Vermont Transportation Carbon Reduction Strategy

prepared for

Vermont Agency of Transportation

prepared by

Cambridge Systematics, Inc.

with

FHI Studio

November 2023

www.camsys.com

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Executive Summary

Introduction

In November of 2021, the federal Infrastructure Investment and Jobs Act created a new Carbon Reduction core highway formula program. The purpose of the Carbon Reduction Program (CRP) is to reduce transportation emissions through the development of State Carbon Reduction Strategies (CRS) and by funding projects designed to reduce transportation emissions. VTrans will receive nearly $32 million in CRP funding over federal fiscal years 2022 through 2026 and is required to develop a Strategy for their use consistent with the Federal Highway Administration Guidance.

At the State level, Vermont's Act 153 (2020) – the Global Warming Solutions Act, or GWSA – establishes greenhouse gas emissions reduction requirements and required the development of the Initial Vermont Climate Action Plan (CAP) which was adopted on December 1, 2021. The Plan identifies specific initiatives, programs and strategies necessary to achieve the State's greenhouse gas (GHG) emission reduction requirements, enhance carbon storage and sequestration, achieve net zero emissions by 2050, and build resilience and adaptation in our natural systems and built environment.

The CAP identifies that the transportation sector is responsible for 40 percent of emissions in Vermont. Therefore, it is incumbent upon the Vermont Agency of Transportation (AOT) to continue to develop and implement programs and projects to reduce greenhouse gas emissions and for the state to evaluate the effectiveness of other reduction strategies for the transportation sector. Through development of this Strategy, AOT sought to understand how its current programs affect greenhouse gas emissions and to assess future policy options and investment strategies towards the reduction of transportation emissions, both within the span of the Agency's authority as well as beyond its authority. This Strategy provides direction for spending CRP funds to support greenhouse gas (GHG) emissions reduction from the transportation sector and serves as Vermont's CRS required under the CRP program. It also identifies additional opportunities for reducing carbon emissions from the state's transportation sector, consistent with the GWSA.

The Vermont Transportation Carbon Reduction Strategy outlines various policies, programs, and other important considerations as the state works to reduce carbon emissions from the transportation sector. AOT can support implementation of the strategy through the choices it makes in its long-range, corridor, and modal planning, project prioritization, Capital Program, and design and materials standards. However, full implementation of the Strategy will require additional actions beyond the purview of AOT, thorough analysis, public engagement processes, and coordination on the part of many stakeholders; including the legislature, executive branch, municipalities and regional planning agencies, and Vermont's citizens, businesses, and public utilities.

Strategy Development Process

Vermont's Transportation Carbon Reduction Strategy was developed with public and stakeholder engagement, including two sets of virtual public meetings; an online survey with approximately 700 respondents; an online comment mailbox; and two rounds of focus groups with representatives of six key interest groups. Development of the Strategy was further guided by an Advisory Committee made up of representatives of various state agencies and interest groups, as well as a Technical Committee to ensure the soundness of the data and analysis methods used to quantify GHG emissions and reduction potential. Both the Advisory and Technical Committees included membership from the Chittenden County Regional Planning Commission (CCRPC) that serves as the only MPO in Vermont, fulfilling U.S. DOT requirements for MPO coordination. CCRPC staff also participated in the stakeholder focus groups.

The technical analysis to support the Strategy included the following elements:

A **baseline forecast** of the state's transportation emissions through 2050, considering current adopted policies.

An assessment of the **GHG impacts of AOT's current Capital Program**, related to project construction, mode shift, efficient traffic operations, and clean vehicles funded by the program.

An assessment of the **gap** between projected baseline emissions and emission levels required under the GWSA in years 2025, 2030, and 2050.

Development and evaluation of potential **strategies** to close the gap, including evaluation of potential benefits, costs, and co-benefits.

The analysis was performed at a high level using available information on the potential effectiveness of emission reduction projects and strategies. The actual effectiveness will depend upon the details of implementation and factors like affordability, consumer uptake, and achievable implementation.

Evaluation of Carbon Reduction Strategies and Scenarios

The baseline forecast estimated that about 2.9 million metric tons (MMT) of carbon dioxide-equivalent (CO_2e) were emitted by Vermont's transportation sector in 2022. This is projected to decline to 2.4 MMT in 2030 and under 800,000 metric tons (MT) in 2050, considering adopted federal fuel efficiency standards and state rules to accelerate adoption of zero-emission cars and trucks and pending ongoing funding to achieve the full potential of these standards and rules, most notably, funding for building out the light and heavy-duty charging networks. While these projected declines are significant, when comparing with the emissions levels from the transportation sector recommended by the CAP, a gap of 410,000 MT in 2030 and nearly 100,000 MT CO_2e in 2050 still remains.[1] Assuming a linear decline, supported by adequate funding for continued investment in vehicle adoption incentive and charging infrastructure programs, the 2030 requirement would be met in approximately 2035.

The vast majority of transportation emissions are from motor vehicles (cars and trucks) operating on Vermont's roadways. Aviation represents just over 3 percent, rail represents just over 2 percent, transit operations are about 0.5 percent, and roadway construction and maintenance emissions comprise about 0.3 percent of total statewide emissions. Current programmed projects in AOT's capital budget are expected to have a small impact (2,115 MT or about 0.1 percent or less emissions reduction) compared to total

[1] The gap evaluated in this work was based on the Vermont Climate Council's recommendation of sectoral proportionality (i.e. transportation accounts for nearly 40% emissions and thus should contribute 40% of the reductions); which may or may not reflect the most cost effective approach to achieving the state's GHG reduction requirements. The gap estimated in this Strategy may be different than the gap estimated by the Agency of Natural Resources in the latest Climate Action Plan. While every attempt was made to align methods and assumptions between the two plans, evolving policies, standards, and assumptions, as well as differences in technical methods between the two, may still lead to different estimations of future emissions and the gap compared to target emissions.

transportation emissions (2.4MMT) in 2030. Potential strategies whose effects could be quantified would further close the 2030 gap by about 18 percent (73,000 MT), with an estimated cost of just over $400 million cumulatively through 2030. These strategies could include:

Bicycle and pedestrian network expansion.

Transit service expansion.

Micromobility subsidies.

Expanded travel demand management programs to encourage less carbon-intensive means of travel.

Transit vehicle electrification.

Compact land use/smart growth.

Broadband expansion to serve the entire state.

Advanced Clean Fleets to further electrify truck fleets in the state.

Feebates to further incentivize clean vehicles.

Additional Carbon Reduction Strategies

Closing the gap between projected emissions and required emissions levels, consistent with the sectoral proportionality recommended by the CAP, goes well-beyond what can be accomplished with the Carbon Reduction Program funding provided by the U.S. DOT and will pose a significant challenge for the transportation sector. The state will need to go beyond simply expanding its current programs and project portfolio and consider additional, innovative policies and programs, some of which may be resource intensive, to support more rapid decarbonization of the transportation sector. The additional strategies fall into the following categories:

1. Expand **transportation capital program investment and services** (bicycle and pedestrian, transit, micromobility, and travel demand management), as feasible consistent with available funding.

2. Expand programs and incentives (tax credits, prioritized funding, etc), provide technical support and design guidance, and reform land use regulations to encourage **compact land use and teletravel.**

3. Support maximum conversion of Vermont’s vehicle fleet to **zero-emission vehicles**.

4. Undertake a process with public and stakeholder involvement to **further evaluate, develop, and implement additional programs** to close the gap between projected and emissions levels required by the GWSA while providing a funding source for additional investments as described in other strategies.

5. **Center equity in carbon reduction** to ensure strategies are designed and implemented in an accessible and affordable manner such that all Vermonters benefit, and that historically overburdened or disadvantaged populations are not placed at further risk of harm or financial burden by emission reduction strategies.

6. **Monitor and track progress**, at a level of detail sufficient to support continuous improvement in the effectiveness of emission reduction policies and programs.

Many of the actions recommended in this Carbon Reduction Strategy are outside AOT's authority to implement and would require authorizing action from the legislature. Furthermore, while some policy changes can be made at modest cost, many of the additional investments and services will require expanded funding sources as they cannot be accomplished with the $31.6 million in Carbon Reduction Program funding provided by the U.S.DOT.

Implementation of Carbon Reduction Program Funds

In federal fiscal years 2022 and 2023, AOT was authorized just over $12.7 million in Carbon Reduction Program funding. These funds have not yet been spent on eligible projects. The total funding expected to be authorized through federal fiscal year 2026 is approximately $31.6 million, or on average $6.3 million per year.

AOT will use CRP funding for projects aligned with three priorities. These priorities were identified based on cost-effectiveness, co-benefits, public support, alignment with other plans, and immediate need and opportunity:

Bicycle and pedestrian projects, including Complete Streets, shared-use paths, bike lanes, and sidewalks, prioritized within designated smart growth locations (town and village centers).

Transit and micromobility services and incentives (e.g., microtransit, shuttles, e-bike incentives).

Fleet conversion, including conversion of transit buses and/or AOT heavy equipment to electric and/or other zero emission technology, and supporting infrastructure.

Looking beyond the Carbon Reduction Program, AOT will work to increase consideration of GHG emissions in capital programming through its project prioritization and selection processes as well as to further reflect Carbon Reduction Strategy priorities in the next update of the state's Long-Range Transportation Plan.

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1.0 Purpose of the Strategy

1.1 Objectives

Climate change represents a threat for Vermont's people and the natural systems upon which we depend for our health and well-being. This Vermont Transportation Carbon Reduction Strategy establishes a plan for directing Carbon Reduction Program funding provided by the U.S. Department of Transportation (DOT) to support greenhouse gas (GHG) emissions reduction from the transportation sector, which AOT can implement, as well as identifying a set of additional carbon reduction strategies that could reduce carbon emissions from the state's transportation sector, consistent with requirements established in the Global Warming Solutions Act (GWSA).

Specifically, to support efforts to reduce transportation emissions at the state level, the Federal Infrastructure Investment and Jobs Act of 2021 established the Carbon Reduction Program. Administered by the U.S. DOT, this program is expected to provide Vermont with $32 million between federal fiscal years 2022 and 2026. The state has broad latitude to spend this money on a variety of carbon reducing projects, such as mode shift, traffic efficiency, and electric vehicle infrastructure. The Federal Highway Administration (FHWA) requires each state to develop and submit a Carbon Reduction Strategy no later than November 15, 2023, to support efforts to reduce transportation emissions and identify projects and strategies to reduce these emissions.

More broadly, in September 2020, the Vermont Legislature passed the Global Warming Solutions Act, a climate-action accountability framework. This Act (Act 153 of 2020) creates a planning process and framework to ensure stepped, strategic action on climate change. It sets deadlines for the state to cut harmful climate pollution, with the 26 percent Paris Climate Accord reduction target as the first milestone and achieving 80 percent reduction by 2050. Pursuant to this Act, the Initial Vermont Climate Action Plan (CAP) was adopted in December 2021 to identify specific initiatives, programs and strategies necessary to achieve the state's GHG emission reduction requirements and build resilience and adaptation. The CAP included a set of priority actions for the transportation sector (see inset on p. 1-3). The CAP also includes guiding principles for a "just transition" to inform recommendations based on how they will impact Vermont's impacted and frontline communities.

The GWSA requires that Vermont reduce its gross GHG emissions at least 26 percent below 2005 levels by 2025; 40 percent below 1990 levels by 2030; and 80 percent below 1990 levels by 2050. At the time the Act was passed, Vermont's greenhouse gas inventory showed the transportation sector making up the largest share (40 percent) of Vermont's climate pollution. Transportation costs also made up the largest share of the energy cost burden facing Vermonters (45 percent of total energy expenditures). Based on the proportion of emissions by sector in 2018, the Vermont Climate Council agreed that the Climate Action Plan should aim to achieve a minimum of 40 percent of Vermont's required emissions reductions from the transportation sector.

This Vermont Transportation Carbon Reduction Strategy meets the FHWA requirements to develop a Carbon Reduction Strategy while also identifying additional strategies that could achieve the emission reductions required under the GWSA for consideration by the Vermont Climate Council.

1.2 Audience and Implementation

This Transportation Carbon Reduction Strategy was developed by the Vermont Agency of Transportation (AOT). AOT can support implementation of the strategy through the choices it makes in its long-range planning and Capital Program investments, as well as through other policies such as street design and materials standards. While these Agency actions will result in some GHG emissions reductions, they are more desirable and effective from a co-benefits standpoint. Many of the most effective strategies to reduce emissions towards the requirements of the GWSA extend beyond the Agency of Transportation's purview. Full implementation of the Strategy will require thorough analysis, public engagement processes, and coordination on the part of many stakeholders, including:

The legislature.

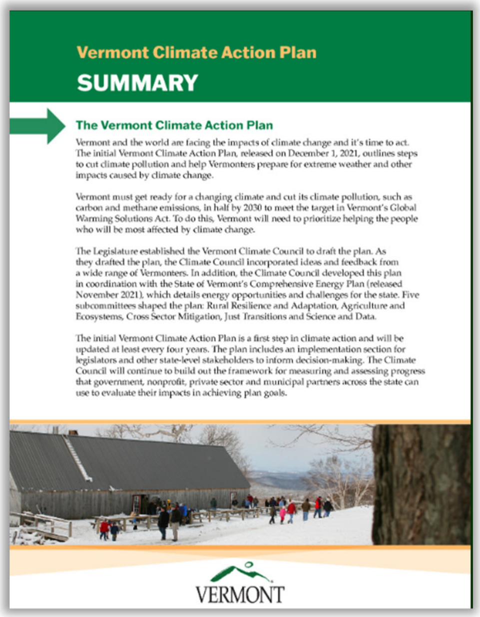
The executive branch.

Municipalities and regional planning agencies.

Vermont's citizens, businesses, and public utilities.

Vermont's Climate Action Plan

Vermont's Initial Climate Action Plan (December 2021) outlines steps to cut climate pollution and help Vermonters prepare for extreme weather and other effects of climate change. The plan, which will be updated at least every four years, includes an implementation section for legislators and other stakeholders to inform decision-making. For transportation, the plan outlines a two-pronged approach to make both vehicles and the transportation system more efficient by 1) replacing carbon intensive fuels (gas and diesel) with zero emission or low carbon fuels such as electricity; and 2) creating options for Vermonters to drive less or use alternatives to the single occupancy vehicle to get where they need to go, while also expanding options for those who cannot drive. High and consensus medium priority actions and associated responsibilities include:


Vermont Climate Action Plan

SUMMARY

The Vermont Climate Action Plan

Vermont and the world are facing the impacts of climate change and it's time to act. The initial Vermont Climate Action Plan, released on December 1, 2021, outlines steps to cut climate pollution and help Vermonters prepare for extreme weather and other impacts caused by climate change.

Vermont must get ready for a changing climate and cut its climate pollution, such as carbon and methane emissions, in half by 2030 to meet the target in Vermont's Global Warming Solutions Act. To do this, Vermont will need to prioritize helping the people who will be most affected by climate change.

The Legislature established the Vermont Climate Council to draft the plan. As they drafted the plan, the Climate Council incorporated ideas and feedback from a wide range of Vermonters. In addition, the Climate Council developed this plan in coordination with the State of Vermont's Comprehensive Energy Plan (released November 2021), which details energy opportunities and challenges for the state. Five subcommittees shaped the plan: Rural Resilience and Adaptation, Agriculture and Ecosystems, Cross Sector Mitigation, Just Transitions and Science and Data.

The initial Vermont Climate Action Plan is a first step in climate action and will be updated at least every four years. The plan includes an implementation section for legislators and other state-level stakeholders to inform decision-making. The Climate Council will continue to build out the framework for measuring and assessing progress that government, nonprofit, private sector and municipal partners across the state can use to evaluate their impacts in achieving plan goals.

VERMONT

- Adopt California's Advanced Clean Cars II and Advanced Clean Trucks Regulations (ANR, legislature).
- Expand and redesign Point of Sale Purchase Incentives for new and used electric vehicles (EVs) and E-bikes (legislature and AOT).
- Continue to fund and expand Replace Your Ride, Mileage Smart, and micro-transit pilot programs (legislature and AOT).
- Design and implement a vehicle efficiency price adjustment to help incentivize the purchase of more efficient new vehicles and disincentivize purchase of less efficient vehicles (legislature and Department of Taxes).
- Continue to fund and support build-out EV charging equipment (legislature; interagency EVSE Working Group with ACCD, AOT, ANR, VDH, PSD).
- Consider and develop beneficial charging rates (legislature, PUC).
- Educate drivers on benefits of electrification and other transportation options to reduce VMT (Agency of Education with ANR and legislature).
- Fund programs that incentivize electric auxiliary systems on medium and heavy-duty vehicles (legislature, ANR).
- Create a State Sustainable Transportation Implementation Plan that addresses (1) smart growth, (2) VMT targets, (3) needed investment across modes, (4) technical assistance to RPCs and municipalities, (5) consideration of free fares for transit users, (6) increasing availability of transit, micro-transit, and rail, and (7) enhanced delivery of Complete Streets and bicycle and pedestrian programs (AOT, legislature, regional and local partners).

Note: ANR = Agency of Natural Resources; ACCD = Agency of Commerce and Community Development; VDH = Vermont Department of Health; PSD = Department of Public Service; PUC = Public Utilities Commission; EVSE = Electric Vehicle Supply Equipment.

Steps currently being implemented towards these CAP actions are outlined in Section 4.

2.0 Strategy Development Process

2.1 Stakeholder and Public Engagement

Vermont's Transportation Carbon Reduction Strategy was developed with public and stakeholder engagement through the following means:

Two sets of virtual public meetings, held in March and August 2023. Meetings were held mid-day and early evening to provide opportunities for more people to attend. Approximately 58 people participated in the March meetings and 41 people participated in the August meetings.

An online survey made available to the general public providing an opportunity to review early modeling results and to provide input on proposed strategies during July and August 2023. The survey was advertised through a media advisory, six social media posts, and at two virtual public meetings. The information was picked up in several local media outlets. Approximately 700 people responded to the survey.

An online comment mailbox to which anyone could send comments. A total of 69 comments were received.

Two rounds of focus groups, held in March and July 2023. The focus groups included representatives from interest groups including:

Businesses.

Community groups with an equity and/or environmental justice focus.

Freight and rail transportation.

Public transportation providers and regional planning agencies.

Environmental interests.

Elected officials (March only, due to scheduling constraints outside of the legislative session).

Presentations to the Vermont Climate Council Cross Sector Mitigation Subcommittee.

A webpage was also developed to provide background information about the strategy development, its status, and ways to provide feedback. The virtual meetings and online survey were advertised through media advisories and social media posts, as well as through stakeholder focus groups and committee meetings.

Development of the Strategy was further guided by an Advisory Committee and a Technical Committee made up of representatives of various state agencies, interest groups, and data, modeling and research experts. The Advisory Committee membership was established to ensure coordination with other state efforts including ongoing development, updates, and implementation of the Climate Action Plan. The Technical Committee ensured the soundness of the analysis methods used to quantify GHG emissions and reduction potential. Appendix A includes the membership of the Advisory and Technical Committees, the affiliations of focus group participants, and the results of the public survey.

2.2 MPO Coordination

U.S. DOT requires that each state's Carbon Reduction Strategy be developed in coordination with the state's Metropolitan Planning Organization(s). Both the Advisory and Technical Committees included membership from the Chittenden County Regional Planning Commission (CCRPC) that serves as the only Metropolitan Planning Organization (MPO) in Vermont. Over the course of the project, four meetings were held with the Advisory Committee and six meetings were held with the Technical Committee. CCRPC staff also participated in the stakeholder focus groups consisting of public transportation providers and regional planning agencies.

2.3 Technical Analysis

The technical analysis to inform the the effect of the Capital Program on GHG emissions included the following elements:

A **baseline forecast** of the state's transportation emissions through 2050, considering current adopted policies. This baseline forecast was developed in coordination with the Agency of Natural Resources and consultants supporting the Climate Action Plan.

An assessment of the **GHG impacts of AOT's current Capital Program projects**. These impacts include emissions generated by roadway construction and maintenance and transit operations in the state, as well as emissions reductions from mode shift (e.g., from transit services and pedestrian and bicycle infrastructure), efficient traffic operations, and clean vehicles.

In addition, to support consideration of the requirements of the GWSA, as well as use of Carbon Reduction Program funds, the analysis included:

An assessment of the **gap** between projected baseline emissions and emission levels required under the GWSA. The gap was evaluated for the target years of 2025, 2030, and 2050 referenced in the GWSA.

Development and evaluation of potential **strategies** to close the gap. A comprehensive list was first developed. Strategies were then evaluated based on general information on potential effectiveness (GHG reduction potential), cost-effectiveness (dollars per ton of pollutant reduced), and other "co-benefits" such as mobility, air quality, and public health. Finally, a quantitative evaluation estimate was made of the potential contribution of each strategy to reducing emissions and closing the gap in each year.

The analysis was performed at a high level using available information on the potential effectiveness of emission reduction projects and strategies. The actual effectiveness will depend upon the details of implementation and factors like affordability, consumer uptake, and achievable implementation.

To develop the baseline forecast, Capital Program evaluation, and strategy evaluation, AOT's consultant team created a spreadsheet tool referred to as the VTrans GHG Sketch Tool. The tool accepts inputs of key baseline parameters (e.g., vehicle-miles of travel, electrification, vehicle efficiency, transit service and fuel consumption) to develop baseline forecasts. The tool also accepts summary data on AOT's Capital Program projects. The tool includes calculation methods to develop planning-level estimates of GHG reductions associated with different types of projects that are or could be included in the Capital Program, including transit service, bicycle and pedestrian improvements, traffic operations, travel demand management (TDM), and electrification infrastructure. The tool was an early version of the Transportation Efficiency And Carbon Reduction Tool (TEA-CART) developed by Cambridge Systematics for the Georgetown Climate Center in 2023 and made available starting in July 2023 as a pilot program for state evaluation and use.

Appendix B provides additional details on the methods for developing the baseline GHG forecast, while Appendix C provides information on the Capital Program evaluation methods and Appendix D provides details on how the proposed carbon reduction strategies were evaluated.

3.0 Evaluation of Carbon Reduction Strategies and Scenarios

3.1 Baseline Forecast

The first step in evaluating carbon reduction strategies was to create a baseline forecast of Vermont's transportation emissions through 2050, considering currently adopted policies, but not the programmed Capital Program projects. The baseline forecast was created using data and assumptions generally consistent with modeling conducted for the Climate Action Plan by consultants for the Agency of Natural Resources (ANR), although the methods and some details varied so the inventories are not identical.

Key assumptions for on-road sources included vehicle-miles of travel (VMT) by vehicle type, vehicle fuel efficiency by vehicle type, and rates of zero-emission vehicle (ZEV) adoption. ZEV adoption rates considered manufacturer sales requirements under the Advanced Clean Cars 2 and Advanced Clean Trucks rules adopted in 2022. The key parameters are shown in Table 3-1.

Table 3-1 Key On-Road Parameters for Baseline Forecast

Parameter	2025	2030	2050
Light Duty Passenger VMT (million)	6,310	6,851	7,301
Medium and Heavy Duty Truck VMT (million)	841	927	1,092
Light Duty Passenger ZEV Stock %	4%	18%	85%
Medium and Heavy Duty Truck ZEV Stock %	1%	10%	58%

Baseline forecasts were also created or obtained for public transit, rail, and aviation, and other transportation source categories:

Public transportation emissions for buses and demand-response service were estimated for the Green Mountain Transit Authority, the state's only service provider reporting to the National Transit Database[2], based on reported fuel use in 2019; and by vehicle-miles of service reported by 10 other Vermont agencies.

Rail, aviation, marine (navigation), and "other" source category emissions output were sourced directly from the Low Emissions Analysis Platform (LEAP) maintained by the Vermont Agency of Natural Resources.

Emissions associated with maintenance of Vermont's existing roadway system were included in the baseline. Maintenance emissions include both maintenance vehicle operations and embedded emissions associated with the production of materials. Although embedded emissions are not technically part of Vermont's transportation sector, they are potentially under the control of the AOT. These emissions were estimated using the Federal Highway Administration (FHWA) Infrastructure Carbon Estimator (ICE) tool with inputs of roadway centerline miles. Emissions are reported in metric tons of carbon dioxide-equivalent (MT CO_2e).

[2] Federal Transit Administration (2019). *National Transit Database*. Accessed online at: https://www.transit.dot.gov/ntd

Baseline forecast emissions are summarized in Table 3-2. A detailed description of methods for onroad vehicles and public transit is provided in Appendix B.[3] The vast majority of transportation emissions are from motor vehicles (cars and trucks) operating on Vermont's roadways. Aviation is just over 3 percent, rail (passenger and freight) are just over 2 percent, transit operations are about 0.5 percent, and roadway construction and maintenance emissions each comprise about 0.3 percent of total statewide emissions.

Table 3-2 Baseline Forecast Emissions (MT CO_2e)

Source Category	2022	2025	2030	2050
Onroad Vehicles	2,650,367	2,546,692	2,146,801	508,778
Public Transit	15,781	15,781	15,781	15,781
Rail (passenger and freight)	63,453	64,221	65,120	65,171
Aviation	99,502	100,702	102,104	102,188
Marine (navigation)	33,555	33,961	34,434	34,465
Other[a]	29,128	29,480	29,892	29,916
Construction and Maintenance	7,390	7,095	6,686	6,179
Total	**2,899,177**	**2,797,933**	**2,400,818**	**762,477**

[a]"Other" mainly includes off-road sources such as agricultural, construction, mining, and lawn and garden equipment, all-terrain vehicles, and snowmobiles.

3.2 Emissions Impacts of AOT's Capital Program

The Legislature approves AOT's Capital Program on an annual basis. The Capital Program includes details on projects underway and to be undertaken over a four-year period and their associated budgets. AOT's Capital Program database was obtained in November 2022. At the time it included 429 unique projects with construction start dates from 2019 to 2028. The database contained basic information including the project type, a description, the length of the project, and geolocation data. Table 3-3 shows a count of projects by type.

[3] Consistent with the state's emissions accounting protocol, this inventory is specific to the transportation sector in the state and includes only direct (tailpipe) emissions. Emissions from electricity generation are not included, as those are reflected in the state's electricity sector. "Upstream" emissions associated with the production and transport of fuels as well as vehicle manufacturing are also not explicitly included. Most of these occur outside of Vermont. Those that occur inside Vermont (e.g., trucks distributing petroleum fuel) are already included in the respective sectoral estimates.

Table 3-3 Count of Capital Program Database Projects

Project Type	Count
Aviation	9
Bike & Pedestrian Facilities	29
Bridge Reconstruction	1
Interstate Bridges	15
Maintenance	3
Municipal Mitigation	16
Park & Ride Lots	3
Paving	76
Rail	55
Rest Areas	6
Roadway Projects	71
State Highway Bridges	56
Town Highway Bridges	24
Traffic & Safety	28
Transportation Alternatives[a]	37
Total	**429**

[a]"Transportation Alternatives" include pedestrian and bicycle projects as well as other project types such as environmental mitigation.

Planning-level estimates were developed for the following emissions changes expected from Capital Program activities:

Agency-generated emissions attributable to:

Construction and maintenance of assets (e.g., roadway maintenance and rehabilitation, bridge replacements).

Operation of assets (emissions from transit operations, which are directly funded by AOT).

Changes in system user emissions associated with projects affecting GHG emissions, such as:

VMT change/mode shift, including bicycle and pedestrian investments, expanded transit service, and expanded TDM programs.

Operational efficiency improvements such as roundabouts and signal re-timing.

Clean technology, including electric/alternative fuel vehicle infrastructure.

Rail and Aviation projects listed in the Capital Program were focused on system maintenance/state of good repair rather than new investments that could encourage passenger or freight mode shifting. Therefore, no changes in emissions related to rail or aviation system users were estimated from these projects. Also, due to lack of data, emissions from rail and airport construction and maintenance were not estimated.

Emissions results for 2025, 2030 and 2050 are summarized in Table 3-4. Appendix B describes the analysis methods and key assumptions in more detail.

Table 3-4 GHG Emissions Impact of AOT Capital Program Projects (MT CO_2e)

Project Type	2025	2030	2050
Bicycle and Pedestrian[a]	-560	-425	-68
Roadway Expansion	0	0	0
Traffic Operations	-1,925	-1552	-564
Transit	-19	-23	-4
Travel Demand Management	0	0	0
Park and Ride	-141	-107	-17
Total	**-2,654**	**-2,115**	**-654**

[a]Includes bicycle and pedestrian Transportation Alternatives projects and shoulder widenings (if resulting shoulder width is at least 4 feet), along with other projects including shared-use path and sidewalk construction.

The following **conclusions** can be drawn from the Capital Program analysis:

Current programmed projects in the capital budget will have a small impact (reducing total transportation emissions by about 0.1 percent or less), with most of these benefits coming from traffic operations improvements.

As more vehicles electrify in the future, VMT reduction, mode shift, and traffic operations improvements will have proportionately smaller impacts as measured in tons of GHG emissions.

The analysis illustrates the limitations of the agency's current suite of VMT and operations-based measures to meaningfully reduce transportation GHG emissions, particularly in the Vermont context where much of the population lives in small urban or rural areas with limited travel options. However, improving travel options and reducing congestion are still important for a variety of other reasons including mobility, health, safety, economic growth, and quality of life.

3.3 Gap Analysis

The 2020 Global Warming Solutions Act sets legally binding emissions reductions for the state. The legislation states that greenhouse gas pollution must be:

26 percent below 2005 by 2025.

40 percent below 1990 by 2030.

80 percent below 1990 by 2050.

The transportation sector is responsible for 40 percent of emissions in the state. Table 3-5 shows the results of the gap analysis for the transportation sector when considering the adopted federal fuel efficiency standards and state rules to accelerate adoption of zero-emission cars and trucks; the full potential of which is dependent on ongoing funding for incentives and building out of the light and heavy-duty charging networks, as well as the Agency's current capital program. Notably, while the state is on track to meet its transportation emissions targets for 2025 based on this modeling, when comparing with the emissions levels from the transportation sector recommended by the CAP, there is a projected gap of around 410,000 MT CO_2e in 2030, and around 100,000 MT CO_2e in 2050.[4] Assuming a linear decline, supported by adequate funding for continued investment in vehicle adoption incentive and charging infrastructure programs, between 2030 and 2050, the baseline projection would reach the 2030 target level by roughly 2035.

Table 3-5 Gap Analysis for Vermont's Transportation Sector (MT CO_2e)

Category	2025	2030	2050
Baseline Emissions	2,797,000	2,400,000	762,000
Target Emissions	2,799,000	1,990,000	662,000
Emissions Gap	-1,400	410,000	100,000

3.4 Potential Carbon Reduction Strategies

Vermont could implement numerous combinations and implementation levels of transportation carbon reduction actions beyond current programmed projects and adopted policies. For purposes of this Carbon Reduction Strategy a sample portfolio of strategies was developed, and emissions benefits and costs estimated for those strategies. The strategies were identified based on past planning efforts (including the Climate Action Plan) as well as input from stakeholders and the public as well as experience from other states and entities working to reduce transportation carbon emissions. The implementation levels were established consistent with stakeholder assessments of aggressive yet feasible implementation of each strategy.

Table 3-6 shows the strategies that were evaluated and the GHG reduction results and estimated public sector costs for implementing each strategy as described. While it is possible to infer a cost per ton of emissions reduced from this table, the strategies in this table should not be evaluated solely on their cost-effectiveness at reducing GHG emissions. As noted in Section 3.7, many of these strategies have various co-benefits, such as mobility, air quality, and health, that should also be considered. Appendix D provides more details on how these strategies were modeled, including cost estimates.

[4] The gap evaluated in this work was based on the Vermont Climate Council's recommendation of sectoral proportionality (i.e. transportation accounts for nearly 40% emissions and thus should contribute 40% of the reductions); which may or may not reflect the most cost effective approach to achieving the state's GHG reduction requirements. The gap estimated in this Strategy may be different than the gap estimated by the Agency of Natural Resources in the latest Climate Action Plan. While every attempt was made to align methods and assumptions between the two plans, evolving policies, standards, and assumptions, as well as differences in technical methods between the two, may still lead to different estimations of future emissions and the gap compared to target emissions. Appendix C provides a gap sensitivity analysis.

Table 3-6 Evaluation of Potential GHG Reduction Strategies

Strategy	Implementation Assumptions	CO_2 Reduction (2030 metric tons)	% of 2030 Gap Closed	Estimated Cost Through 2030 ($M)
Bicycle and pedestrian network expansion	Build an additional 150 directional miles of new bicycle lanes and shared use paths and 150 directional miles of widened shoulders statewide (outside Chittenden County); build out proposed bicycle facilities from Chittenden County Active Transportation Plan to roughly double the amount of bicycle infrastructure in the county; increase sidewalk coverage across the state. Complete half of the buildout by 2030.	220	0.1%	55.7
Transit service expansion	Increase Green Mountain Transit Bus Service from 20 to 15-minute frequencies (30% service increase). Expand rural fixed-route bus service to include weekend service (34% service increase).	690	0.1%	44.0
Micromobility	Provide over $1 million annually to incentivize e-bike adoption for 50% of the purchase price.	1,420	0.3%	7.9
Travel demand management	Expand funding for Vermont's travel demand management program "GO! Vermont" which helps facilitate travel in non- single occupancy vehicle modes.	80	0.0%	2.8
Transit vehicle electrification	Fully electrify all of Vermont's registered transit agency fleets by 2050 (25% electric by 2030).	4,260	1.0%	31.5
Land use	Concentrate future housing unit growth in higher-density, mixed-use areas with lower VMT per capita. Assume turnover of existing housing stock (4% each decade or 1,300 housing units/year) supports redevelopment in mixed-use areas with lower VMT per capita.	5,660	1.4%	NA[a]
Broadband expansion	Complete expansion of the Vermont rural broadband network to serve all Vermonters by 2030.	5,300	1.3%	191.7
Advanced Clean Fleets	Adopt California's Advanced Clean Fleets rule with proportionately similar benefits for introducing zero-emissions trucks.	35,700	7.7%	79.3
Feebates	Adopt a "feebate" program in which vehicles with lower fuel efficiency receive a surcharge and vehicles with higher fuel efficiency receive a rebate at the time of registration.	19,800	4.8%	NA[b]

[a]The land use strategy would incur some administrative costs (e.g., for assisting municipalities with planning and zoning updates), as well as some incentive costs and potentially additional costs and/or cost savings associated with infrastructure and services (e.g., water/wastewater, municipal services) that may depend upon the location of development. These potential costs and/or cost savings were not estimated due to a lack of reliable information on the full set of costs and/or savings that might be incurred.

[b]The feebate program would be designed to be revenue-neutral, but would incur an undetermined amount of costs for administering the program.

Additional strategies were considered but their effects were not quantified. These strategies, and the reason for not modeling their effects, are presented in Table 3-7.

Table 3-7 Carbon Reduction Strategies Not Quantified

Strategy	Implementation Assumptions	Reason for Not Modeling
Electric or zero-emission vehicle and infrastructure incentives	Expand incentives for purchasing new or used zero-emission vehicles and/or charging equipment beyond those currently offered.	Assumed to be a supporting strategy for Advanced Clean Car and Truck rules, not providing additional benefits beyond those rules (which are included in the baseline emissions projection).
ZEV charging/ refueling infrastructure	Expand public ZEV charging/refueling network beyond existing funding levels.	Assumed to be a supporting strategy for Advanced Clean Car and Truck rules.
Clean Transportation Standard[a]	Adopt a policy to require fuel suppliers to decrease the life-cycle carbon intensity of transportation fuels by 20 percent by the early 2030s.	More detailed program design and analysis required to model benefits.
Cap-and-invest[a]	Adopt a cap-and-invest program that would establish a declining emissions cap and direct revenue from the auction of emissions allowances towards carbon reduction strategies, including mitigation of costs for low to moderate income households.	More detailed program design and analysis required to model benefits.

[a] Section 4.4 provides a more detailed discussion of the potential benefits and costs of Clean Transportation Standard and cap-and-invest programs, and considerations related to implementing these programs.

3.5 Combined Effects of Quantified Strategies

Table 3-8 shows the combined effects of the strategies evaluated. The strategies are shown in three scenarios, starting with only transportation investments and services, then adding land use and broadband, and finally adding Advanced Clean Fleets and feebates.

Table 3-8 Combined Strategy Effects

Scenario	Strategies	CO2 Reduction (2030 metric tons)	% of 2030 Gap Closed	Estimated Cost Through 2030 ($M)
1	Transportation investment and services	6,500	1.6%	$141.8
2	Transportation + land use + broadband	17,600	4.3%	$333.5
3	Transportation + land use + broadband + Advanced Clean Fleets & feebates	73,000	17.8%	$412.8
	Gap	**450,000**		

Even the full scenario 3 closes less than 20 percent of the projected 2030 emissions gap, and scenarios 1 and 2 close less than 5 percent of the 2030 gap. Appendix E provides results for 2050. To close the 2030 and possibly the 2050 emissions gaps and meet the requirements of the GWSA, it is highly likely that programs beyond those listed above will be needed. Depending on how they are designed and how effectively they are implemented, a Clean Transportation Standard and/or cap-and-invest program could potentially close the gap between projected and required emissions. Overall funding and costs are further discussed in Section 5.1 Use of Carbon Reduction Program Funds.

3.6 Co-Benefits

Although the impact of many carbon reduction strategies on overall GHG emissions appears relatively modest, these strategies can have significant benefits in addition to reducing GHG emissions. These important benefits include (but are not limited to) local air quality (reduction of hazardous air pollutants), mobility, and public health. Table 3-10 summarizes the relative cost-effectiveness of each type of strategy for creating selected co-benefits.[5] Carbon reduction should not be the only, or in some cases even the primary, consideration for deciding how much to invest in these strategies.

Table 3-9 Cost-Effectiveness and Co-Benefits of Carbon Reduction Strategies[a]

Strategy	GHG Emissions	Air Quality (particulate emissions)	Mobility (new non-SOV trips)	Health (cost savings)
Bicycle and Pedestrian Network	++	++	+++	+++
Transit: Service Expansion	+	-	+++	+
Micromobility	++	++	+++	++
Travel Demand Management	++	++	+++	++
Transit: Vehicle Electrification	+++	+++	-	++
Telework	++	+++	-	-
Land Use	+++	++	-	+++
Advanced Clean Fleets	+++	+++	-	++
Feebates	+++	-	-	-

[a]More "+" signs means a higher cost-effectiveness, based on public sector implementation costs. See Appendix D, Section D.10 for a legend and description of the co-benefits analysis.

[5] Cost-effectiveness is considered based on the benefit received per unit of public sector implementation cost. It does not consider private sector costs or cost savings. Examples of cost savings include reduced vehicle purchase and/or operating costs as a result of improved travel options, or business cost savings due to improved labor force access. Examples of costs include the incremental cost of purchasing new vehicles, charging hardware, or telecommunications equipment.

4.0 Additional Carbon Reduction Strategies

The strategy analysis showed that closing the gap between projected emissions and emissions levels required by the CAP will pose a significant challenge for the transportation sector. The state will need to go beyond simply expanding AOTs current programs and project portfolio and consider the development and implementation levels of additional, innovative policies and programs to move towards more rapid decarbonization. These additional strategies fall into the following categories:

1. Expand **transportation capital program investment and services**, as feasible consistent with available funding.
2. Expand programs and incentives (tax credits, prioritized funding, etc), provide technical support and design guidance, and reform land use regulations to encourage **compact land use and teletravel.**[6]
3. Support maximum conversion of Vermont's vehicle fleet to **zero-emission vehicles.**
4. Undertake a process with public and stakeholder involvement to **further evaluate, develop, and implement additional programs** to further close the remaining gap between projected and emissions levels required by the GWSA while also providing a funding source for additional investments as described in other strategies and ensuring equitable outcomes that benefit all Vermonters.
5. **Center equity in carbon reduction** to ensure strategies are designed and implemented in an accessible and affordable manner such that all Vermonters benefit, and that historically overburdened or disadvantaged populations are not placed at further risk of harm or financial burden by emission reduction strategies.
6. **Monitor and track progress**, at a level of detail sufficient to support continuous improvement in the effectiveness of emission reduction policies and programs.

The following sections provide an overview of current activities, to set the context for additional actions; provide opportunities for additional actions; and discuss stakeholder comments and potential concerns related to each set of strategies and how those concerns were or could be addressed.

4.1 Expand Transportation Capital Program Investment and Services

This set of strategies includes directing transportation capital program investment towards projects and services that cost-effectively reduce carbon emissions, while balancing needs to maintain a state of good repair for the transportation system and achieve other objectives such as safety and equitable mobility, within overall funding availability/constraints. It also includes further alignment of transportation agency policies that may be needed to support such investment by the state

[6] Teletravel is defined as conducting activities virtually (on-line) rather than physically traveling to them. Teletravel includes telework as well as remote shopping, health care, education, and other activities.

and its municipalities. This set of strategies is generally within the control of the Agency of Transportation, within the context of available funding.

4.1.1 Current Programs and Activities

Current carbon-reducing activities in AOT policy, programming, and research include:

$13 million per year programmed by AOT in 2023-2026 for **bicycle and pedestrian facilities**, including shared-use paths and sidewalks; with an additional unquantified cost related to shoulder widenings included as part of other highway projects.

$150,000 funded in the FY2024 Transportation Bill for **micromobility** through the e-bike incentives program, available to low to moderate income individuals.

$40 million per year in funding to support **transit** services throughout the state, including planning, administration, and operations.

$800,000 per year to fund the Go! Vermont **travel demand management** program to help people find alternatives to driving.

Research on **low-carbon materials**, including a Recycled Materials Working Group, a high recycled asphalt pavement (RAP) specification – to be piloted in 2024, and development of high-longevity concrete.

4.1.2 Additional Programs and Activities

Additional projects, services, and policies include:[7]

Further expand and enhance **pedestrian and bicycle infrastructure**, especially in village and downtown centers and other compact communities.

Support **micromobility** through incentives such as electric bicycle subsidies and support for bikeshare and scooter-share programs. Continue to target incentives towards travelers who most need them.

Expand **transit service** through increased frequency, expanded hours of operation, and/or new services, including flex-route microtransit and intercity transit), at times and locations that will best encourage new ridership.

Expand **travel demand management** programs, including Go! Vermont and other educational resources, to encourage less carbon-intensive means of travel.

[7] Expanded passenger and freight rail were not included as additional actions based on stakeholder feedback that the potential for truck-rail mode shifting was very limited, and also that passenger rail would serve limited markets compared to more flexible services such as microtransit that could serve a broader range of Vermont's communities. Given that rail improvements are capital-intensive it was felt that limited funds are best prioritized to more cost-effective strategies. This should not preclude the state from leveraging federal and/or private funds when available to continue to improve Vermont's rail network to support faster and more reliable passenger and freight rail service.

Prioritize low- to moderate-cost **traffic control improvements**, such as signal optimization and roundabouts, to smooth traffic flow and reduce idling.

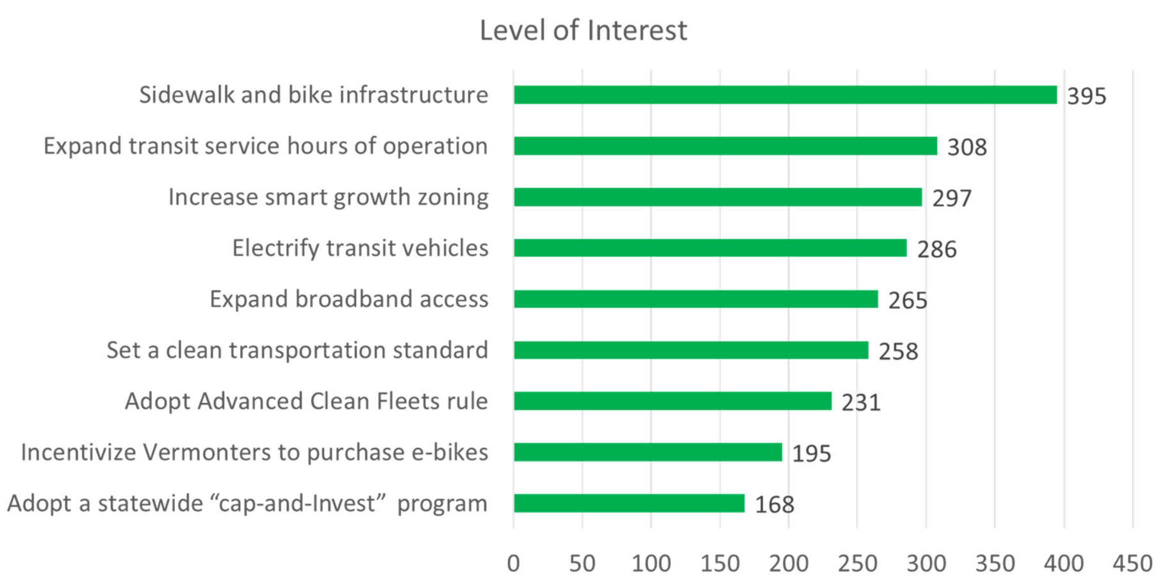
Further research and develop specifications for **low-carbon construction materials**.

Evaluate potential **funding sources** to support expansion of these projects and services.

4.1.3 Considerations

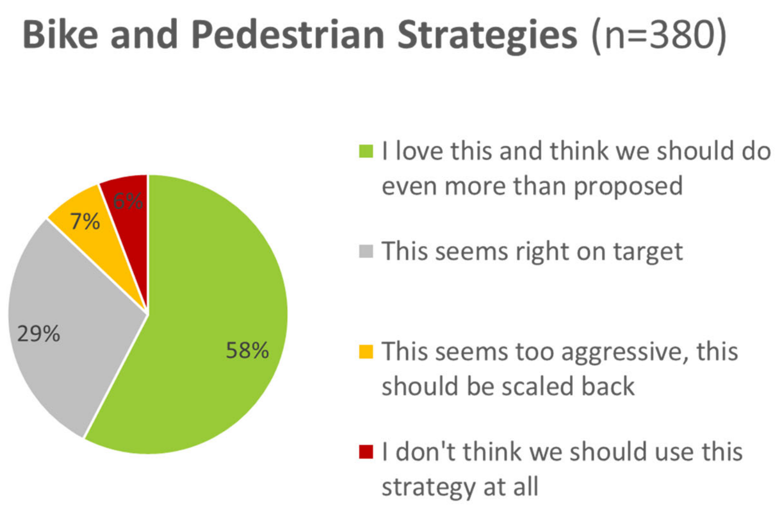
Strong support for these strategies was exhibited for improved travel options in the public and stakeholder outreach for this plan, especially from low-income and younger Vermonters (see Figure 4-1, which compares public survey respondent interest in all the strategies evaluated; and Figure 4-1 and Figure 4-3, which illustrate support for the bicycle and pedestrian and transit strategies at the investment levels described in 3.4). Improved transit services were especially noted as being important to support equity through better access to jobs and services for transportation-disadvantaged Vermonters. Investment in active transportation options was desired to support the vibrancy of Vermont's downtowns and village centers. Travel demand management programs, traffic control improvements, and low-carbon materials were mentioned much less frequently from the outreach.

Figure 4-1 Number of Respondents Indicating "Most Interest" by Strategy[a]



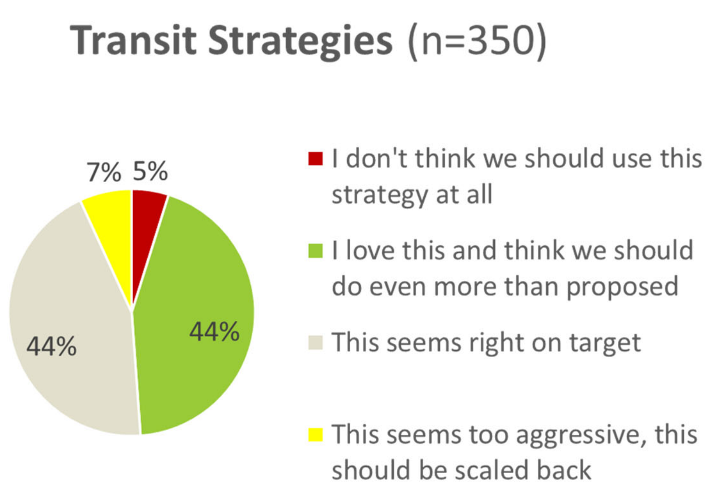
[a]This public survey question asked, "what strategy most interests you?" Respondents were allowed to make multiple selections.

Figure 4-2 Survey Respondent Opinions about Bike and Pedestrian Strategies[a]



[a] In the public survey, information was presented on what was modeled for each of five types of strategies and presenting general information on cost and impact of that level of strategy deployment. The information presented was consistent with the investment levels and assessment of benefits and costs presented in Section 3.4. Respondents were then asked to indicate how they felt about each strategy.

Figure 4-3 Survey Respondent Opinions about Transit Strategies



The primary concern expressed was around the need for a sustainable funding source to increase multi-modal investments and services. Federal transportation funds are not likely to increase beyond current levels in the near term, given current Federal reliance on motor fuel tax revenue that is expected to gradually decline in the future as vehicles become more fuel-efficient and electrify. State motor fuel tax revenue will similarly decline unless an alternative funding source is found. To expand beyond AOT's current programming, the state will need to identify additional funding from a source that can be sustained for a multi-year period.

Some concerns were expressed about whether alternatives to driving were really feasible in the more rural and lower-density parts of the state, and that funding for these strategies would mainly benefit urban areas. Respondents suggested that innovative services such as flex-route “microtransit” and other ridesharing applications might be more effective than traditional transit service in some parts of the state. Some concerns were also expressed that these strategies might not be very effective year-round given the climate in Vermont that could discourage active travel during the winter. Some commenters noted that winter maintenance of pedestrian and bicycle facilities would be important to help make year-round active travel more feasible. Suggestions included providing towns with more control over the design and maintenance of Class 1 trunk highways in town and village centers. When planning and implementing improved infrastructure and services to support travel alternatives, the state should consider the unique needs of smaller towns and rural communities, as well as the role that municipal partners can play in developing and maintaining year-round infrastructure.

4.2 Encourage Compact Land Use and Teletravel

4.2.1 Current Programs and Activities

This set of strategies includes incentives and policy changes to encourage more efficient development patterns and “virtual” travel for work, school, health, and other purposes. Vermont has already adopted some programs that could be expanded, including:

Downtown and Village Center tax credit program - Administered by the Agency of Commerce and Community Development, $4.35 million in state income tax credits are available in fiscal year 2024 to support general rehabilitation and code compliance work, flood mitigation upgrades, and façade improvements.

Sales tax reallocation - Municipalities and the developer of qualified projects may jointly apply to the Downtown Board for a reallocation of sales taxes on construction materials for projects in a designated downtown district. The reallocated taxes are used to support the project.

Homes for All and Neighborhood Partnership Development – The Department of Housing and Community Development has pursued a suite of policies and programs that support growth in housing and housing choices in compact, walkable neighborhoods. New legislation preempts exclusionary zoning and removes lots size barriers to building more affordable housing in compact, walkable centers and neighborhoods. The Homes for All Toolkit provides small scale developers with resources to build missing middle housing (housing with multiple units that are compatible in scale and form with detached single family homes). The Neighborhood Partnership Development aligns government and organization investments in the public infrastructure needed to support the development of homes in inclusive, smart growth neighborhoods.

Broadband expansion – Currently, nearly 97 percent of Vermonters have access to basic broadband and 83 percent have access to higher-speed broadband.[8] The state has a number of coordinated initiatives to make broadband accessible to all residents, including: legislation adopted in 2015 allowing towns and cities to collaborate and form communications union districts (with over 200 municipalities representing over three-quarters of the state's population participating as of 2022); creation of the Vermont Community Broadband Board (VCBB) to support to districts; and allocation of more than $240 million in state and federal recovery funds for broadband deployment projects.

4.2.2 Additional Programs and Activities

Additional strategies include:

Expand **Downtown and Village Center** tax credits and sales tax reallocations to make development and redevelopment in existing compact locations more financially feasible.

Provide additional **incentives for "smart growth" zoning** to allow more compact, mixed-use development and reduce barriers for affordable housing. For example, Massachusetts' Chapter 40R program provides fiscal incentives for municipalities that rezone areas meeting specific density and location criteria.

Increase **technical support** for municipalities to update zoning and subdivision regulations.

Finalize and adopt new **Multimodal Highway Guidance** for AOT-funded projects that update the Vermont State Standards to ensure that Vermont's transportation facilities are planned and designed to meet the current and future transportation needs of our communities.

Prioritize funding for the types of infrastructure that promote smart growth/land use goals, such as Complete Streets, other pedestrian amenities and safety improvements, and reduction of surface parking.

Consider **reform of Act 250 and/or state designation programs**[9] to reduce barriers to development that helps preserve Vermont's natural environment by being located in existing built-up areas where there is also less need for driving.

Complete the **Vermont rural broadband** expansion by 2030 to serve all Vermonters.

[8] "Basic" is defined here as at least 4 megabits per second (Mbps) upload speed and 1 Mbps download. "Higher speed is defined as at least 25 Mbps upload and 3 Mbps download. Source: https://publicservice.vermont.gov/telecommunications-and-connectivity/broadband-high-speed-internet-availability-vermont, accessed August 2023.

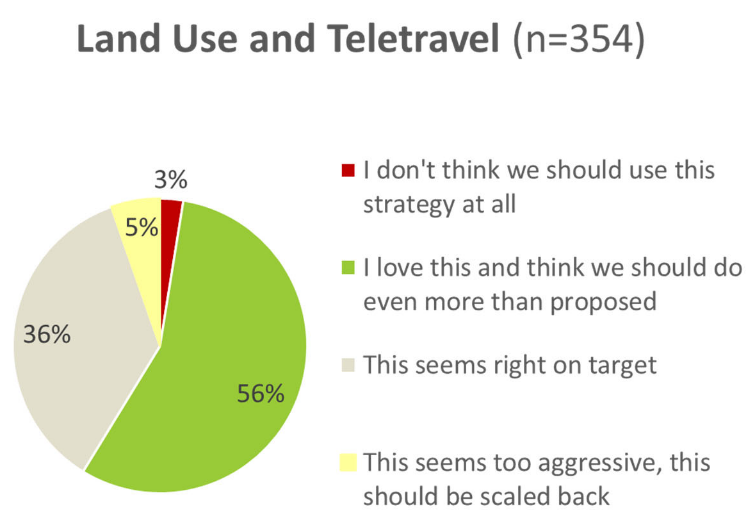
[9] The state designation programs, administered by the Agency of Commerce and Community Development, provide incentives, align policies and give communities the technical assistance needed to encourage new development and redevelopment in compact, designated areas including Downtowns, Village Centers, New Town Centers, Growth Centers and Neighborhood Development Areas.

4.2.3 Considerations

> *"By combining transportation and land use Vermont can achieve more social and health equity, more housing in mixed income walkable neighborhoods, so more Vermonters than today can experience prosperity."*
>
> *- Online Survey Participant*

Strong support for these strategies was exhibited in the public and stakeholder outreach (see Figure 4-4). It was noted that compact land use is an important complement to active travel and transit investment for helping to provide alternatives to vehicle travel. Land use strategies also have relatively modest financial resource requirements, although strategies such as tax credits and technical assistance will require some state funding. In the long run, compact development may even help reduce state and municipal infrastructure costs by supporting efficient provision of services. Broadband completion is well underway thanks to an influx of federal as well as state funding.

Figure 4-4 Survey Respondent Opinions about Land Use and Teletravel Strategies



Some concerns were expressed in the stakeholder and public outreach regarding the potential regulation of land use and restrictions on the ability to develop land. Others noted land use planning is also needed to support provision of more housing, especially affordable housing. Additional strategies in this space should be focused on encouraging – and removing barriers to – beneficial development rather than restricting development of private property. Strong market demand has been exhibited for development in compact, walkable communities. Removing existing barriers to development would help the private market to function more efficiently while also supporting Vermont's economy, carbon reduction requirements, and quality of life.

Stakeholders also noted the importance of AOT supporting downtown and village center development by encouraging multimodal accommodations and reduced traffic speeds on state roads in these areas. AOT is in the process of revising the Vermont State Standards, which guide roadway design, into new Multimodal Highway Guidance assuring accommodations for all modes and all users.

Successful implementation of land use strategies will require collaboration across multiple agencies and with stakeholder and public input to ensure regulations and incentives support positive market forces while not appearing overly restrictive. It will also require thoughtful communication around the benefits and implications of any changes to Vermont's businesses, homeowners, and renters. For any additional incentives that are offered, the state will need to identify a funding source or otherwise make prioritization decisions in the budgeting process.

While broadband access is critical to full integration into today's economy and society, the effectiveness of tele-travel as an emissions reduction strategy is somewhat uncertain. People who telework generally offset the reduced work travel to some degree through trips for other purposes. Furthermore, in the long run, ubiquitous broadband access can encourage people to live in more remote locations whether they need to drive longer distances when they do take trips. Despite these uncertainties it is still important for the state to invest in broadband services for all Vermonters given the critical importance of these services in 21st century life.

4.3 Support Maximum Conversion of Vermont's Vehicle Fleet to Zero-Emission Vehicles

4.3.1 Current Programs and Activities

This set of strategies expands programs and actions already underway to support and incentivize zero-emission vehicle adoption. Current policies, programs, and incentives include:

The Advanced Clean Cars II and Advanced Clean Trucks regulations effective as of December 2022. These regulations require vehicle manufacturers to produce and deliver or sell an increasing percentage of zero-emission vehicles annually through 2035. After 2035, all new light-duty vehicles delivered will be zero-emission.

Vermont state incentives, including up to $5,000 for new EV purchases; up to $5,000 for a used high efficiency vehicle; and up to $5,000 for scrapping an older internal combustion engine (ICE) vehicle. Incentives are income-restricted, except for the those issued through the new fleet incentives to businesses, municipalities and other tax-exempt organizations. Vermont's utilities also offer incentives for both EV purchases and charging infrastructure.

Electrify Your Fleet - $500,000 included in the 2023 transportation bill for SFY24 spending, providing up to $2,500 per vehicle for the purchase or lease of EVs in fleets.

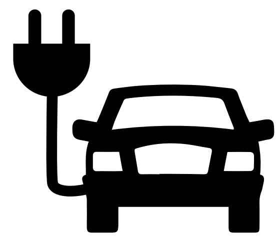
Federal incentives including tax credits of up to $7,500 for new zero-emission cars and light trucks and up to $40,000 for zero-emission heavy trucks.

State and federal formula and grant funding programs for charging infrastructure. For example, the State Legislature has authorized funding for multi-unit dwelling, workplace, and community charging and the U.S. DOT National Electric Vehicle Infrastructure (NEVI) Program is providing $21 million over five years to build fast-charge infrastructure along Vermont's long-distance travel corridors.

4.3.2 Additional Programs and Activities

While the ACC II and ACT rules require manufacturers to supply zero-emission vehicles, additional incentives and investment will be needed to enable consumers to purchase and use these vehicles to their full potential – especially low to moderate income households and small businesses for which the up-front cost of vehicles and charging infrastructure can pose a substantial burden.

The additional strategies provided for below are *necessary* to realize the full potential of the adoption of the ACCII and ACT rules. They include:



Build out a public charging infrastructure network to serve the entire state, in a timeframe to support anticipated EV market penetration consistent with Vermont's adopted Advanced Clean Cars 2 and Advanced Clean Trucks rules.

Provide additional incentives for electric cars and trucks and for investment in private charging infrastructure, including charging equipment and electrical service upgrades at private homes, multifamily dwellings, workplaces, retail locations, and visitor destinations such as ski resorts. Target incentives towards lower-income households and/or disadvantaged communities where appropriate.

Work to **fully electrify the state's bus fleet**, including supporting operators with both vehicles and charging infrastructure.

Pilot and demonstrate the application of low-and **zero-emission heavy equipment** in AOT's fleet to prove the technology, ultimately leading to broader state, municipal, and contractor fleet conversion.

Evaluate potential targeted incentives to specifically encourage **"super-users"** (those who drive the most) to shift to zero-emission vehicles.[10]

In the short term, there is ample funding available from federal programs, U.S. DOT and U.S. Environmental Protection Agency (EPA) programs, as well as Volkswagen settlement funds and utility-funded programs, to begin to build out public charging infrastructure. As these funds are depleted, however, additional funding will be needed beyond 2026, especially if the Federal government does not continue to invest at current levels. Federal and state vehicle and charging infrastructure incentives are also available at the current time. The state should closely monitor incentive and infrastructure programs to ensure that demand is not exceeding supply and that incentives are being used by those who need them most.

While light-duty vehicles are likely to transition to battery electric as the dominant zero-emission technology, it is possible that hydrogen fuel cells may still emerge as a preferred zero-emission technology for trucks and buses, especially those in long-haul use. Vermont should monitor the development of hydrogen technology and support build-out of infrastructure should it appear to be a viable technology. The state should coordinate with neighboring states on efforts to develop hydrogen refueling networks for interstate travel.

[10] A Washington State study found that 10 percent of drivers accounted for one-quarter of light-duty vehicle emissions (Encouraging High-Consumption Fuel Users to Use Electric Vehicles, Washington State Joint Transportation Commission, 2023). The study proposed four targeted policy options for high-mileage drivers: 1) EV lease incentives, 2) EV purchase incentives; 3) gas-powered loaner vehicles for long trips; and 4) Level 2 home charger incentives. These incentives have not yet been tested in practice.

4.3.3 Considerations

While Vermonters generally recognized the need to move toward electric and/or other zero-emission vehicles (Figure 4-5), some concerns were heard:

Affordability – many Vermont residents and businesses cannot afford the up-front cost of a new electric vehicle and/or any charging infrastructure that may be needed at their home or place of business. The state and its utilities have begun to address this through income-targeted incentives, but more assistance may be needed to make these vehicles more broadly affordable. Over time, as more used EVs become available, affordability should improve. However, support will still be needed for electrical upgrades and equipment to support high-powered charging.

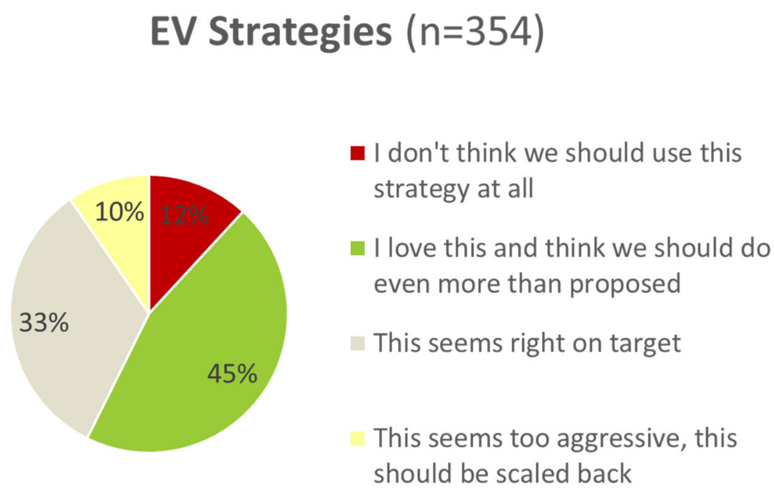
Availability – While light-duty Evs of a range of styles and performance are increasingly available, medium and heavy zero-emission vehicles are still in their infancy. Models for many vocations are either not yet available or have significant range and performance limitations. Supply chain limitations have led to short-term challenges in acquiring many types of new vehicles and especially Evs. In the longer term, by 2030 and beyond, it is expected that vehicle manufacturers will be able to scale up production and meet increasing consumer demand for light-duty vehicles, while also developing and producing a broader range of medium and heavy zero-emission vehicles.

Life-cycle impacts – Zero-emission vehicles are only truly zero-emission at the tailpipe. Producing the vehicle still creates emissions, and the mining and manufacturing of materials for batteries required for Evs makes producing an EV more carbon-intensive than producing an ICE vehicle. These emissions were not quantified in this study, as Vermont's GHG inventory and requirements only consider in-state emissions. Mining and manufacturing of batteries also can create other environmental impacts such as local air and water pollution. Even considering these upstream emissions, an EV with 300-mile range still provides net benefits, producing less than half of the life-cycle emissions of an ICE in the U.S. (and even lower in Vermont, which has a much cleaner electricity grid than the U.S. average). EV life-cycle emissions are projected to decline to one-quarter of ICE emissions in the future as manufacturing process and the electricity grid become even cleaner.[11]

Priorities – Some concerns were expressed that investing in EVs would mean less funding available to improve transit, which may be more important for populations for whom a new vehicle is unaffordable regardless of subsidies, or who are unable to or prefer not to drive.

[11] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "FOTW #1208, Oct 18, 2021: Life Cycle Greenhouse Gas Emissions for a 2020 Electric Small SUV Were Half Those of a Conventional Gasoline Small SUV." https://www.energy.gov/eere/vehicles/articles/fotw-1208-oct-18-2021-life-cycle-greenhouse-gas-emissions-2020-electric

Figure 4-5 Survey Respondent Opinions about Electric Vehicle Strategies



The state can address these concerns through thoughtful policy and program design (for example, income-targeted incentives, balancing investment across different strategies), "lead-by-example" to introduce and demonstrate new types of vehicles in the state's fleet, and communication strategies (for example, education surrounding the life-cycle emissions and cost benefits of EVs).

4.4 Further Evaluate, Develop and Implement Additional Programs to Close the Gap

4.4.1 Programs and Activities

The Carbon Reduction Strategy analysis demonstrated that the strategies presented thus far will still leave a significant gap between actual and required GHG emissions levels. This Strategy identifies additional programs to further close the remaining gap while also potentially providing a funding source for additional investments in other strategies. These additional programs would require thorough analysis, public engagement processes, and coordination on the part of many stakeholders.. These additional programs could include:

The **Advanced Clean Fleets** regulation to further accelerate zero-emission trucks.

A **Clean Transportation Standard** for transportation fuels.

A **cap-and-invest** program.

A vehicle **feebate** program to encourage purchase of more fuel-efficient and zero-emission vehicles.

An addendum to the Climate Action Plan supports design and implementation of either, or both, a Clean Transportation Standard or Cap and Invest (see inset p. 4-12) as a policy recommendation for the transportation sector. These additional programs would need to be developed and evaluated carefully to verify their potential to close the gap and to ensure that, if implemented, they result in affordable and equitable outcomes that benefit all Vermonters. Additional considerations related to program design, implementation, and impacts are discussed below.

Climate Action Plan Support for Cap-and-Invest and Clean Transportation Standard Programs

The Vermont Initial Climate Action Plan includes a Transportation Addendum that was adopted by the Vermont Climate Council on November 14, 2022 by a vote of 11-5, with 1 abstaining. The memorandum states,

"The only currently known policy options for which there is strong evidence from other states, provinces and countries of the ability to confidently deliver the scale and pace of emissions reductions that are required of the transportation sector by the GWSA are one or a combination of:

a) a cap and invest/cap and reduce policy covering transportation fuels and/or

b) a performance standard/performance-based regulatory approach covering transportation fuels

Importantly, based on research associated with their potential implementation, these approaches can also be designed in a cost-effective and equitable manner."

Advanced Clean Fleets

California's Advanced Clean Fleets rule, adopted in April 2023, complements and builds on the Advanced Clean Trucks rule to further transition medium and heavy trucks and buses to zero-emission vehicles. The rule requires fleet owners operating vehicles for private services such as last-mile delivery, as well as federal fleets such as the Postal Service and state and local government fleets, to begin transitioning toward zero-emission vehicles starting in 2024. The rule also increases the stringency of Advanced Clean Trucks to require that automakers deliver and place in service more electric trucks to Vermont by 2036. This rule should be evaluated specifically for its impact on public and private fleets operating in the State of Vermont, including:

How many fleets and vehicles will be subject to the regulation?

What concerns do fleet owners and operators have about the proposed rule?

What is the status of neighboring states with respect to rule consideration/adoption? Could there be unintended consequences if Vermont adopts the rule and neighboring states don't?

What additional policies or supporting programs (e.g., incentives, technical assistance, etc.) might be needed to mitigate any potential impacts of this rule on Vermont's businesses and economic climate, and to maximize the benefits of the rule?

Clean Transportation Standard

A Clean Transportation Standard, also known as a low-carbon fuel standard, is a market-based policy that is designed to decrease the carbon intensity (CI) of transportation fuels. It uniquely considers CI from a lifecycle perspective, including upstream emissions that may occur outside of the state's boundaries. Fuel suppliers buy or sell a limited (and declining) number of credits for each unit of carbon emitted in the production and combustion of each fuel based on the relative CI of the fuel. California, Oregon, Washington, and British Columbia have all adopted requirements to reduce the CI of transportation fuels by 20 percent by 2030 – 2034, thus creating a base of U.S. experience with this type of program. In addition, Canada has adopted a national Clean Fuels Standard requiring a 15 percent reduction in the CI of gasoline and diesel fuels by 2030.[12] New York State has proposed a program modeled after California's. California has proposed to greatly accelerate the CI reduction beyond 2030, to a 90 percent reduction target in 2045.[13]

Key program design considerations for Vermont include:

Which fuels are covered, and what other credit-generating mechanisms may be available. California's program includes three credit-generating mechanisms: 1) fuel-pathway based crediting (e.g. providers of low carbon fuels); 2) project-based crediting (e.g. emission-reducing actions at refineries and crude oil production facilities, and carbon capture and sequestration using direct air capture); and 3) zero-emission vehicle infrastructure crediting.

The rate at which the CI cap declines over time.

Life-cycle CI factors for available fuels. The California Air Resources Board (CARB) maintains a "Current Fuel Pathways" table with CI factor for all certified fuels.[14]

Measures to limit excessive instability of credit prices and facilitate compliance, such as price caps and floors, credit clearance markets, and banking and trading of credits.

A Clean Transportation Standard will incur some administrative costs related to managing the program and operating the credit market. Typically, these costs would be paid out of credits generated so the program would be self-funding. California's program generated more than $2 billion in credit transactions in 2018, with 520 reporting entities in 2022.[15]

A Clean Transportation Standard may increase the cost of fuels to consumers, depending on how much more expensive renewable or "clean" fuels are compared to conventional fuels, and on the degree to which credits can be generated by other mechanisms. Studies of existing low-carbon fuel standards have shown somewhat mixed results regarding cost impacts. Bates White (2022) found that the LCFS price effect at the

12 https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html

13 https://www.srectrade.com/blog/srec/low-carbon-fuel-standard

14 https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

15 https://ww2.arb.ca.gov/resources/documents/lcfs-credit-clearance-market

pump is not a major driver of retail fuel prices in California – the effect of the LCFS in combination with other unexplained factors adding less than $0.20 to the price of gasoline between 2015 and 2019. The study also found that some renewable fuels provided cost savings relative to conventional fuels, and that opening up the market for renewables could help mitigate against swings in the cost of petroleum fuels due to factors such as production capacity challenges or international conflicts.[16]

Vermont could consider the adoption of a Clean Transportation Standard based on, or aligning with, similar standards adopted or considered in other states. This would include coordinating with neighboring states and/or provinces on a potential regional standard. It may also include outreach to the Pacific Coast Collaborative, through which the western states and provinces are collaborating on best practices for implementing their low-carbon fuel standards. The Clean Transportation Standard can be an important complement to multi-sector cap-and-invest systems by ensuring the emissions intensity of transportation fuels is reduced.

Cap-and-Invest Program

A cap-and-invest program would establish an emissions “cap” that declines over time consistent with state requirements. The state would raise revenue from the auction of emissions “allowances” and reinvest revenue towards carbon reduction strategies. California has had a cap-and-invest program that includes transportation fuels since 2015, and Quebec has joined with this program. Washington State adopted its own program in 2023, and New York State is developing a program.[17] Vermont previously participated in the development of the Transportation and Climate Initiative - Program (TCI-P) with 13 other northeast and mid-Atlantic States to adopt a regional cap and invest program specific to the transportation sector, although this initiative has not been implemented.

Key program design considerations include:

Which emissions sources are covered (sectors and regulated entities).

The stringency of the emissions cap and the rate at which it declines over time.

Which sources may be provided allowances instead of being required to purchase them in the market. For example, existing programs typically provide allowances to certain "emissions-intensive, trade exposed" industries that are considered at high risk of disadvantage to non-covered competitors due to the program.

Measures to limit excessive instability of credit prices and facilitate compliance, such as auction price floors and ceilings, and banking and trading of credits.

Use of offsets (i.e., purchases of certified emission reductions from other entities) to cover credits.

Mechanism and policies for distributing revenues. These may include provisions to ensure that a certain fraction of program revenues are directed to support equity-focused investments and technology transitions (e.g., targeted to disadvantaged communities, low-income households, or small businesses).

[16] Bates White Economic Consulting (2022). Low Carbon Fuels Standards Market Impacts and Evidence for Retail Fuel Price Effects. https://www.bateswhite.com/media/publication/226_BW%20LCF%20Report%20-%20April%202022.pdf

[17] https://capandinvest.ny.gov/

A cap-and-invest program will incur some administrative costs related to managing the program and operating the credit market. Typically, these costs would be paid out of credits generated so the program would be self-funding. Western Climate Initiative, Inc. (WCI) is an emissions trading service that is currently supporting the California, Quebec, and Washington State programs. WCI's 2023 budget was just over $12 million; costs are allocated to each participating jurisdiction based on the size of its allowance cap, plus any jurisdiction-specific costs such as onboarding.[18] If allocated in proportion to population Vermont's share (if the state joined this program) the cost to Vermont would be about $200,000. The state would incur additional, potentially significant administrative costs to design, implement, enforce, and manage the program which have not been estimated.

A cap-and-invest program is also expected to result in higher fossil fuel energy costs for consumers. Bates White (2022) found price impacts of $0.15 to $0.20 per gallon of gasoline for the 2015 – 2019 period. California's auction prices have been in the range of $25 to $30 per ton since 2021.[19] If fully passed through to consumers, that would result in a price increase of about $0.25 to $0.30 per gallon of conventional gasoline or diesel fuel. However, this cost impact would be mitigated through reinvestment of revenue into programs that benefit consumers financially (e.g., EV rebates); providing other services of value such as enhanced transit or active transportation infrastructure; and/or decreases in costs for renewable or other low-carbon fuels.

Vermont could join with other states and provinces, including neighboring states and provinces, in a multi-sector cap-and-invest program, rather than implementing a stand-alone program. A regional and multi-sector approach creates many efficiencies including economies of scale in administration, and more stable and efficient program design since the most cost-effective emission reductions can be sought out across many economic sectors and geographic markets. New York State has been undertaking a detailed program design and evaluation process in 2023, and Vermont could potentially become a collaborator in that process.

Vehicle Feebates

Feebates are an incentive/disincentive policy to encourage the adoption of more fuel-efficient vehicles, including zero-emission vehicles. Vehicles with lower fuel efficiency receive a surcharge at the time of purchase, while vehicles with higher fuel efficiency receive a rebate. Feebates can be designed to be revenue neutral.

A 2019 study conducted for AOT at the direction of the legislature found effective examples of feebate programs operating in other countries, including France, Denmark, and Singapore. However, the report also noted a number of implementation challenges with feebates, including a lack of any U.S. experience; potential equity impacts on residents and businesses needing larger vehicles; communications challenges that may be related to more complex systems; and the potential cost/level of effort required to administer the program including setting and collecting fees and redistributing rebate values.

The administrative cost for a feebate program would need to be quantified based on further discussion with state agencies, including the Department of Motor Vehicles and Department of Taxes, to understand staffing needs related to collection of fees, disbursement of rebates, data tracking, and compliance enforcement. There will also be costs for dealer and consumer education regarding the fee/rebate structure, and for

[18] https://wci-inc.org/documents/budget-documents

[19] https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/program-data/cap-and-trade-program-data-dashboard

periodic adjustment of fee scales as needed to balance revenues and disbursements. Administrative costs are likely to depend on the volume of motor vehicle sales (about 43,000 new light duty vehicles were registered in Vermont in 2021)[20] as well as the complexity of the fee/rebate structure.

If considering a feebate program, the state should also consider the degree to which such a program may complement or overlap with other carbon reduction policies proposed for adoption, including ZEV incentives and a cap-and-invest program.

4.4.2 Considerations

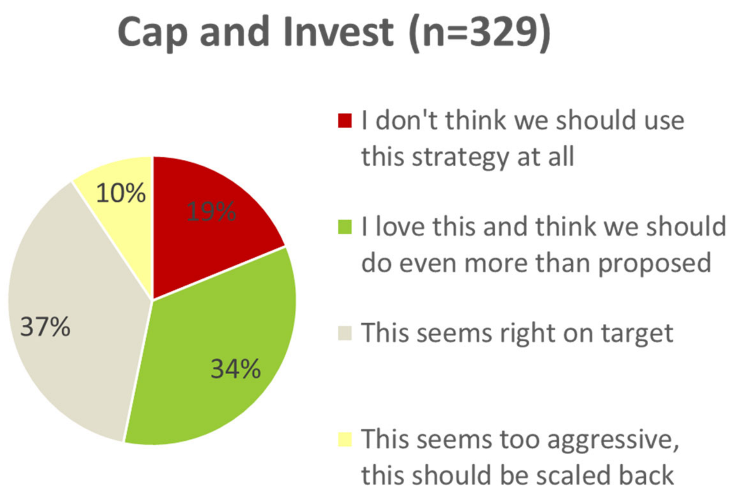
Feedback was received from a number of commenters that additional programs such as these would be needed to close Vermont's emissions gap. Cap-and-invest was especially called out as a program that has the potential to support other clean transportation strategies by providing a sustainable revenue source.

A number of commenters, especially from the business community, expressed concern about potential regulations that could make it harder or more expensive to live or do business in Vermont, and that might have the unintended effect of driving population and economic growth to other states. Vermont could address these concerns, to the degree possible, by coordinating program development and/or joining programs with neighboring states, and by leveraging lessons learned from other states about how to design programs without negatively impacting the business community or low to moderate income households. Programs that the state adopts unilaterally may need to have "safety valves" to ensure that the cost of living or doing business does not increase disproportionate to Vermont's neighbors. Conversely, Vermont could also make itself a more attractive state to live, work, and visit by reinvesting revenue into incentives for clean technology available to the state's residents and businesses. Furthermore, it is important to consider that if a regional market-based carbon management program develops and Vermont does *not* participate, the state could be impacted by the costs while receiving none of the benefits.

These strategies are less widely understood by the public, and public and stakeholder feedback reflected this uncertainty about what these policies could mean for Vermonters (Figure 4-6). A thorough public engagement process and awareness campaign would support the development of these strategies.

[20] Vermont Auto Dealers Association – Vermont Auto Outlook. https://www.vermontada.org/vermont-auto-outlook.html, accessed October 20, 2023.

Figure 4-6 Survey Respondent Opinions about the Cap and Invest Strategy



4.4.3 Advancing Additional Programs to Close the Gap

If Vermont were to move forward with any of these additional programs, it should only do so after recognizing the importance of adequate funding and focused implementation of other identified strategies outlined in the above subsections and with cost-effectiveness, affordability, and accessibility as the guiding principles. Of the additional programs, a cap-and-invest and/or Clean Transportation Standard program are likely the two most promising options to close the gap in projected emissions vs. required emissions levels for the transportation sector, in addition to the Advanced Clean Fleets standard. While either a cap-and-invest program or a Clean Transportation Standard could be undertaken on its own, based on experience in California and other states, the two are viewed as complementary programs that together would yield the greatest chance of success at reducing carbon emissions to required levels.

To explore and analyze these additional strategies, Vermont could:

Seek to initiate discussions with New York State to more closely understand current program development and rulemaking processes, including relevant modeling and analysis.

Initiate additional technical analyses to further develop a multi-sector cap-and-invest program as well as a Clean Transportation Standard for the state. Technical analyses should include modeling of specific programs to understand the impacts of Vermont joining a multi-jurisdictional program or implementing a program unilaterally (e.g. modeling the impact of linking with New York's multi-sector cap-and-invest).

Elements of this work program should include:

Define the mechanics and potential requirements and implications of linking with the Western Climate Initiative (currently California, Quebec, Washington State) or the New York State program once it is implemented.

Define the steps needed to develop and implement a low-carbon fuel standard.

Conduct outreach to the states currently participating in, or developing, these programs to identify program modeling and evaluation information to better understand potential costs and benefits.

Assess costs, timeframe, and potential information benefits of modeling Vermont-specific program effects, and if practical, undertake state-specific modeling/analysis.

Evaluate the pros and cons of program options, including revenue allocation, sectors of the economy and sources to include, and linking with other existing programs, and make a preliminary assessment of a preferred path forward.

Develop and execute an outreach and communications strategy to engage decisionmakers, other stakeholders, and the public in the consideration of program options. Additional research and outreach on potential adoption of the Advanced Clean Fleets rule is also recommended, as described in Section 4.4.1.

4.5 Center Equity in Carbon Reduction

In 2023, AOT developed a Transportation Equity Framework Report[21] that will guide the Agency in how investments and services are carried out throughout the state to ensure affordable and equitable outcomes for all people. Consistent with this framework, the state and the Agency should consider affordability and equity throughout their transportation carbon reduction strategies and programs.

The state is already proactively addressing equity concerns through strategies such as income-qualified electric vehicle incentives. As the state implements additional actions from this Strategy it should consider their implications on affordability and equity and implement them in a way that will ensure benefits are realized by all Vermonters, including low-income households and the transportation-disadvantaged. Examples include:

Provide transportation services that help **meet basic mobility** needs in addition to encouraging mode shift from driving.

Provide incentives that **recognize the full set of costs** consumers will face when transitioning to clean transportation, such as support for upgrading home electrical systems to accommodate EV charging, as well as providing charging options for multifamily and renter-occupied dwellings.

Consider **recycling revenue** into tax refunds or relief for low-income households to offset potential costs related to higher fuel prices.

Additional equity-related actions are included in the additional actions specific to the strategies in Sections 4.1 through 4.4 above.

4.6 Measure and Report Progress

The emissions levels and reduction effects projected in this strategy document are only projections. It is critical that the state maintain good tracking systems to ensure progress towards its emission reduction requirements. While overall transportation emissions can be tracked through fuel sales, monitoring of key indicators and strategies in more detail can help the state understand which strategies are most effective and

[21] Vermont Agency of Transportation (2023). Transportation Equity Framework Report. https://vtrans.vermont.gov/equity

where strategies might be falling short of expectations – helping to prioritize and target future policies and investments.

Vermont should enhance its data and analysis tools to support strategy evaluation and progress tracking and reporting specific to transportation sector emissions. Examples could include:

AOT should collaborate with ANR to develop annual updates **reporting on key drivers** of emissions (e.g., VMT, average vehicle economy, electrification, fuel sales, rail volumes). AOT can use these updated data in the sketch tool developed for this project to update emissions estimates and projections by transportation source (light-duty vehicle, truck, bus, rail, aviation, and other).

AOT should conduct post-implementation data to **evaluate the effectiveness** of implemented projects and programs and assist in designing more effective programs in the future. Examples might include monitoring usage of shared-use paths; or conducting occasional surveys of transit riders, micromobility users, and active travelers to understand how they would have traveled if the facility or service were not available.

5.0 Implementation

5.1 Use of Carbon Reduction Program Funds

The U.S. DOT Carbon Reduction Program is one source of funds that AOT will use to support carbon reduction strategies. Other sources that the state has and/or will use in the future include the Congestion Mitigation and Air Quality Improvement Program (CMAQ), the NEVI Program, and Surface Transportation Program (STP) including the Transportation Alternatives set-aside (STP-TA). In Fiscal Years 2022 and 2023, AOT was authorized just over $12.7 million in Carbon Reduction Program funding. These funds have not yet been spent on eligible projects. The total funding expected to be authorized through Fiscal Year 2026 is approximately $31.6 million.

AOT will use its CRP funding for projects aligned with the priorities shown in Table 5-1. The approximate target percentage for each category of projects is shown in the table. The exact percentage may vary to meet requirements for project readiness and geographic suballocation by urbanized area. These priorities were selected based on 1) relative cost-effectiveness at reducing GHG emissions and providing other co-benefits; 2) support from stakeholders and the public; 3) alignment with the Vermont Climate Action Plan and Long-Range Transportation Plan; and 4) immediate need and opportunity. The approximate GHG reductions estimated from the spending shown are also estimated based on illustrative project mixes, using the sketch tool described in Appendix D. A list of activities eligible for Carbon Reduction Program funding can be found in Appendix F.

Table 5-1 Carbon Reduction Program Funding Priorities for State-Directed Funds

Project Type	Target %	Approximate Funds Available FY22-26	MT GHG Reduced (2030)
Bicycle and pedestrian projects, including Complete Streets, shared-use paths, bike lanes, and sidewalks, prioritized within designated smart growth locations (town and village centers)	33%	$9-10 million	130
Transit and micromobility services and incentives (e.g., microtransit, shuttles, e-bike incentives)	33%	$9-10 million	1,200
Fleet conversion, including conversion of transit buses and/or AOT heavy equipment to electric and/or other zero emission technology, and supporting infrastructure	33%	$9-10 million	530

The CRP and other existing funding sources will not provide adequate funding to fully implement all of the strategies identified in this plan, estimated to be in the range of $140-330 million by 2030 (beyond current spending levels) for the strategies quantified in Section 3.4. The agency has limited ability to redirect other funding that is needed to maintain Vermont’s existing roadway system and transit services. Furthermore, funding is likely to decrease in the future as the federal and state gas taxes – the state’s main source of transportation revenue – declines as vehicles become more efficient and electrify. Additional funding sources will be needed. A cap-and-invest program is one strategy that can work towards emission reductions and provide a potential funding source. Examples of other mechanisms that have been expanded, newly implemented, or proposed in various states and local jurisdictions to support transportation programs include motor vehicle registration fees, motor fuel taxes, mileage-based road user fees, road tolls, sales taxes, and carbon pricing.

5.1.1 Suballocation of Funds by Urbanized Area Size

U.S. DOT guidance on the CRP requires suballocation to urban areas within each state in proportion to population, according to a set formula. Vermont's urban area size groupings and the share of program funding in each year of the program that must be allocated to projects in each size group are shown in Table 5-2.

Table 5-2 Suballocation of CRP Funding

Urban Area Size	Urban Areas	Population (2020)	Percentage of funding
Size 50,000 – 200,000 population	Burlington	118,032	11%
5,000 – 49,999 population	Barre—Montpelier, Bennington, Brattleboro, White River Junction, Middlebury, Milton, Rutland, St. Albans, Springfield	99,881	11%
Less than 5,000 population		405,434	43%
Use anywhere in state			35%
Total		643,077	100%

5.2 Incorporation into the Long-Range Transportation Plan and Capital Program

5.2.1 Long-Range Transportation Plan

Vermont's Long-Range Transportation Plan (LRTP) is the state's blueprint for guiding transportation decision-making and investments over the next 20 years. Vermont's 2040 LRTP was adopted in 2018 and has been amended as recently as 2023. The 2040 LRTP includes six goals and associated objectives and strategies. Those most directly relating to GHG emissions and carbon reduction, as noted under *Goal 5: Practice environmental stewardship*, are shown in Table 5-3.

Table 5-2 2040 Long-Range Transportation Plan Objectives and Strategies for Goal 5: Practice Environmental Stewardship

Objective	Strategies
5.2 Reduce air pollution associated with fossil fuels used in transportation.	• Increase the use of, and support additional access to and development of, alternative fuels that could reduce Vermont's reliance on fossil fuels. • Encourage the development and use of transportation construction and operations technologies that reduce emission of greenhouse gases. • Actively participate and support the build-out of Vermont's electric vehicle charging network and the overall transition to fleet electrification.
5.3 Reduce the overall level of energy use by the transportation system users.	• Implement the transportation recommendations included in the 2016 Comprehensive Energy Plan, including supporting efficient land-use, reduction in single occupancy vehicles, and electrification of the light duty vehicle fleet, as well as alternative fuels for the heavy / commercial fleet. • Work in partnership with the Agency of Natural Resources and the Public Service Department to take an active role in rate cases at the Public Utilities Commission and advocate for competitive electric rates to support electrification of the transportation sector. • Work in partnership with the Regional Planning Commissions in the implementation of the regional energy plans that have received determinations of energy compliance from the Public Service Department. • Increase use of walking, biking, transit, rail, and Travel Demand Management (TDM) options by developing infrastructure and educational campaigns.

The plan notes that transportation is the largest end use of energy and the largest generator of greenhouse gases in Vermont. The plan notes the following principles to reduce transportation's environmental impacts:

Emphasize maintenance and preservation of the existing system.

Provide a multimodal system.

Focus on downtown and village investments.

The plan sets a strong foundation for carbon reduction activities, referencing many of the strategies identified in this Carbon Reduction Strategy. The LRTP will be updated beginning in late 2023, providing an opportunity to more specifically reference the actions identified in this Carbon Reduction Strategy.

5.2.2 Capital Program and STIP

Per U.S. DOT requirements, AOT must annually develop a Statewide Transportation Improvement Program (STIP), detailing the specific projects the agency will undertake and the funding by fiscal year, covering the next four fiscal years. The program must identify the specific funding source(s) for each project (federal, state, and local/other and specific programs). AOT also develops a Capital Program, or "budget book", a one-year budget passed annually by the legislature and governor for the next state fiscal year. The Capital Program is consistent with the STIP. AOT's Project Selection and Prioritization (VPSP2) is the system used to evaluate and select projects for inclusion in the Capital Program and STIP. Currently GHG emissions are considered indirectly, through an "environment" criterion that is scored based on the number of environmental mitigations included in a project.[22] AOT will be working to enhance the consideration of GHG emissions in programming decisions including for projects funded through other sources than the CRP. For example, this may include updating its VPSP2 scoring to directly assign points for GHG reduction based on the relative effectiveness or cost-effectiveness of each type of project with carbon reduction benefits. AOT could use the evaluation tool developed for this strategy to estimate effectiveness and cost-effectiveness.

A Federal Highway Administration (FHWA) Notice of Proposed Rulemaking published July 15, 2022 proposes to add a GHG measure to existing National Highway Performance Program performance measures.[23] The proposed GHG measure is described as *the percent change in tailpipe CO_2 emissions on the National Highway System (NHS) compared to the reference year.* As proposed in October 2022, the rule would require state DOTs and MPOs to establish declining targets. Should this rule be adopted, AOT could use the evaluation tool developed for this strategy to assist in setting reasonable targets and evaluating projects and programs for their expected contribution towards meeting these targets.

5.3 Policies and Strategies Outside of AOT's Authority

Many of the actions recommended in this Carbon Reduction Strategy are outside of the AOT's authority to implement. They will require additional authorizing action on the part of Vermont's legislature, as well as implementation action on the part of other state agencies such as the Agency of Natural Resources (ANR), Department of Commerce and Community Development, and Department of Public Service. Municipalities and Regional Planning Commissions (RPCs) also play a role in implementing some strategies, such as land use and EV charging infrastructure. Table 5-4 shows general implementation responsibilities for the various types of strategies recommended.

Table 5-3 Implementation Responsibilities

Strategy	Agency of Transportation	Other State Agencies	Legislature	Municipalities & RPCs
Transportation investments & services	✓		✓	
Land use & teletravel		✓	✓	✓
Zero-emission vehicles	✓	✓	✓	✓
Additional policies and programs		✓	✓	

Tracking progress will also require a coordinated effort between the AOT and ANR to develop and maintain the data systems needed to estimate and update progress on transportation GHG emissions and associated drivers.

[22] Three air quality mitigations are currently listed: 1) design incorporates potential for EV charging stations; 2) design supports operational efficiency; 3) design features address TDM resulting in reduced VMT.

[23] Federal Highway Administration, U.S. Department of Transportation. National Performance Management Measures; Assessing Performance of the National Highway System, Greenhouse Gas Emissions Measure. 87 FR 42401

Appendix A. Committee and Focus Group Participants

A.1 Technical and Advisory Committee Membership

Name	Affiliation
Advisory Committee	
Charles Baker	Chittenden County Regional Planning Commission
Bryan Davis	Chittenden County Regional Planning Commission
Christopher Jolly	Federal Highway Administration
Jason Rasmussen	Vermont Association of Planning and Development Agencies
Bronwyn Cooke	Vermont Agency of Commerce and Community Development
Megan O'Toole	Vermont Agency of Natural Resources
Jane Lazorchak	Vermont Agency of Natural Resources
Michele Boomhower	Vermont Agency of Transportation
Ross MacDonald	Vermont Agency of Transportation
Erin Sisson	Vermont Agency of Transportation
Jared Ulmer	Vermont Department of Health
Johanna Miller	Vermont Natural Resources Council
Elaine Haytko	Vermont Public Transportation Association
Technical Committee	
Eleni Churchill	Chittenden County Regional Planning Commission
Jason Charest	Chittenden County Regional Planning Commission
Melanie Needle	Chittenden County Regional Planning Commission
Jared Duval	Energy Action Network
James Sullivan	University of Vermont – Transportation Research Center
Greg Rowangould	University of Vermont – Transportation Research Center
Nick Van Den Berg	Vermont Agency of Transportation
Kevin Marshia	Vermont Agency of Transportation
Andrea Wright (Project Manager)	Vermont Agency of Transportation
Patrick Murphy	Vermont Agency of Transportation
Gina Campoli	Vermont Climate Council, Cross-Sector Mitigation Team
Collin Smythe	Vermont Agency of Natural Resources

A.2 Stakeholder Focus Group Participants

Name	Affiliation
Business Focus Groups	
Jenna Evans	Ben & Jerry's
Kiersten Bourgeous	Dairy Farmers of America and Northeast Logistics
Kristen Graf	Darn Tough
Brian Maggiotto	Inn at Manchester, Vermont Lodging Association
Kay Gebhardt	King Arthur Bakery
Russ Scheller	King Arthur Bakery
Austin Davis	Lake Champlain Chamber of Commerce, Green Mountain XXXX
Matt Coda	Meadow Hill, Trade Association VT Petroleum Association
Christopher Carrigan	Statewide Chambers of Commerce, Governor's Aviation Council
Molly Mahar	Vermont Ski Area Association
Community, Equity, and Environmental Justice Focus Groups	
Sue Minter	Capstone Community Action
Anne Nelson Stoner	Chittenden County Regional Planning Commission
Michael Weiss	Rights & Democracy
Britaney Watson	Rights & Democracy
Megan Roush	Vermont Housing Finance Agency
Environmental Focus Groups	
Charlie Gliserman	AARP Vermont
Annie Bourdon	CarShare Vermont
Eliana Fox	Champlain College
Sandy Thibault	Chittenden Area Transportation Management Association
John Katz	Chittenden Area Transportation Management Association
Dale Azaria	Conservation Law Foundation
Cara Robechek	Energy Action Network
Lena Stier	Energy Action Network
Jamie Smith	Green Mountain Transit
Christina Erickson	Local Motion
Debra Sachs	Net Zero Vermont
Robb Kidd	Sierra Club, Vermont Chapter
Karl Kemnitzer	Sierra Club, Vermont Chapter
Abby Bleything	University of Vermont
Karl Kemnitzer	VBike
Peggy O'Neill	Vermont Clean Cities Coalition
Sophia Donforth	Vermont Energy Education Program
Kati Gallagher	Vermont Natural Resources Council

Name	Affiliation
Johanna Miller	Vermont Natural Resources Council
Ben Edgerly Walsh	Vermont Public Interest Group
John Haffner	Vital Communities
Freight and Rail Focus Groups	
David Mullett	All Earth Renewables
Matt Coda	Meadowhill Consulting (Vermont Petroleum Association, Vermont Vehicle and Automotive Distributors Association)
Jeffrey Castle	New England Central Railroad General Manager
Dennis Carroll	OMYA, Inc
Peter Young	Vermont Rail
William Smith	Vermont Truck and Bus Association
Regional Planning and Transit Focus Groups	
Adam Lougee	Addison County Regional Planning Commission
Christian Meyer	Central Vermont Regional Planning Commission
Bonnie Waninger	Central Vermont Regional Planning Commission
Sandy Thibault	Chittenden Area Transportation Management Association
Logan Nicoll	Mount Ascutney Regional Commission
Jason Rasmussen	Mount Ascutney Regional Commission
David Snedeker	Northeastern Vermont Development Association
Liam Abbate	Northeastern Vermont Development Association
Doug Morton	Northeastern Vermont Development Association
Devon Neary	Rutland Regional Planning Commission
Rita Seto	Two Rivers-Ottauquechee Regional Commission
Chris Company	Windham Regional Commission
Elected Officials Focus Group	
Representative Dara Torre	
Representative Jonathan Williams	
Representative Kate Logan	
Representative Noah Heyman	
Representative Scott Campbell	
(as well as others who arrived late and participated but did not have the opportunity for formal introduction)	

Appendix B. Greenhouse Gas Inventory and Forecast

A baseline greenhouse gas (GHG) emissions inventory and forecast was estimated for the transportation sector for 2022, 2025, 2030, and 2050. Direct emissions (emissions occurring at the tailpipe) as well as upstream emissions from electric vehicles were estimated for the following source categories: on-road vehicles, public transportation, passenger and freight rail, aviation, and construction and maintenance activities.

B.1 Onroad Vehicles

A baseline GHG inventory and forecast for on-road vehicles was estimated using a set of key outputs from the LEAP model, developed by a consultant team under contract to the Vermont Agency of Natural Resources for the Climate Action Plan, in combination with other assumptions. Key assumptions for on-road sources included vehicle-miles of travel (VMT) by vehicle type, vehicle fuel efficiency by vehicle type, and rates of zero-emission vehicle (ZEV) adoption. ZEV adoption rates considered manufacturer sales requirements under the Advanced Clean Cars 2 and Advanced Clean Trucks rules adopted in 2022. These assumptions were coordinated as much as possible with those used in the Climate Action Plan modeling. Due to differences in methods, however, the estimates could not be completely reconciled between the two efforts.

The following steps were taken to produce a baseline emissions forecast for on-road vehicles.

1. **Fuel economy by vehicle type-fuel type**. Data was sourced from the LEAP model for forecasts on on-road fuel economy by vehicle type-fuel type combinations.

2. **Emissions rates by vehicle type-fuel type**. Using data collected from the U.S. Environmental Protection Agency (EPA) on fuel emission factors, as well as data from the Energy Action Network on the electricity grid emission rate in Vermont, emission rates (grams per mile) were developed for each vehicle type-fuel type combination.

3. **Vehicle miles traveled by vehicle type-fuel type**. Vehicle miles traveled (VMT) estimates for each vehicle type-fuel type combination were sourced from the LEAP modeling output.

4. **Total emissions by vehicle type-fuel type**. Total emissions were calculated by combining the VMT by vehicle type-fuel type with the emissions rates.

B.2 Public Transit

Emissions for public transit were estimated using data reported through the National Transit Database (NTD) for year 2019. The following steps were taken to produce a baseline emissions forecast for on-road public transit.

1. **Vehicle Fuel Economy Data**. Vehicle fuel economy data by mode (e.g. bus, commuter bus, demand response) was collected from the NTD for Green Mountain Transit Authority (note: GMTA was the only transit agency which reported fuel consumption)

2. **Vehicle Revenue Mile Data**. For all public transit agencies, vehicle revenue miles (VRM) was collected by mode from the NTD.

3. **Calculate Emission Rates by Mode**. Using fuel economy and VRM data provided by GMTA, transit vehicle emission rates (grams CO_2e per mile) were calculated by mode. This emission rate was then applied to all transit agencies.

4. **Forecast VRM**. In the baseline forecast, there is no assumed increase in transit VRM.

5. **Forecast Vehicle Technology**. Under the baseline forecast, there is no assumed change in the fuel type of the vehicle fleet.

B.3 Construction and Maintenance

Emissions from construction and maintenance activity were calculated using the Federal Highway Administration Infrastructure Carbon Estimator tool, using inputs synthesized from the Vermont Capital Program. A detailed description of the process for synthesizing capital program inputs can be found in Appendix C.

Appendix C. Gap Sensitivity Analysis

Many uncertainties exist, both in the baseline projection (which determines the projected gap) and the extent to which various strategies will close the gap. If population were to increase at a faster rate than projected, or electric vehicle adoption was slower than anticipated, the emissions gap would be larger. Adoption of ZEVs could also encourage people to drive more because the per-mile cost of driving is lower than for a gasoline vehicle, an effect known as the “rebound effect.” The emissions gap could also be smaller than projected, for example, if reduced levels of travel observed in the post-pandemic years continued to hold. Table 3-9 shows alternative gaps under these different scenarios. Even with the more optimistic baseline projection, the emissions gap in 2030 would still be about 330,000 metric tons, well beyond the ability of transportation investment strategies to close.

Table 3-4 Alternative Baselines and Effect on Gap (MT CO2e)

Scenario	2025	2030	2050
Baseline	-1,400	410,000	100,000
Higher population growth[24]	800	430,000	106,000
Slower ZEV adoption[25]	11,500	481,000	407,000
Lower VMT per capita[26]	-1,400	331,000	91,000

[24] A scenario was tested where population growth was 30 percent higher than baseline. This translates to around 5,000 additional Vermont residents by 2030.

[25] A scenario was tested where EV adoption 20 percent slower than anticipated. As a result, light duty electrification is at 14 percent (compared to 18 percent in baseline) in 2030, and medium/heavy duty electrification is at 8 percent (compared to 10 percent in baseline).

[26] The current baseline model shows VMT fully converging with pre-pandemic projections by 2030. However, Annual Energy Outlook data shows that VMT is around 5 percent lower in 2023 than the pre-pandemic forecast for that year. Therefore, under this lower-VMT per capita scenario, forecast years are adjusted downward to reflect possible lingering pandemic travel patterns.

Appendix D. Capital Program Analysis

This appendix outlines the methodology employed to estimate the effects of the Vermont Agency of Transportation (AOT) Capital Program on the state's greenhouse gas emissions. The estimated changes in greenhouse gas emissions resulting from the capital program are divided into two categories: (1) the greenhouse gas emissions associated with the construction, maintenance, and operation of public assets and (2) the estimated changes in transportation system user emissions resulting from AOT projects and investments.

D.1 Preparation of the Capital Program

Before estimating the greenhouse gas effects of the capital program, a number of steps were taken to prepare, clean, and supplement the capital program dataset with relevant inputs needed for estimation.

D.1.1 Cleaning the Dataset

First, the most recent capital program database was downloaded from the agency's REST Endpoint Server. This server houses two geographic shapefile datasets of the capital program for projects displayed as "Points" and projects displayed as "Segments[27]." After downloading both datasets, each dataset was filtered to only include projects whose status was "Active" in order to filter out projects that may have already been completed.

D.1.2 Supplementing the Dataset

The capital program dataset contains information related to the project type, project description, and project length. However, in order to estimate the greenhouse gas emissions effects of the projects, additional information is needed for each project relating to the area type and roadway attributes. For the methods applied here, information is needed on roadway type (interstate, arterial, etc.), number of lanes, shoulder width, area type (urban, rural), as well as population density.

In order to associate each project with the relevant attributes, geographic spatial joins were conducted in the geographic information systems (GIS) software ArcMap. The following layers were used or obtained from publicly available sources or through correspondence with agency staff:

Roadway Classification – Roadway classification was obtained through the publicly available VT Road Centerline Dataset on the Vermont Open Geodata Portal. Roadways are classified with a number between 1 and 7, with 1 representing Interstates and 7 representing Local Roads.

Lanes and Shoulder Width – A separate shapefile of the roadway system, containing information on number of lanes, as well as shoulder width, was provided directly by agency staff through correspondence.

[27] Typically, projects in the "segment" database were roadway projects that were best displayed on the map as a line segment, whereas projects in the "points" database contained a mix of projects that were best displayed as a point on the map.

Area Type: Project area type (urban vs. rural) was defined using the Urban Areas shapefile available through the US Census TIGER/Line Shapefiles.

Population Density. Population density was calculated at the census tract level by downloading population estimates from the US Census at the tract level and joining population estimates to the census tract shapefile provided by US Census TIGER/Line. Population densities were computed as population per square mile for the census tract[28].

In ArcMap, the Points and Segments shapefiles were spatially joined to each of the individual layers so that each project in the capital database could contain the necessary area and roadway attributes.[29][30]

D.1.3 Coding the Dataset

The final step required for the preparation of the capital program database involves coding the database so that it can be translated into discreet inputs used for estimation. In order to understand how to best code the data, it is important to understand the tools (and inputs) that will be used to conduct the final emissions calculations.

Coding the Dataset for the FHWA ICE Tool

In order to estimate emissions associated with the construction, maintenance, and operation of assets, projects must be coded to into inputs that will feed into the FHWA Infrastructure Carbon Estimator Tool.

The ICE tool is designed to estimate the energy and emissions impacts associated with construction and maintenance related to several activities, including but not limited to: bridges, parking, bicycle and pedestrian facilities, culverts, roadway rehabilitation, and new roadway construction. Figure C-1 shows an example set of inputs prepared for the FHWA tool for the roadway rehabilitation category.

[28] Population densities were classified into four buckets based on the population per square mile: core (>10,000), urban (4,000 – 10,000), suburban (500 -4,000), and rural (<500).

[29] While not all attributes may relevant for the calculations of each project, it is most efficient to perform this process once for all projects rather than selecting a subset of projects for each attribute.

[30] When performing the spatial joins, it is important to ensure that the appropriate functions and characteristics are chosen in ArcMap or the geographic software of choice so that the spatial join performs correctly. If certain parameters of the spatial join are not selected properly, then a roadway project may not pull the attributes of the appropriate roadway.

Figure C-1 Example of Input Required for FHWA ICE Tool

Roadway System for Road Rehabilitation		
Facility type	Resurface (lane miles)	Reconstruct (lane miles)
Rural Interstates	52	0
Rural Principal Arterials	162	14
Rural Minor Arterials	420	0
Rural Collectors	363	0
Urban Interstates / Expressways	474	0
Urban Principal Arterials	255	13
Urban Minor Arterials / Collectors	385	8

To prepare the capital database for usage in the FHWA ICE tool, columns were added to the database spreadsheet so that projects could be "tagged" into subcategories, and then aggregated into the appropriate units as shown in Table C-1.

Table C-1 Inputs and Categories for Use in the FHWA ICE Tool

Category	Subcategory	Unit
Bridges	Construct New Bridge	Number of bridges
	Reconstruct Bridge	Number of bridges
	Add Lane to Bridge	Number of bridges
Parking	Surface Parking	Number of bridges
	Structured Parking	Number of space
Bicycle and Pedestrian Facilities	Off-Street Bicycle or Pedestrian Path	Miles of new construction, miles of resurfacing
	On-Street Bicycle Lane	Miles of new construction, miles of resurfacing
	On-Street Sidewalk	Miles of new construction, miles of resurfacing
Culverts	Culverts	Number of culverts
Roadway Rehabilitation	Resurface	Number of lane miles by facility type
	Reconstruct	Number of lane miles by facility type
New Roadway Projects	New Roadway	Lane miles by facility and area type
	Construction Additional Lane	Lane miles by facility and area type
	Realignment	Lane miles by facility and area type
	Lane widening	Lane miles by facility and area type
	Shoulder Improvement	Centerline miles by facility and area type

Coding the Dataset for GHG Sketch Tool

In order to estimate emissions changes associated with change in user behavior, projects were coded to into inputs that were fed into the custom Vermont GHG Sketch Tool developed by Cambridge Systematics.

The tool is designed to estimate the change in transportation system user emissions resulting from projects and programs in areas including but not limited to: bicycle and pedestrian strategies, roadway expansion, traffic operations, transit, travel demand management, and park-and-ride. Table C-2 shows the project categories, subcategories, and required data inputs employed for this this effort.

Table C-2 AOT Capital Program Project Categories, Subcategories, and Data Units Required for Vermont GHG Sketch Tool

Category	Subcategory	Data Units
Bicycle and Pedestrian Facilities	New shared-use path	Miles of facility by population density
	Re-surface shared use-path	Miles of facility by population density
	New bicycle lane	Miles of facility by population density
	New separated bike lane	Miles of facility by population density
	New/improved sidewalk	Miles of facility by population density
	New complete Streets Treatment	Miles of facility by population density
	Widened shoulder	Miles of facility by population density
Roadway Capacity	Lane addition	New lane miles by facility/area type
Traffic Operations	New or re-timed signals	Number by facility/area type
	New roundabouts	Number by facility/area type
	Reconfigured intersection/interchange	Number by facility/area type
Park and Ride	Park and Ride	New Spaces
Public Transit	Fixed Route Service	New Annual VRM by Vehicle/Fuel Type
	Demand Response	New Annual VRM by Vehicle/Fuel Type
Transportation Demand Management	TDM Outreach	Number of covered people

D.2 Calculating Effects of the Capital Program

D.2.1 Bicycle and Pedestrian Investments

To estimate the greenhouse gas impacts of bicycle and pedestrian investments, the following equation was employed:

Annual Emissions Change (MT CO_2e) = New Facility Miles * New Daily Users Per Facility Mile * Average Trip Length * Prior Drive Mode Share * Light Duty Vehicle Emission Rate

Table C-3 and Table C-4 detail the values and sources for these key parameters

Table C-3 Bicycle and Pedestrian Activity Levels per New Facility

Facility Type / Area Type	New Bicyclists (Daily) – Per Facility Mile[31]	New Walkers – Per Facility Mile[31]
Shared-use path - core urban	327	798
Shared-use path - urban	174	247
Shared-use path – suburban	55	13
Shared-use path – rural	11	2
Bike lane/facility - core urban	150	
Bike lane/facility - urban	80	
Bike lane/facility – suburban	25	
Bike lane/facility – rural	5	
Separated bike lane - core urban	203	
Separated bike lane - urban	108	
Separated bike lane - suburban	34	
Separated bike lane - rural	7	
Sidewalk/ pedestrian facility - core urban		798
Sidewalk/ pedestrian facility - urban		247
Sidewalk/ pedestrian facility - suburban		13
Sidewalk/ pedestrian facility – rural		2
Widened Shoulder - suburban	25	
Widened Shoulder- rural	5	

Table C-4 Other Key Parameters for Bicycle and Pedestrian Modeling

Parameter	Value	Source
Prior drive share new bikers/walkers - Core	47%	GCC (2023) [31]
Prior drive share new bikers/walkers - Urban	59%	GCC (2023) [31]
Prior drive share new bikers/walkers - Suburban	60%	GCC (2023) [31]
Prior drive share new bikers/walkers - Rural	75%	GCC (2023) [31]
Average Trip Length – Bike (miles)	0.7	GCC (2023) [31]
Average Trip Length – Walk (miles)	2.3	GCC (2023) [31]
Light Duty Vehicle Emissions Rate (g CO_2e / mi) – 2030	229	Vermont-specific analysis from B.1

[31] Georgetown Climate Center (2023). *Transportation Investment Strategy Tool.* Accessed online at: https://www.georgetownclimate.org/files/report/GCC_Investment_Tool.pdf

D.2.2 Transit

While transit service was not expanded through capital program funds, ridership increases were forecasted as a result of continued funding from the U.S. DOT Congestion Mitigation and Air Quality Improvement (CMAQ) Program. Carbon emission impacts were calculated from changes in ridership through the following equation:

Annual Emissions Change (MT CO_2e) = New Ridership * Average Trip Length * Prior Drive Mode Share * Light Duty Vehicle Emission Rate

Key transit parameters are shown in Table C-5.

Table C-5 Key Parameters for Transit Modeling

Parameter	Value	Source/Notes
Urban Bus – New Ridership	212	AOT[32]
Rural Bus – New Ridership	690	AOT
Rural Demand Response – New Ridership	9,150	AOT
Intercity Bus – New Ridership	4,139	AOT
Urban Bus – Average Trip Length	2.8	NTD (2019): GMTA
Rural Bus – Average Trip Length	5.7	Set equal to Urban
Rural Demand Response – Average Trip Length	10.3	NTD (2019): GMTA
Intercity Bus – Average Trip Length	22	NTD (2019): GMTA
Urban Bus – Prior Drive Mode Share	47%	GCC (2023) [31]
Rural Bus – Prior Drive Mode Share	60%	GCC (2023) [31]
Rural Demand Response – Prior Drive Mode Share	60%	GCC (2023) [31]
Light Duty Vehicle Emissions Rate (g CO_2e / mi) – 2030	229	Vermont-specific analysis from B.1

D.2.3 Park and Ride

Carbon emission impacts were calculated from park-and-ride strategies using the following equation:

Annual Emissions Change (MT CO_2e) = Number of Spaces * Average Work Trip Length * Daily Utilization Rate * Workday Annualization * Light Duty Vehicle Emission Rate

Table C-6 details the values and sources for these key parameters.

[32] Ridership forecasts from CMAQ funded transit provided through internal correspondence.

Table C-6 Key Parameters for Park-and-Ride Modeling

Parameter	Value	Source
New Spaces	147	Capital Program
Average Work Trip Length (miles)	12.7	USDOT National Household Travel Survey (2017)[33]
Daily Utilization Rate	50%	Assumption
Workday Annualization	250	Assumption
Light Duty Vehicle Emission Rate (2030)	229	Vermont-specific analysis from B.1

D.2.4 Traffic Operations

Carbon reductions were estimated through the capital program's traffic operations strategies for two strategies: arterial signal re-timings and roundabout conversions.

Arterial Signal Re-Timing

Calculating carbon emission changes related to arterial signal re-timings features two offsetting effects: reduced delay from congestion (resulting in emission reduction), and induced travel resulting from higher travel speeds (resulting in higher emissions). Table C-7 outlines the key parameters involved in the estimation of the impacts of signal re-timing.

Table C-7 Key Parameters for Arterial Signal Re-Timing Modeling

Parameter	Value	Source
# of Re-timed Signals: Urban Arterial	39	AOT Capital Program
# of Re-timed Signals: Rural Arterial	5	AOT Capital Program
Annual Average Daily Traffic (AADT): Principal Urban Arterial	10,429	Vermont GIS Analysis
AADT: Principal Rural Arterial	5,107	Vermont GIS Analysis
Travel Speed: Principal Urban Arterial	33	Vermont GIS Analysis
Travel Speed: Principal Rural Arterial	44	Vermont GIS Analysis
Elasticity of VMT with Respect to Travel Time	-0.30	GCC (2023) [31]
Re-timing Impact: Corridor Travel Time Change (%)	12%	GCC (2023) [31]

Roundabouts

Carbon emission impacts were calculated from roundabout conversions using the following equation:

Annual emissions change (MT CO_2e) = roundabouts * annual vehicle volume * kg CO2 reduced per vehicle

[33] USDOT (2017). National Household Travel Survey: Summary of Travel Trends. Accessed at: https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

Table C-8 outlines the key parameters involved in the estimation of the impacts of signal re-timing.

Table C-8 Key Parameters for Roundabout Modeling

Parameter	Value	Source
Roundabouts: Urban	1	AOT Capital Program
Roundabouts: Rural	1	AOT Capital Program
AADT: Principal Urban Arterial	10,429	Vermont GIS Analysis
AADT: Principal Rural Arterial	5,107	Vermont GIS Analysis
Kg CO_2e Reduced Per Vehicle	-0.07	Hu et. al (2014)[34]

[34] Hu, W.; A.T. McCartt, J.S. Jermakian, S. Mandavilli (2014). Public Opinion, Traffic Performance, the Environment, and Safety After Construction of Double-Lane Roundabouts. Transportation Research Record no. 2402.

Appendix E. Strategy Analysis

E.1 Bicycle and Pedestrian

Bicycle and pedestrian strategies were modeled through the increased buildout and construction of bicycle and pedestrian facilities across the state.

First, in order to estimate the total miles of bicycle facilities that would be built through the strategy, data was sourced from the Chittenden County Active Transportation Plan, which included a map of proposed bicycle network buildout[35]. The map of proposed facilities was then overlaid on census block group data to determine how many miles of facility fell within different population density area types[36]. Finally, each proposed facility was assigned a facility type (multi-use path, bicycle lane, protected bicycle lane, or widened shoulder), based on the corresponding speed and annual average daily traffic conditions of the corresponding roadway[37].

To expand the proposed strategy to be inclusive of the entire state, assumptions were made using professional judgement in the absence of other county-wide proposed bicycle plans. As such, the estimated strategy assumed that the remainder of the buildout statewide would be equal to the total miles of buildout in Chittenden County, 80 percent of that buildout would correspond to “Rural” area type densities, and 20 percent of that buildout would correspond to “Suburban” area type densities. All facilities built in suburban areas were assumed to be bicycle lanes, whereas all facilities built in rural areas were assumed to be widened shoulders.

Table D-1 displays the total two-way miles of facility by facility-type and area type based on these estimates.

Table D-1 Modeled Two-Way Miles of Bicycle Facilities

	Core	Urban	Suburban	Rural	Total
Bike Lanes	0.0	0.6	23.0	0.0	23.5
Separated Bike Lanes	0.0	3.8	0.0	0.0	3.8
Multi-Use Path	0.4	0.2	21.5	23.9	46.0
Paved Shoulders	0.0	0.0	10.8	145.4	156.2
Total	0.4	4.6	55.2	169.3	229.6

In order to estimate the total miles of constructed pedestrian facilities as part of the strategy, an alternative approach had to be utilized. In the absence of a defined proposed sidewalk plan, a “goals-based” strategy was employed based on existing coverage. This process involved the following steps:

[35] https://ccrpc.maps.arcgis.com/apps/webappviewer/index.html?id=2430019a1c2e4b81b16c534b32648682

[36] Area types were defined by four categories, as measured by persons per square mile (ppsm): Core urban (>10,000ppsm), Urban (4,000-10,000 ppsm), Suburban (500-4,000 ppsm), and Rural (<500ppsm).

[37] Criteria for facility selection are outlined in page 11 of the memo prepared for CCRPC titled “Bicycle Network Recommendations” available at: https://www.ccrpcvt.org/wp-content/uploads/2022/12/4.1_2022_11_30_CCRPC_ATP_Update_Infrastructure_Recommendations_Memo_FINAL.pdf

1. Using the Chittenden County Bicycle and Pedestrian Inventory[38], calculate the total existing coverage of pedestrian facilities, with pedestrian facilities defined as all sidewalks or shared-use paths.

2. Using the Vermont Roadway Centerline File[39], calculate the total potential miles of roadway in Chittenden County that could feature a sidewalk facility. For the purposes of this calculation, all interstates or multilane highways were excluded.

3. Calculate the total percent "coverage" of pedestrian facilities by dividing the total existing pedestrian facilities milage by the total potential mileage of facilities available in the county.

4. Set an area-type goal to determine the number of miles of buildout for the strategy.

Table D-2 show the results of this four-step process for Chittenden County.

Table D-2 Modeled Two-Way Miles of Pedestrian Facilities in Chittenden County

	Core	Urban	Suburban	Rural
Total Existing Miles (directional miles)	21	41	257	177
Total Potential Miles (directional miles)	19	59	492	1,715
Existing Coverage (%)	100%[40]	70%	52%	10%
Coverage Goal (%)	100%	90%	65%	14%
Total New Miles	0	6	31	31

Similar to the bicycle strategy development, an assumption was made that Chittenden County would represent 50 percent of the statewide buildout, thereby doubling the total mileage of sidewalk facilities. For the remainder of the state, 50 percent of the new pedestrian facility mileage was assumed to be constructed in Suburban areas, with the other 50 percent occurring in Rural areas.

Finally, for both the bicycle and pedestrian facility buildout, it was assumed that half the buildout would be completed by 2030, with the remaining half completed by 2050[41]. Taken together, the total statewide number of two-way facility miles across the state is displayed in Table D-3.

Table D-3 Total Statewide Buildout of Bicycle and Pedestrian Facilities

Two- Way Miles of Facility Type	Area Type	2030	2050	Total
Shared-Use Path	Core	0.2	0.2	0.4
	Urban	0.1	0.1	0.2
	Suburban	10.7	10.7	21.5
	Rural	12.0	12.0	23.9

[38] https://geodata.vermont.gov/datasets/d69b3471dfb741c4a38e874e6facbb94_0/explore

[39] VT Road Centerline | VT Road Centerline | Vermont Open Geodata Portal Your source for geospatial data

[40] The "core urban" areas technically features greater than 100 percent coverage because sidewalks and shared-use paths are both counted as pedestrian facilities.

[41] It is assumed the full buildout would be completed before 2050, but for purposes of reporting and emissions estimation, 2050 marked the next horizon year for reporting.

Two- Way Miles of Facility Type	Area Type	2030	2050	Total
Bike Lanes	Core	0.0	0.0	0.0
	Urban	0.3	0.3	0.6
	Suburban	11.5	11.5	23.0
	Rural	0.0	0.0	0.0
Separated Bike Lanes	Core	0.0	0.0	0.0
	Urban	1.9	1.9	3.8
	Suburban	0.0	0.0	0.0
	Rural	0.0	0.0	0.0
Sidewalks	Core	0.0	0.0	0.0
	Urban	2.9	2.9	5.8
	Suburban	32.8	32.8	65.6
	Rural	33.0	33.0	65.9
Widened Shoulders	Suburban	5.4	5.4	10.8
	Rural	72.7	72.7	145.4

Using this modeled buildout, carbon emission reductions were modeled using the methodology outlined in C.2.1. Key cost assumptions are outlined in Table D-4.

Table D-4 Key Cost Parameters for Bicycle and Pedestrian Strategies

Facility Type	Cost per two-way mile[42]
Bicycle lane	$27,500
Buffered bicycle lane	$125,000
Sidewalk	$337,000
Shared-use path	$430,000

E.2 Transit: Expanded Service

Expanded transit service was modeled through two separate strategies: expanded urban fixed-route bus service and expanded rural fixed-route bus service.

The proposed strategy for increasing urban fixed-route bus was to increase frequencies for the Green Mountain Transit Authority (GMTA). An analysis of several key routes for the GMTA show that routes typically operate from 6am to 10pm, with roughly 20 minutes frequencies from 6am-6pm, then switching to hourly service after 6pm. To model expanded service within this agency, the proposed strategy models an increase from 20-minute frequencies to 15-minutes frequencies between the hours of 6am and 6pm. This increase corresponds to a daily vehicle revenue mile (VRM) increase of around 30 percent. Applying this 30

[42] Costs sourced from FHWA (2023): Pedestrian Safety Guide and Countermeasure Selection System. Available online at: http://www.pedbikesafe.org/PEDSAFE/countermeasures.cfm

percent increase across the agency annually accounts for around 450,000 additional VRM in service by GMTA each year.

Emissions reductions from this strategy were calculated using the following equation:

Annual emissions change (MT CO_2e) = New bus VRM * bus emission rate - new bus VRM * load factor * prior drive mode share * light duty vehicle emission rate

Table D-5 details the values and sources for these key parameters:

Table D-5 Key Parameters for Urban Fixed-Route Transit Service Modeling

Parameter	Value	Source
New Bus VRM	458,298	30 percent increase over GMTA VRM, as reported to the National Transit Database in 2019
Bus Emission Rate (grams CO_2e /mile): 2030	0	All new service assumed to run on electricity, which is outside transportation emissions scope
Load Factor	4.5	National Transit Database (2019): Green Mountain Transit Authority
Prior Drive Mode Share	47%	GCC (2023) [31]
Light Duty Vehicle Emission Rate (2030)	229	Vermont-specific analysis from B.1

The proposed strategy for increasing rural fixed-route bus service was to increase hours of service. Specifically, analysis and discussion of these rural fixed-route providers highlighted a lack of weekend service for most routes. To model increased hours of service, the proposed strategy assumes that all rural fixed-route bus service will adopt weekend service at similar levels to weekday service (typically hourly headways), resulting in a 34 percent increase in VRM.

Emissions reductions from this strategy were calculated using the following equation:

Annual emissions change (MT CO_2e) = New bus VRM * bus emission rate - new bus VRM * load factor * prior drive mode share * light duty vehicle emission rate[43]

Table D-6 details the sources of the values for these key parameters.

[43] The light duty vehicle emission rate varies based on the year of analysis due to the changing fuel economy average of on-road vehicles as well as the increasing number of electric vehicles in the fleet mix.

Table D-6 Key Parameters for Rural Fixed-Route Transit Service Modeling

Parameter	Value	Source
New Bus VRM	753,078	34 percent increase in rural bus VRM, as reported to the National Transit Database in 2019
Bus Emission Rate (grams CO_2e /mile): 2030	0	All new service assumed to run on electricity, which is outside transportation emissions scope
Load Factor	3.3	National Transit Database (2019): All agencies[44]
Prior Drive Mode Share	60%	GCC (2023) [31]
Light Duty Vehicle Emission Rate (grams CO_2e /mile): 2030	229	Vermont-specific analysis from B.1

Key cost assumptions are outlined in Table D-7.

Table D-7 Key Cost Parameters for Expanded Transit

Parameter	Value	Source
Electric Bus Capital Cost	$887,000	APTA Vehicle Database (2019-2025)
Operation and Maintenance Cost per VRM	$0.32	Value of $0.42 reported for current VT bus fleet for diesel buses. NREL reports O&M cost per VRM for electric buses ~24% lower than conventional fuel
Electricity Fuel Cost ($/kwh)	$0.17	EIA (2023) – Vermont Commercial Electricity Price
Cost Per EV Charger (Bus)	$50,000	NREL (2020)
Electric Bus Capital Cost	$887,000	APTA Vehicle Database (2019-2025)

E.3 Micromobility

Micromobility strategies were modeled as subsidies for the purchase of electric bicycles or “e-bikes”. Specifically, an annual subsidy fund covering 50 percent of the purchase price of 1,500 e-bikes was modeled for this strategy.

Emissions reductions for this strategy were calculated using the following equation:

Annual emissions change (MT CO_2e) = # e-bikes * bike trips per week * week annualization factor * average trip length * prior auto mode share * light duty vehicle emission rate

Table D-8 details the sources of the values for these key parameters.

[44] Vehicle revenue miles and ridership (unliked passenger trips) are reported for all rural agencies. However, passenger miles are not reported for rural agencies. As such, as assumption was made that trip lengths for these providers were roughly twice in length to urban trips (resulting in an average trip length of 5.7 miles) in order to calculate a load factor

Table D-8 Key Parameters for Micromobility Modeling

Parameter	Value	Source
E-Bike Cost	1,500	REI (2022)[45]
Bike Trips Per Week	5.7	Portland State University (2018)[46]
Week Annualization Factor	40	Per discussion with stakeholders, excluded winter months (12 weeks) from annual ridership activity estimates
Average trip length	9.3	Portland State University (2018)
Prior auto mode share	28%	Portland State University (2018)Error! Bookmark not defined.
Light Duty Vehicle Emission Rate (grams CO_2e /mile): 2030	229	Vermont-specific analysis from B.1

E.4 Travel Demand Management

Travel demand management was modeled through the expansion of the Go! Vermont travel demand program. Specifically, this effort modeled a 50 percent increase in program funding, from around $793,000 annually to nearly $1.2 million annually.

Per the latest year of program reporting, the Go! Vermont program resulted in annual reductions of around 706,402 vehicle miles traveled. Given current funding levels, this translates to around 890 VMT reduced per $1,000 invested in the program (0.89 VMT per $). This relationship was assumed for the effects of a program expansion, with emission reductions for this strategy calculated using the following equation:

Annual emission change (MT CO_2e) = additional funding * VMT reduced per $ * light duty vehicle emission rate

E.5 Land Use

Land use strategies were modeled through two different mechanisms.

First, land use strategies were modeled as the concentration of future population growth (i.e., population added beyond the state's current levels) into lower-VMT regions and localities. To do this, data on Vermont per-capita VMT was sourced from the concurrent *Vermont Smart Growth, VMT and GHG Project*[47]. Table D-9 displays weekly and annual Vermont per-capita VMT, broken out by five quantiles.

[45] REI (2022). How Much Do Electric Bikes Cost? How Much Do Electric Bikes Cost? | REI Expert Advice

[46] Portland State University (2018). *A North American Survey of Electric Bicycle Owners*. Accessed online at: A North American Survey of Electric Bicycle Owners (calbike.org)

[47] AOT (2023) – Prepared by RSG. Vermont Smart Growth, VMT, and GHG Research Project: Task 4 Technical Report. Draft as of May 26, 2023. Accessed through AOT correspondence.

Table D-9 Vermont VMT Per Capita by Quantile

Quantile	Weekly VMT	Annual VMT
1	81.2	4,222
2	115.9	6,027
3	127.7	6,640
4	133.0	6,916
5	141.5	7,358

Next, population growth estimates were sourced from the LEAP model provided by Vermont Agency of Natural Resources. Table D-10 shows the population projections from the model.

Table D-10 Vermont Population Projection

Year	Population
2022	622,961
2025	630,475
2030	639,251
2050	639,776

To illustrate the possible effects of focusing new population in lower-VMT regions of the state, VMT changes were estimated by comparing the VMT if the new populations exhibited median VMT-per capita behavior (quantile 3 of Table D-9) against the VMT if the new populations exhibited VMT-per capita behavior evenly distributed between quantiles 1 and 2.

As such, the annual emissions change from this strategy were calculating using the following equation:

Annual emissions change (MT CO_2e) = new population * ((quantile 1 +quantile 2 VMT)/2) - quantile 3 VMT * light duty vehicle emission rate

Second, land use strategies were modeled through land use changes affecting the existing Vermont population, through increased density or rezoning. To illustrate the possible magnitude of this type of land use change, it was first assumed that the housing stock would turn over at a rate of 4 percent per decade. Then, it was assumed that the new housing units (through denser or mixed-use development), would shift from quantile 3 VMT patterns to quantile 2 VMT patterns[48].

Annual emissions change (MT CO_2e) = population associated with housing turnover * (quantile 2 - quantile 3 VMT * light duty vehicle emission rate

[48] A shift to quantile 2 (rather than a split between quantile 1 and 2) was assumed in order to be more conservative with respect to VMT impacts within the existing population.

E.6 Telework

Expanded opportunities for telework can reduce carbon emissions by reducing work related vehicle travel. Specifically, telework strategies were modeled for this effort through the completed expansion of rural broadband.

To conduct this analysis, county-by-county broadband coverage data[49] was sourced from the Vermont Department of Public Service[50] to determine the number of uncovered buildings. Next, county-by-county employment data was sourced from the Bureau of Labor Statistics to determine the number jobs within each county that were conducive to remote work ("remote-friendly")[51]. Building coverage was then used as a proxy for job coverage within the state.

Emissions reductions for this strategy were calculated using the following equation:

Annual emissions change (MT CO_2e) = total remote friendly jobs without broadband * telework days per week * 52 weeks * average trip length * light duty vehicle emission rate

Table D-11 details the sources and values for these key parameters.

Table D-11 Key Parameters for Telework Modeling

Parameter	Value	Source
Buildings without Broadband	54,531 (17%)	Vermont DPS[50]
Total Remote-Friendly Jobs	89,125	US Bureau of Labor Statistics
Total Remote-Friendly Jobs without Broadband	11,721	Applying the 17% coverage gap to the total remote-friendly job number
Average Trip Length	12.7	USDOT National Household Travel Survey (2017)[52]
Telework Days Per Week	1.5	Assumption
Light Duty Vehicle Emission Rate (grams CO_2e /mile): 2030	229	Vermont-specific analysis from B.1

[49] Broadband coverage was defined as speeds of 25 download/3 upload Mbps or better.

[50] https://publicservice.vermont.gov/telecommunications-and-connectivity/broadband-high-speed-internet-availability-vermont

[51] Jobs conducive to remote work included jobs within the following sectors: Information, Financial, Professional, and Government. To be conservative, jobs within healthcare and education were not included.

[52] USDOT (2017). National Household Travel Survey: Summary of Travel Trends. Accessed at: https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf

The costs of broadband coverage was sourced from the Vermont DPS Broadband Action Plan[53], with a value of $3,515 per covered building employed for this analysis.

E.7 Transit Electrification

The transit electrification strategy was modeled as the electrification of all motor bus (MB), commuter bus (CB), and demand response (DR) vehicles from all Vermont agencies reporting to the National Transit Database (NTD). Specifically, it assumes 100 percent electrification by 2050, with 5 percent electrification by 2025 and 25 percent electrification by 2030.

Because electricity emissions are not considered in scope for this analysis, emissions reductions for this strategy were calculated using the following equation:

Annual Emissions Change (MT CO_2e) = Cumulative Vehicles Replaced * VRM per Vehicle * Replaced Vehicle Emissions Rate[54]

Table D-12 details the sources of the values for these key parameters:

Table D-12 Key Parameters for Transit Electrification Modeling

Parameter	Value	Source
VRM Per Bus (Urban)	27,279	NTD (2019): Green Mountain Transit Authority
VRM Per Bus (Rural)	29,126	NTD (2019): Southeast Vermont Transit
VRM Per Demand Response (Urban)	14,780	NTD (2019): Green Mountain Transit Authority
VRM Per Demand Response (Rural)	38,676	NTD (2019): Rural Community Transportation
VRM Per Commuter Bus	37,675	NTD (2019): Green Mountain Transit Authority
Diesel Bus Fuel Economy (mpgge)	8.5	NTD (2019): Green Mountain Transit Authority
Gasoline DR Fuel Economy (mpgge)	12.3	NTD (2019): Green Mountain Transit Authority

Note: mpgge = miles per gallon of gasoline - equivalent

Key cost assumptions are outlined in Table D-13.

[53] Accessed online at: https://publicservice.vermont.gov/sites/dps/files/documents/EBAP%20Revised%20additional%20comments%206-24-20.pdf

[54] Replaced vehicle emission rate is determined based on the fuel economy of the vehicle as well as the carbon content of the fuel

Table D-13 Key Cost Parameters for Transit Electrification

Parameter	Value	Source
Battery Electric Bus (BEB) Capital Cost	$887,000	APTA Vehicle Database (2019-2025)
Diesel Bus Capital Cost	$507,824	APTA Vehicle Database (2019-2025)
Electric DR Capital Cost	$126,939	Assume cost markup equivalent to BEB
Gasoline DR Capital Cost	$72,634	APTA Vehicle Database (2019-2025)
O&M Cost per VRM (Diesel Bus)	$0.42	Vermont NTD (2019)
O&M Cost per VRM (BEB)	$0.32	NREL Factor of 24%
O&M Cost per VRM (Gas DR)	$0.026	Vermont NTD (2019)
O&M Cost per VRM (Electric DR)	$0.019	NREL Factor of 24%
Gasoline Fuel Cost ($/gal)	$3.50	AAA (2023)
Diesel Fuel Cost ($/gal)	$4.07	AAA (2023)
Electricity Fuel Cost ($/kwh)	$0.17	EIA (2023)– Vermont Commercial Electricity Price
Cost Per EV Charger (Bus)	$50,000	NREL (2020)

E.8 Advanced Clean Fleets

To estimate the impact of the adoption of the Advanced Clean Fleets (ACF) rule, the modeling team obtained data from the California Air Resources Board (CARB) modeling ACF adoption. Then, zero-emission medium and heavy duty truck stock percentages were compared to the internal modeling conducted under the baseline with the adoption of the ACT rule to determine the number of additional trucks which would be subject to the rule. Emissions reductions were calculating using the following equation:

Annual emissions change (MT CO_2e) = number of additional trucks affected * VRM per truck * internal combustion engine truck emissions rate

Table D-14 details the sources of the values for these key parameters.

Table D-14 Key Parameters for Advanced Clean Fleets Modeling

Parameter	2030	2050	Source
Additional Zero-Emission Medium Duty Trucks	0	7,409	CARB Workbook, LEAP Model Output
Additional Zero-Emission Heavy Duty Trucks	1,355	1,734	CARB Workbook, LEAP Model Output
Medium Duty VRM Per Truck	17,013	17,013	LEAP Model Output
Heavy Duty VRM Per Truck	28,531	28,531	LEAP Model Output
Medium Duty Truck: Gasoline (g CO_2e /mile)	988	872	LEAP Model
Medium Duty Truck: Diesel (g CO_2e /mile)	558	509	LEAP Model
Heavy Duty Truck: Diesel (g CO_2e /mile)	1,014	896	LEAP Model

Key cost assumptions are outlined in Table D-15.

Table D-15 Key Cost Parameters for Advanced Clean Fleets

Parameter	Value	Source
DCFC: Dedicated truck/bus (50kw): hardware cost per unit	$28,401	ICCT (2019)[55]
DCFC: Dedicated truck/bus (350kw): hardware cost per unit	$140,000	ICCT (2019)
DCFC: Dedicated truck/bus (50kw): installation cost per unit	$26,964	ICCT (2019)
DCFC: Dedicated truck/bus (350kw): installation cost per unit	$39,097	ICCT (2019)

Note: DCFC = Direct current fast charge

E.9 Feebates

To model the impact of feebates, it was assumed that a feebate policy would work to incentivize the purchase of higher-fuel economy vehicles. While there are limited studies on the effect of feebates due to its limited policy adoption, estimates from France have shown that carbon emission from new vehicles were roughly 6 percent lower one year after policy adoption[56]. In order to be conservative, this study assumes that all new vehicles sold will have a 4 percent reduction in carbon emissions. Finally, this analysis assumes the feebate takes effect in 2024.

Emissions reductions were calculating using the following equation:

Annual emissions change (MT CO_2e) = number of new onroad light duty vehicles * VRM per vehicle * new vehicle emission rate * feebate impact

Table D-16 details the sources of the values for these key parameters.

Table D-16 Key Parameters for Feebate Modeling

Parameter	Value	Source
Cumulative New Onroad Gas Cars (2024-2030)	60,303	Analysis from LEAP Output
Cumulative New Onroad Gas Light Trucks (2024-2030)	93,118	Analysis from LEAP Output
VRM Per Car	9,902	Analysis from LEAP Output
VRM per Light Truck	10,598	Analysis from LEAP Output
New Passenger Car Fuel Economy: Gas	35.4	LEAP Output
New Light Truck Fuel Economy: Gas	25.1	LEAP Output
Feebate Impact	-4%	AOT (2019)[56]. Value of -6% replaced with -4% for a more conservative estimate.

[55] ICCT (2019). *Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas*. Available online at: https://theicct.org/publication/estimating-electric-vehicle-charging-infrastructure-costs-across-major-u-s-metropolitan-areas/

[56] AOT (2019). *Vehicle Feebate and Vehicle Incentive Programs Funding Report*. Available online at: https://legislature.vermont.gov/assets/Legislative-Reports/Feebate-Study-Report-10-15-2019-Final.pdf

E.10 Co-Benefits

Table 3-10 illustrates the relative benefits and co-benefits of the various carbon reduction strategies, measured in terms of unit of benefit per million dollars invested in the strategy. Table D-17 provides a legend for this table. Benefits are shown for:

GHG emissions: metric tons reduced per million dollars invested.

Air quality: Pounds of fine particulate matter ($PM_{2.5}$) reduced per million dollars invested.

Mobility: New trips taken by modes other than single-occupancy vehicle (SOV) per million dollars invested.

Health: Value of health benefits due to increased physical activity and reduced air pollution per million dollars invested.

Table D-17 Legend for Co-benefits Table

Benefits Range	GHG emissions: mt per $M	Air quality: $PM_{2.5}$ lbs/$M	Mobility: New non-SOV trips per $M	Health: Value of benefits per $M
-	<10	<1	<1,000	<$0.1M
+	10 – 100	1 – 10	1,000 – 50,000	$0.1 – $0.25M
++	100 – 1,000	10 – 100	50,000 – 250,000	$0.25M - $2.5M
+++	>1,000	>100	>250,000	>$2.5M

General co-benefits of strategies were estimated by Cambridge Systematics, Inc. using the Transportation Investment Strategy Tool developed for the Georgetown Climate Center. The methods and assumptions in the tool are documented in:

> Cambridge Systematics, Inc. (2023). Transportation Investment Strategy Tool Documentation, 2023. Prepared for Georgetown Climate Center.
> https://www.georgetownclimate.org/files/report/GCC_Investment_Tool.pdf

Appendix F. 2050 Modeling Results

Table E-1: Evaluation of GHG Reduction Strategies

Strategy	CO_2 Reduction (2050 metric tons)	% of 2050 Gap Closed	Estimated Cost Through 2050 ($M)
Bicycle and pedestrian network expansion	70	0.1%	231.3
Transit service expansion	90	0.1%	60.0
Micromobility	870	0.9%	30.4
Travel demand management	10	0.0%	10.7
Transit vehicle electrification	17,000	17.0%	110.3
Land use	900	0.9%	0
Broadband expansion	850	0.8%	191.7
Advanced Clean Fleets	112,000	112%	461.8
Feebates	2,800	2.8%	0

Table E-2: Combined Strategy Effects

Scenario	Strategies	CO2 Reduction (2050 metric tons)	% of 2050 Gap Closed	Estimated Cost Through 2050 ($M)
1	Transportation investment and services	18,400	18%	$443
2	Transportation + land use + broadband	20,600	21%	$634
3	Transportation + land use + broadband + Advanced Clean Fleets & feebates	147,300	135%	$1,091
	Gap	**92,000**		

Appendix G. Carbon Reduction Program Eligible Activities

This list of eligible activities is summarized from the FHWA Carbon Reduction Program Implementation Guidance.[57] Readers should consult the guidance for specific language and details.

Traffic monitoring, management, and control facility or program, including advanced truck stop electrification systems.

Public transportation projects, including construction of a bus rapid transit corridor or dedicated bus lanes.

A transportation alternatives project including the construction, planning, and design of on-road and off-road trail facilities for pedestrians, bicyclists, and other nonmotorized forms of transportation.

A project for advanced transportation and congestion management technologies.

A project for the deployment of infrastructure-based intelligent transportation systems capital improvements and the installation of vehicle-to-infrastructure communications equipment.

A project to replace street lighting and traffic control devices with energy-efficient alternatives.

A project or strategy designed to support congestion pricing, shifting transportation demand to nonpeak hours or other transportation modes, increasing vehicle occupancy rates, or otherwise reducing demand for roads, including electronic toll collection, and travel demand management strategies and programs.

Efforts to reduce the environmental and community impacts of freight movement.

A project to support deployment of alternative fuel vehicles, including publicly accessible electric vehicle charging infrastructure or hydrogen, natural gas, or propane vehicle fueling infrastructure; and the purchase or lease of zero-emission construction equipment and vehicles as well as supporting facilities.

Diesel engine retrofits.

Projects to improve traffic flow that are eligible under the Congestion Mitigation and Air Quality Improvement (CMAQ) Program, and that do not involve construction of new capacity.

A project that reduces transportation emissions at port facilities, including through the advancement of port electrification.

Other projects that are not listed above may be eligible for CRP funds if they can demonstrate reductions in transportation emissions over the project’s lifecycle. Examples include sustainable pavements and construction materials, use of highway right-of-way for carbon sequestration or renewable energy generation, and mode shift, including micromobility and electric bike projects.

Projects to add general-purpose lane capacity for single occupant vehicle use will not be eligible absent analyses demonstrating emissions reductions over the project’s lifecycle.

[57] Memorandum from Gloria M. Shepherd to Division Administrators and Directors of Field Services, INFORMATION: Carbon Reduction Program (CRP) Implementation Guidance, April 21, 2022, U.S. Department of Transportation, Federal Highway Administration, Office of Planning, Environment, and Realty. https://www.fhwa.dot.gov/environment/sustainability/energy/policy/crp_guidance.pdf