every year. By using the fuel type

proportions from the BAU to split VMT by fuel type, the emission reduction calculations reflect the expected increase in EV usage.

Average fuel efficiencies for each fuel type were used to estimate gallons of fuel usage reduction for each project and each year. See Appendix C for a detailed description of how average fuel efficiencies were calculated. Projected EV efficiencies (kWh per mile) from 2019 through 2040 were used to estimate reductions in kWh consumed by EVs due to the TMP projects. This assumes that as technology improves over time, EVs will consume less electricity per mile.

Emissions were calculated for each project for every year from 2022 through 2040 based on the VMT, fuel consumption, and kWh consumption values for each year. To ensure emissions calculations accounted for the different types of vehicles on the road, VMT within each fuel type was split by the proportion of each vehicle type in the 2019 baseline (i.e., passenger vehicles, light-duty trucks, heavy vehicles, and motorcycles). This assumes that the type of vehicles on the road does not change significantly over time but allows for more accurate emission calculations. An average emission factor, calculated for each year from 2019 through 2040 from all of Boulder County's electric utilities, was used to calculate emissions from EVs. See Appendix C for more information about the average emission factor. Emissions by vehicle and fuel type were summed to get total emissions reductions for each project in each year.

Transit Projects

Emissions reductions and additional emissions from bus activity were calculated for transit projects. The methodology described above for all other project types was used to calculate emissions reductions from transit projects.

Additional emissions from the transit projects come from changes to existing routes (increased route travel frequency or change in route distance) or the addition of new routes. Additional emissions from each of these scenarios were calculated by comparing the expected VMT of the route due to the implementation of a transit project to the VMT on the same route in 2019.

For transit projects that changed existing routes, the 2019 VMT on that route was calculated. A January 2019 headway table, provided by Regional Transit District (RTD), was used to count the number of times a day that each route was traveled (weekday and weekend). Frequencies were adjusted to reflect annual travel on each route. Annual frequencies were multiplied by the distance of that route (taken from a spreadsheet provided by RTD of all route distances) to get the total 2019 bus miles traveled on each route.

Updated route annual VMT was calculated based on assumptions about new headways for each route. The route distance stayed the same for all transit projects except for the

Colorado 7 Bus Rapid Transit project. See Appendix D for the list of headway assumptions used for the updated route VMT calculations.

Updated route annual VMT was calculated based on the headway assumptions and route distances, then scaled up to get annual VMT. Additional transit VMT was calculated by subtracting the 2019 annual VMT from the updated project annual VMT.

For new routes, route distances taken from Fox Tuttle's VMT reduction analysis and headway assumptions were used to calculate annual VMT additions. As there were no bus-related VMT on these new routes in 2019, all annual bus-related VMT from these routes is considered additional for these projects.

Lotus assumed that all buses use diesel fuel, and that bus fuel efficiency would not increase over time. Bus efficiency may increase in future years but there are currently no projected bus efficiency data available from which to make defensible estimates. Additional transit VMT was assumed to be the same for each year from 2022 through 2040. Additional VMT in each year was divided by the diesel bus fuel efficiency value to get gallons of diesel fuel used. Emissions were then calculated from gallons of fuel used and bus VMT. Additional emissions for each project in each year were subtracted from avoided emissions from each corresponding project and year.

The Northwest Corridor Commuter Rail project does not cause additional bus emissions but creates emissions from diesel rail operations. Additional emissions from this project were calculated separately from the other bus transit projects. The average trip distance along the corridor was multiplied by an estimate of daily ridership and by 365 to get total annual passenger-miles traveled. Emission factors from the EPA, in units of emissions per passenger-mile, were used to estimate additional emissions from the Northwest Corridor Commuter Rail project.

Project Analysis

The calculated emissions reductions for all projects were used in two ways:

- Emissions reductions were evaluated for each project by analyzing the first year (2022), 2040, and cumulative emissions reductions expected from each project. This analysis looks at the emissions reduction potential of all projects if they were to be implemented in 2022 and does not consider implementation timelines for any projects.
- Emissions reductions were evaluated for each project based on implementation year data provided by Boulder County. Emissions reductions in this analysis do not begin for any project until the implementation year.

Conclusion

The sixty-two TMP projects evaluated in this analysis are projected to avoid 262,841 mt CO_2e cumulatively by 2040 when project implementation dates are considered. Total estimated costs for all sixty-two projects would be $3.9 billion, with an estimated $843 million coming from Boulder County funds. Excluding project implementation dates, all projects would avoid 477,053 mt CO_2e cumulatively from 2022 to 2040. In 2040, the TMP projects would avoid 23,169 mt CO_2e, a 2.6 percent reduction from Boulder County's 2019 transportation emissions (654,905 mt CO_2e). Regardless of when TMP projects are implemented, this analysis highlights how the TMP projects are a step forward towards Boulder County's overall emissions reduction goal and are an integral part of climate action in Boulder County.

The actual benefit of the Boulder County's TMP on GHG emissions depends on how much progress the county can make on implementing these projects. Completing all or some of these projects will help Boulder County reach its goals of a 90 percent reduction in community GHG emissions below 2005 levels by 2050. Total Boulder County emissions in 2005 measured 5,067,448 mt CO_2e.[5] If all analyzed TMP projects were implemented, the avoided emissions would contribute a 0.5 percent reduction towards this goal in 2040.

The TMP includes a goal to reduce Boulder County's VMT per capita. Without the TMP projects, VMT per capita in 2040 would be 6,816. If all projects were implemented by 2040, the TMP projects would reduce VMT per capita by 308 miles to 6,508 VMT per capita. These calculations of VMT per capita include only Boulder County residents. Individuals who work in Boulder County but live elsewhere are not included.

It must be noted that the analyzed TMP projects have many co-benefits outside of VMT and GHG emissions reductions. While not quantified in this analysis, these projects will also contribute to air quality improvements and bettering quality of life in the County.

All but one of the projects included in this analysis had a net positive impact on GHG reductions. All transit projects (transit service and fare free projects together) present the largest opportunity for overall GHG reductions but come at a much higher cost than other project categories. Projects with the greatest benefit per dollar invested such as bikeways and multi-

[5] https://assets.bouldercounty.gov/wp-content/uploads/2017/03/greenhouse-gas-inventory-2006.pdf

use paths tend to be used for shorter trips, are more weather dependent, and are less available for general commuting trips.

However, the proposed multi-use path projects have higher net GHG reductions than transit service projects as transit service projects that add or extend routes will produce additional emissions from buses or rail. Multi-use path projects have high potential for VMT and GHG reductions and require less investment to realize those reductions than all other project categories except for fare free transit projects.

This work provides the Boulder County Transportation Department with insight into how the analyzed projects support the TMP's goal of minimizing environmental impacts from the County's transportation system. Promoting projects to reduce VMT from fossil fuel vehicles is a key action included in the TMP to combat climate change and reach the TMP's environmental goal. Boulder County can use this analysis to identify projects with the greatest potential for VMT and GHG emissions reductions and track emissions reductions as projects are implemented. Fox Tuttle and Lotus hope that this work enables Boulder County to continue to evaluate project impacts on GHG emissions, and on the County's environmental goals at large, for this version of the TMP and in future years.

Appendices

Appendix A: VMT Reduction Calculation Methodology

TMP Projects to Evaluate

The Fox Tuttle/Lotus team was provided with a list of over 100 projects for consideration in this analysis. The goal was to estimate, where possible, the amount of automobile VMT that would be reduced resulting from the implementation of the TMP projects, and subsequently the amount of GHG emissions that would be reduced. The projects were divided into four groups as follows:

- 35 bicycle or bicycle/pedestrian facility projects with a specific location and length that would result in more bicycle travel in a particular corridor and a reduction in automobile VMT. (See Supplementary Table VMT1)
- 20 transit projects with specific routes and enough information to estimate transit ridership increases and the resultant decrease in automobile VMT. (See Supplementary Table VMT2)
- 26 projects at point locations (such as bridge replacements, underpasses, or localized sidewalk improvements). While these projects would provide localized safety or multimodal improvement, they would not likely have a significant VMT impact. However, these projects were considered when estimating resulting travel mode shifts related to other bicycle or pedestrian projects noted above. These projects are included in Supplementary Table VMT1) but do not include a VMT reduction calculation.
- 25 other projects that would improve multimodal travel or safety but would not likely result in a reduction or increase of automobile VMT (such as uphill improvements for recreational bicyclists in a mountain corridor). These projects were not given further consideration in this effort unless they would enhance one or more of the projects listed above. These projects are also included in Supplementary Table VMT1) without any VMT calculation.

The 62 projects included in the first two groups were evaluated for VMT impacts.

VMT Reduction Methodology

A literature review was conducted to identify industry-standard methodologies for calculating VMT reductions from the pedestrian, bicycle, and transit improvement projects. No prior studies could be appropriately applied to the diversity of the Boulder County transportation network,

or the range of project types considered in this analysis. Most steps used to calculate VMT reduction from the TMP projects are specific to this project and are described below.

Information to estimate the impacts of converting a transit route to a "fare-free" service was taken from the CDOT's Policy Directive Development – GHG Mitigation Measures[6].

Existing and Projected Automobile Traffic

Existing automobile traffic volumes on specific roadways in each of the intercity and regional travel corridors were documented using the latest traffic count information available on the Boulder County traffic volume map, CDOT's traffic count database, and DRCOG's traffic count map. Most counts were taken before the influence of COVID-19 and therefore were considered appropriate estimates of existing conditions.

A future year or 20-year traffic growth factor was identified to allow an estimate of future growth in automobile traffic. CDOT's corridor-specific 20-year growth factors were used where available, and the remaining corridors were assumed to experience a 20-year growth factor of 1.20, which represents an approximate annual traffic growth rate of just less than 1 percent per year. Local 20-year traffic growth factors of 1.20 are commonly used in traffic impact studies in the Colorado front range area.

This information then formed the basis for estimating the amount of traffic along a particular corridor that could be shifted away from automobile travel because of one or more of the TMP projects.

Intercity Automobile Travel Patterns and Distances in Boulder County

An understanding of intercity and regional travel patterns in Boulder County is needed to estimate shifts in VMT. This study utilized information from the updated TMP[7] that estimated travel patterns between communities within Boulder County and between other parts of the Denver and North Front Range Regions. Table A 1 lists the estimated daily trip made between subareas and includes an estimate of the travel distance between the approximate centers of any two subareas. This information was then considered when estimating the potential mode shift effect of the various TMP projects under consideration.

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[6] CDOT's Policy Directive Development – GHG Mitigation Measures: https://www.codot.gov/programs/environmental/greenhousegas/assets/pd-1610-ghg-mitigation-measures-may-19-2022-signed.pdf

[7] See figure 15 on page 30 of Boulder County's Transportation Master Plan: https://assets.bouldercounty.org/wp-content/uploads/2020/02/transportation-master-plan-tmp-update-technical-document-final.pdf

Transit Related Travel Mode Assumptions and VMT Reduction Estimation (20 projects)

Existing and projected daily (assumed to be weekday) transit ridership was provided by Boulder County staff or taken from the Northwest Area Mobility Study (NAMS) or various other transit-related studies. Projected daily ridership for the 20-year planning horizon was also provided.

The average length of a transit trip (miles) on a particular transit route was estimated based on the route, the communities through which the route traveled, and an estimate of the average bus trip length along that route. It was not assumed that the average transit trip was as long as the entire transit route under consideration.

An auto occupancy factor of 1.15 was used to convert between transit ridership and automobile trips where necessary.

A factor of 250 was utilized to convert weekday transit ridership to annual ridership, assuming that the transit ridership was predominantly focused on weekday travel throughout the year.

The increase in ridership on transit routes that converted to "fare-free" service was estimated in Table A 2 based on information contained in Table 3 of CDOT's GHG Mitigation Measures Policy Directive, where it is estimated that fare-free service will result in a 30 percent increase in transit ridership. The existing ridership for each route under consideration for fare-free service was provided by others. The 30 percent ridership increase and the average transit trip length on each route were used to calculate daily VMT reduction from fare-free transit services.

New transit routes in corridors where no existing transit service currently exists were assumed to generate a ridership equivalent to 5 percent of the existing automobile travel in that specific corridor. This allowed an estimate of the potential automobile VMT reduction along that specific route.

The automobile VMT reduction for the future Northwest Corridor Commuter Rail project was estimated assuming there were 1,400 riders per weekday and the average rail trip length was 25 miles along the 40-mile rail corridor length.

The automobile VMT reduction of the future Flex Service between Fort Collins, Longmont, and Boulder was estimated assuming an average bus trip length of 40 miles, but only a 2 percent reduction of the 23,000 vehicle trips per day on a key roadway segment in the heart of this intercity corridor.

In some cases, the increase of transit vehicle VMT was calculated so that the increased GHG resulting from the increased bus traffic could be subtracted from the GHG reduction resulting from the shift in travel from automobile to bus.

The 20 transit projects considered in this category, if fully implemented, are estimated to result in an annual reduction of 68,489,000 vehicle miles of automobile travel per year in the Year 2040.

Bicycle Related Travel Mode Assumptions and VMT Reduction Estimation

Many of the identified projects in the TMP will provide improved facilities for travel by bicycle. Project types include bikeable shoulders, buffered shoulders, gravel multiuse paths, and paved multiuse paths. Some projects are in suburban areas, and some are in rural areas. Some projects provide a short missing link between existing bikeways, and some are longer, connecting between communities. And some others are more localized, providing an underpass of a roadway or a connection to a transit facility. A short project, such as a two-mile section of buffered bike shoulders, could be the catalyst to encourage bicycle travel of 10 miles between communities. Another project may have a much more localized effect on reducing automobile travel. Some may influence a shift in mode use between communities that are connected by multiple roadways, and some may influence travel only on a specific roadway corridor. Each project was considered individually in this context.

The anticipated reduction in automobile travel was estimated based on the area type (suburban or rural) and the type of new bicycle facility. Table A 3 includes the projected increase in bicycle travel or reduction in automobile travel for each facility and area type combination. This projected travel mode shift from automobile to bicycle travel was assumed to be in addition to the existing county-wide travel mode information summarized in the TMP.

The calculation methodology considered the amount of automobile travel in the most appropriate parallel travel corridor, and the estimated average trip length in that area of the County. The mode shift assumption from Table VMT 5 was then applied to the travel being considered, and the daily travel was expanded to annual travel using a 250-day-per-year factor. Lastly, 20-year traffic growth factors were applied to account for increased travel over time within the County.

The 35 projects considered in this category, if fully implemented, are estimated to result in an annual reduction of 33,641,000 vehicle miles of automobile travel per year in the Year 2042.

MAKING ADJUSTMENTS TO VMT CALCULATIONS

The potential reduction in automobile VMT has been calculated for 62 of the 100+ projects identified in the Boulder County Transportation Master Plan. Any of the key assumptions that were used in calculating automobile VMT reduction for each project can be adjusted in Supplementary Tables VMT1 or VMT2. The project-specific reductions can be recalculated and the resulting totals by project category then are updated.

Individual projects can be grouped with others in phases to help illustrate the impacts of various funding alternatives over the next 20 years.

As it stands currently, the 20 proposed transit improvement projects have over twice the potential to reduce automobile VMT than the 35 bicycle improvement projects considered.

Table A 1. Fox Tuttle Table VMT3: Year 2040 Intercity Automobile Travel in Boulder County - Approximate Distance and Daily Traffic Volume (Per TMP).

			Year 2040 Projected Traffic Volume Between Communities**							
		Boulder	Longmont	Erie	Niwot	Lafayette	Louisville	Superior	Lyons	Golden
	Boulder		46,000	8,500	9,800	17,500	25,600	4,000	2,800	24,000
Automobile Travel Distance Between Communities* (Miles)	Longmont	12		12,500	6,200	5,300	2,900	1,000	2,700	
	Erie	10	10		100	2,000	1,500	500	25	
	Niwot	8	6	10		50	50	50	50	
	Lafayette	10	12	6	11		3,800	1,000	90	100
	Louisville	9	12	9	10	3.5		1,000	100	100
	Superior	9	15	12	11	5	4		10	100
	Lyons	15	12	23	13	23	23	25		
	Golden	19				22	20	17		

* Estimated automobile travel distance between communities

** Projected Year 2040 Automobile Traffic Between Communities from Boulder County TMP

Table A 2. Fox Tuttle Table VMT4: VMT Reduction of Converting Existing Transit to Fare-free.

Route	Existing (2019) Total Boardings	Anticipated New Boardings When Fare Free Service	Assumed Average Transit Trip Length (miles)	Estimated VMT Reduction[4]	Year 2025 CO2 Reduction (Tons)[1]	Year 2030 CO2 Reduction (Tons)[2]	Year 2040 CO2 Reduction (Tons)[3]
HOP	786,203	235,861	5.00	1,025,482	311	263	122
JUMP	497,366	149,210	14.00	1,816,467	550	465	216
DASH	577,951	173,385	13.00	1,960,008	594	502	233
228	104,160	31,248	7.00	190,205	58	49	23
BOLT	413,772	124,132	14.00	1,511,167	458	387	180
LD	245,057	73,517	19.00	1,214,630	368	311	145
NB	125,337	37,601	15.00	490,449	149	126	58
Total:	2,749,846	824,954		8,208,409	2,487	2,101	977

1. 303 tons of CO2 per million vehicle miles (MVM) of automobile travel reduced per Table 3
2. 256 tons of CO2 per MVM reduced in Year 2030 per Table 3
3. 119 tons of CO2 per MVM reduced in Year 2040 per Table 3
4. Assume automobile auto occupancy = 1.15 in this calculation

Table A 3. Fox Tuttle Table VMT5: Anticipated Travel Mode Shift from Automobile to Bicycle Travel.

	Travel Setting	
New Bicycle Facility Type	Intercity Suburban Travel	Intercity Rural Travel
Bikeable Shoulder	5%	3%
Buffered Shoulder	8%	6%
Multiuse Path - Gravel	9%	7%
Multiuse Path - Paved	10%	8%

Appendix B: 2019 Baseline Calculation Methodology

On-road Vehicles

Baseline emissions from on-road vehicles (excluding transit) in 2019 were calculated based on a combination of data inputs including VMT, vehicle type, fuel type distributions, and average fuel efficiencies. VMT data for Boulder County in 2019 was provided by Dale Evans at the Colorado Department of Health and Environment (CDPHE). These VMT data were provided as daily totals split by vehicle types as defined by the Highway Performance Monitoring System (HPMS) Code ID:

- Motorcycle (HPMS ID - 10).
- Passenger Car (HPMS ID - 20).
- Light Truck (HPMS ID - 30).
- Bus (HPMS ID - 40).
- Single Unit Truck (HPMS ID - 50).
- Combination Unit Truck (HPMS ID - 60).

Daily VMT for each vehicle type was multiplied by 365 to get the annual VMT for Boulder County. EV VMT was then subtracted from passenger car VMT to avoid double counting as EV emissions are calculated separately. See below for the methodology used for EVs.

Kevin Kihn from the Colorado Department of Revenue (CDR) provided a regional vehicle distribution by fuel type (gasoline, diesel, electric, etc.) by county. These data from CDR and CDPHE were used to determine VMT split by vehicle type and fuel type within Boulder County. Fuel efficiencies, taken from the U.S. Environmental Protection Agency's (EPA) state inventory tool[8], were used to estimate gallons of fuel consumed from each vehicle and fuel type. It was assumed that all gasoline consumed contains 10 percent ethanol. VMT and gallons of fuel consumed were calculated for gasoline, ethanol, and diesel fuel types.

Emissions were calculated for each vehicle type and fuel type using emission factors corresponding to each type. Gallons of fuel consumed are used to calculate CO_2 emissions and VMT is used to calculate CH_4 and N_2O emissions. Global warming potentials (GWPs) from

[8] For more information visit EPA's State Greenhouse Gas Inventory and Projection Tools -- Mobile Combustion Module at: https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool.

the Intergovernmental Panel on Climate Change Sixth Assessment Report[9] were used to convert emissions calculated for each GHG into units of carbon dioxide equivalent (CO_2e).

For EVs, the percent of registered vehicles that were battery electric (BEVs) or plug-in hybrids (PHEVs) was calculated from the CDR data. EV VMT was calculated by multiplying the percent of registered vehicles for each EV type by the total VMT in Boulder County from the CDPHE data. BEV and PHEV efficiency values taken from the Department of Energy (Table B 1. EV efficiencies) were used to calculate the electricity used by EVs in Boulder County in 2019. EV electricity consumption was multiplied by an average emission factor for Boulder County to calculate baseline 2019 emissions from EVs.

Table B 1. EV efficiencies.

Vehicle Type	Efficiency (kWh/mile)
Battery Electric Vehicle	0.33
Plug-in Hybrid Electric Vehicle	0.70

The average emission factor was calculated by taking the weighted average of the 2019 emission factors of the utilities serving Boulder County. Boulder County receives electricity from Xcel Energy, Longmont Power and Communications, and from two utilities that receive electricity from Tri-State Generation and Transmission Association. 2019 emission factors were collected from each utility and weighted by the proportion of the electricity they provided to Boulder County in 2016 (the latest year for which Lotus had access to electricity usage from all utilities in Boulder County).

TRANSIT

Emissions from transit in 2019 were calculated from the total miles traveled by Regional Transportation District (RTD) buses within Boulder County in 2019. To calculate total bus VMT, RTD provided a spreadsheet of all bus routes and the distance of each route split by municipality. This spreadsheet was filtered to only show routes and route distances within Boulder County. RTD also provided a table of all weekday, Saturday, and Sunday headways for each route. This table was used to count the two-way frequency traveled along each route on weekdays, Saturdays, and Sundays. The total frequency traveled on each route from the headway table was matched to the route distance data and multiplied by the route distance to identify daily weekday, Saturday, and Sunday VMT along each route in Boulder County. To

[9] For more information visit: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07.pdf.

calculate annual VMT, each route's weekday VMT was multiplied by 5 and by 52, and the Saturday and Sunday daily VMT was multiplied by 52. The annual VMT for each route was summed across all routes to get the total annual VMT by RTD buses within Boulder County.

It was assumed that all buses are diesel buses and the fuel used contained no biodiesel. Diesel consumed from RTD buses was calculated based on an assumed bus fuel efficiency of 7.69 miles per gallon. Bus VMT and gallons of diesel consumed were used to calculate emissions from RTD activity in Boulder County.

The City of Boulder also runs an electric bus in addition to RTD buses. 2019 miles traveled by this bus were provided by Natalie Stiffler, Director of Operations, with Via Mobility Services. VMT from the electric bus was converted to kWh of electricity consumed based on an electric bus efficiency factor from the National Renewable Energy Laboratory[10] (NREL). 2019 electricity emission factors for the main electric utilities (Xcel Energy, United Power, and Longmont Power and Communications) were used to calculate emissions from the electric bus.

The total baseline 2019 transportation emissions were calculated by taking the sum of all transit emissions and all on-road emissions. This baseline value is used to project out transportation emissions in Boulder County to 2040. Additionally, it allows the emissions reductions from the TMP projects to be compared against a starting value.

[10] For more information see: https://www.nrel.gov/docs/fy19osti/72864.pdf

Appendix C: Business-As-Usual Model Calculation Methodology

Business-As-Usual (BAU) emissions were calculated for on-road (non-transit vehicles) and transit activity from the 2019 baseline out to 2040. On-road emissions are projected by assuming that VMT increases at the same rate as population growth. Population data, projected out to 2050, from the Colorado State Demographer Office was used to estimate VMT out to 2040. VMT was projected split by each vehicle type. To account for electric vehicles (EVs), EV market projections were used to identify an average annual rate of increase in EV adoption in addition to EV VMT increases from population growth. EV VMT was subtracted from projected gasoline and ethanol VMT from each year to prevent double-counting as it is assumed that EV adoption replaces VMT from gasoline passenger vehicles.

Fuel usage was estimated for each year by dividing each fuel type VMT by an average fuel efficiency value. Average fuel efficiencies for each fuel type were calculated by dividing the total VMT from each fuel type by the total gallons consumed by that fuel. Fuel efficiency is expected to increase over time for new vehicles. To account for this fuel efficiency projections based on CAFE standards were used. As these standards would only affect new vehicles, they were not directly used. Instead, the year-to-year percent increase in fuel efficiency from the projected CAFE standards was used to adjust the average fuel efficiencies calculated from the baseline VMT and fuel consumption.

To calculate emissions for on-road vehicles in future years, Lotus assumed that the spread of vehicle types (passenger, light-duty, etc.) would stay constant over time. Emissions were calculated using the same emission factors as were used in the baseline, and VMT was split by vehicle type using the 2019 vehicle spread to accurately calculate CH_4 and N_2O emissions. For EVs, EV VMT was converted to kWh using projected efficiency values from 2019 through 2020. Emission factors from the electric utilities serving Boulder County were projected out to 2040 based on each utility's renewable energy goals.

The weighted average based on the electricity provided by each utility in 2016 was taken to provide a single electricity emission factor. This would reduce emissions from EVs over time as the grid becomes cleaner. kWh consumed in each year was multiplied by that year's corresponding average emission factor to calculate emissions from EVs.

For diesel buses from transit activity, emissions are projected by increasing VMT year-to-year based on population growth. However, unlike on-road vehicles, fuel efficiency was not projected to improve over time as no future standards have been set. Electric buses were not

modeled to increase in activity over time outside of population growth. Without concrete goals dictating the increased adoption of electric buses, no assumption could accurately be made. Emissions from electric bus activity were calculated in the same way as for EVs.

The BAU projection allows the emissions reductions from transit projects to be modeled on a year-by-year basis rather than just looking at an individual year. The same assumptions used in the BAU (electric vehicle adoption, vehicle type spread, and constant diesel bus efficiency) are used to accurately calculate emissions reductions from transit projects based on the expected conditions calculated in the BAU.

Appendix D: Transit Headway Assumptions

To calculate annual VMT from transit projects that altered existing route headways or distances and projects that add new routes, the following assumptions were made:

- US 287, 119, and CO 7 BRT: 15-minute headways from 6-9am and 3-6pm, 30-minute headways from 5-6 am, 9am - 3 pm, 6 - 10pm.
- All other BRT routes: 30-minute headways all day.
- Highway 93/South Foothills Transit: 30-minute peak headways and hour headways off-peak.
- Lyons to Longmont Special Service: 10 one-way trips per day (20 round trips).
- Baseline Road Transit: 15-minute peak headways and 30-minute headways off-peak.
- Highway 52 Regional Service Extension to I-25: 30-minute headways in peak only.
- Highway 119 Transit Extension to I-25 Park-n-ride: 30-minute peak headways and hour headways off-peak.
- Nederland to Black Hawk Special Service: 2 trips per day (4 round trips).
- The route distance for the CO 7 route increased from 19.7 miles to 25.9 miles.

Appendix E: Cumulative Emissions Reductions by Project

The table below displays cumulative emissions reductions for each project first for the analysis that did not consider project implementation dates (cumulative emissions reflect 2022 through 2040) and the analysis that did consider project implementation dates (cumulative emissions reductions reflect the implementation year through 2040).

Table E 1. Cumulative emissions reductions by project for each analysis.

Project Name	Project Category	Cumulative Emissions Reductions Excluding Implementation Dates	Cumulative Emissions Reductions Including Implementation Dates
Colorado 7 Bus Rapid Transit, Intersection Safety and Commuter Bikeway	Transit Service	81,364	62,742
Northwest Corridor Commuter Rail – Denver to Longmont	Transit Service	33,738	7,715
South Boulder Road / Broadway Bus Rapid Transit - DASH	Transit Service	19,945	9,094
US287 Bus Rapid Transit, Intersection Safety and Commuter Bikeway	Transit Service	13,600	7,601
FLEX service – Fort Collins to Boulder via Longmont	Transit Service	5,758	5,758
Highway 119 Transit Extension to I-25 Park-n-Ride	Transit Service	5,712	3,038
Highway 52 Regional Service Extension to I-25	Transit Service	5,233	2,910
Baseline Road Transit	Transit Service	4,036	855
Colorado 119 Bus Rapid Transit and Commuter Bikeway	Transit Service	2,953	2,509
Highway 93 / South Foothills Transit	Transit Service	2,578	496
Nederland to Black Hawk Special Service	Transit Service	-29	-37
Recreational Shuttle at Hessie	Transit Service	-31	-31
Recreational Shuttle at 4th of July Trailhead	Transit Service	-131	-115
Recreational Shuttle to Brainard Lake	Transit Service	-159	-160
Recreational Shuttles at Eldorado Canyon	Transit Service	-406	-406
Colorado 42 Bus Rapid Transit	Transit Service	-1,356	-1,088
Lyons to Longmont Special Service	Transit Service	-1,965	-1,660
Fare Free Option - DASH	Fare Free Transit	11,953	10,531
Fare Free Option - JUMP	Fare Free Transit	11,077	9,760
Fare Free Option - BOLT (SH 119)	Fare Free Transit	9,215	8,119
Fare Free Option - LD (US287)	Fare Free Transit	7,407	6,526
Fare Free Option - HOP	Fare Free Transit	6,254	5,510
Fare Free Option - NB	Fare Free Transit	2,991	2,635
Fare Free Option - 228	Fare Free Transit	1,160	1,022

Boulder to Longmont Multiuse Path	Multi-Use Path	48,305	26,559
Highway 93 Multi-use Path – Hwy 170 south to Jefferson County	Multi-Use Path	35,982	8,638
US 287 Bikeway – Hwy 66 to Larimer County Line	Multi-Use Path	33,667	8,279
Highway 7 Multiuse Path - 119th Street to East County Line	Multi-Use Path	20,737	11,401
Longmont to Weld County Multiuse Path	Multi-Use Path	15,065	8,283
North Foothills / US 36 Multi-use Path /Bikeway	Multi-Use Path	14,638	8,048
Lafayette / Erie to Longmont Multi-use Path	Multi-Use Path	7,758	4,265
East County Line Rd Ped Connect – Hwy 119 to St Vrain Crk	Multi-Use Path	3,660	2,012
Longmont-to-Boulder Trail – Jay Road / Spine Road Multi-use Path	Multi-Use Path	2,935	2,416
McCaslin Boulevard Calmente Trail (Superior)	Multi-Use Path	610	335
95th Street Multiuse Path - Hecla to Short (Louisville)	Multi-Use Path	305	251
104th Street Trail – Dillon to Sterns Lake	Multi-Use Path	61	34
Highway 66 Frontage Road/Bike facility – Lyons to 95th Street	Road	5,855	3,219
East County Line Rd Shoulders – Pike to Hwy 52	Road	4,849	3,991
Baseline Road Buffered Shoulders – Cherryvale to 95th Street	Road	4,574	2,515
South Boulder Road Reconstruction – Boulder to Louisville	Road	4,529	2,490
75th Street Buffered Shoulders – Lookout Road to Baseline Road	Road	3,660	2,012
East County Line Rd Safety & Resiliency (Erie) – Hwy 52 to Coal Creek	Road	3,431	2,824
Jay Road Buffered Shoulders – US 36 to 75th Street	Road	3,050	750
Isabelle Road Shoulders – 95th Street to US 287	Road	2,989	1,643
95th Street Buffered Shoulders – Yellowstone to Larimer County	Road	1,921	1,581
75th / 83rd Street Buffered Shoulders – Hwy 66 to Larimer County	Road	1,830	1,006
73rd / 75th Street Buffered Shoulders – Niwot Road to Hwy 66	Road	1,784	439
Highway 170 Buffered Shoulders – Hwy 93 to Eldorado Springs	Road	1,757	966
79th Street Shoulders – Hwy 52 to Lookout Road	Road	976	537
East County Line Rd Shoulders – Hwy 66 to 17th Ave (Longmont)	Road	914	503
Highway 66 Improvements – Main to Hover	Road	869	715
Niwot Road Shoulders – 79th Street to US 287	Road	755	415
Hygiene Road Shoulders – US 36 to 75th Street	Road	439	241
Oxford Road Shoulders – US 287 to East County Line	Road	206	113
Lafayette-to-Boulder Bike/Ped Multi-use Path	Trail	7,624	1,875
Callahan Trail Extension – Baseline Road to East Boulder Trail	Trail	5,337	2,934
Boulder-to-Erie Regional Trail	Trail	4,269	2,347
St. Vrain Greenway Trail – Longmont to Lyons	Trail	3,842	2,113
75th Street Trail Connection – RTD tracks to Jay Road	Trail	3,736	2,054

Dry Creek Trail Extension	Trail	1,647	405
County Road 130 Trail to Nederland High School	Trail	160	132
120th Street Bridge Replacement over Coal Creek (Lafayette)	Road	1,429	1,177

Appendix F: Supplementary Materials

The materials listed below are the files used in the VMT reduction analysis and the emissions reductions analysis. These files were provided to Boulder County along with this report.

VMT Reduction Materials

Table VMT 1: Boulder County TMP Project VMT Reduction Calculation Spreadsheet

Table VMT 2: Boulder County VMT Reduction - Transit projects only

Table VMT 3: Travel Distance and Volume between communities

Table VMT4: Fare-free Transit

Table VMT5: Bicycle Mode Shift

GHG Emissions Reductions Materials

GHG Emissions Reductions Modeling Tool: Boulder_County_TMP_Emissions_Reductions.xlsx