CLIMATE POLLUTION REDUCTION GRANT

PRIORITY CLIMATE ACTION PLAN

submitted by the

Vermont Climate Action Office

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VERMONT

AGENCY OF NATURAL RESOURCES

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Executive Summary

Heavy rain throughout the summer of 2023 caused severe flooding in Vermont, leaving lasting damage and a changed landscape throughout the state. Due to climate change these storms and weather patterns are the new normal, and Vermonters will continue to be impacted by the hazards caused by severe storms. Vermonters are also experiencing increased periods of prolonged drought, extreme temperatures, and poor air quality due to wildfire smoke; these conditions highlight the increasingly urgent need for investment in climate mitigation to address the myriad impacts of climate change.

In 2020, the Vermont legislature adopted the Vermont Global Warming Solutions Act (GWSA), which converted Vermont's greenhouse gas (GHG) reduction goals into statutory requirements, created the Vermont Climate Council, and charged the Council with adopting, and subsequently updating, a Climate Action Plan. Vermont is required to reduce its GHG emissions by no less than 26% below 2005 GHG emission levels by January 1, 2025; by no less than 40% below 1990 GHG emission levels by January 1, 2030; and no less than 80% below 1990 GHG emission levels by January 1, 2050. The Initial Vermont Climate Action Plan was adopted on December 1 of 2021 and includes 234 unique actions to mitigate, adapt to, or be more resilient to climate change. Achieving these goals will require enormous effort and investment in Vermont's economy and landscape.

Vermont is making good progress to reduce its climate pollution through policies and recent federal funding from the American Rescue Plan Act, the Bipartisan Infrastructure Bill, and now the Inflation Reduction Act. Specifically, the Inflation Reduction Act (IRA) offers a historic opportunity to make investments that will be critical to achieving those goals. The Vermont Agency of Natural Resources (ANR), Climate Action Office, developed this Priority Climate Action Plan as part of the Environmental Protection Agency (EPA) Phase 1 Climate Pollution Reduction Grant Program. The grant program is one of many funding opportunities provided in the federal IRA and has the stated objectives to prioritize measures: 1) that achieve maximum reductions in greenhouse gas emissions while driving benefits to surrounding communities, and 2) to invest in measures that are ready to receive funds to use over the next several years.

This plan is not designed to address all the necessary and needed actions for emission reductions in Vermont. Instead, it is continuing the story of climate action in Vermont. It has been developed to achieve the most impactful reductions, and in the most critical sectors, where other funding is not currently available. The Climate Action Office (CAO), working collaboratively with the members of the Inter-Agency Advisory Board to the CAO, identified the measures included in this plan to meet EPA's criteria provided in the Notice of Funding Opportunity for the CPRG Implementation grant. This plan builds upon the mitigation work already advancing in Vermont by enhancing the scale and scope of existing frameworks, analyses, policies, and programs.

The four main mitigation sectors identified in this plan are 1) transportation, 2) residential and commercial buildings, 3) natural and working lands, and 4) waste and materials management. The first three categories contribute the most to greenhouse gas emissions in Vermont, making up more than 90% of the state's emissions. In addition, mitigation actions related to waste management have not advanced as far or as fast as other sectors, making it a high priority for action in this PCAP while utilizing the existing framework and partnerships developed by solid waste policies and priorities in ANR.

Transportation – the movement of people and goods – is essential to the state's economy and Vermonter's quality of life. The state's rural character and low population density also means that Vermonters depend primarily on cars and trucks to get around. Vermont's auto-reliant system is fueled almost entirely with carbon-intensive gasoline and diesel, making transportation the largest source of climate pollution – a full 40% of the state's greenhouse gas emissions. The combination of our mostly rural nature, dispersed land use patterns and heavy reliance on fossil-fueled vehicles is a significant reason why Vermonters emit more greenhouse gases per capita than any other state in New England. This reality makes transforming the state's transportation system essential to meeting the emissions reduction requirements of the GWSA. Incentivizing zero-emission vehicles in all classes of vehicles and developing the necessary trainings to give consumers the confidence to buy these vehicles will achieve significant reductions in GHGs. Co-benefits include improved public health in communities that are nearest to transportation corridors by lowering tailpipe emissions of criteria pollutants such as diesel particulate matter, and toxic air pollutants such as benzene. Vermont also proposes to increase the use of idle reduction technologies as a bridge to further reduce emissions in this sector.

Vermont's housing stock is dominated by homes built before 1975, with over a quarter of them built before 1939. Thermal energy use for these buildings produces over a third of the state's GHG emissions and represents roughly 35 percent of our energy expenditures. Replacing carbon-intensive fossil-fueled heating sources with available, lower carbon alternatives will significantly contribute to meeting Vermont's climate goals. Further incentives are needed to improve the efficiency of existing and new buildings, promote the transition to clean equipment and appliances, and increase building weatherization to realize the pace and scale of the transition needed by 2030. In addition, further investments in support systems are needed to help low-income Vermonters easily access incentives. Co-benefits include improved indoor air quality (including from wildfire smoke) and saving homeowners, business owners, and renters money on heating and cooling.

Vermont farmers and forestland owners are motivated to be part of climate change solutions, and many already include climate mitigation as a major goal in managing their woodlots and farms. Carbon sequestration in agricultural landscapes and working forestlands is the mitigation strategy that yields the greatest co-benefits, is the easiest and most immediate to implement, has equitable impacts, and has been prioritized by the global and scientific communities as a critical mitigation strategy. Vermont envisions further supporting restoration activities, land acquisition, and agronomic practices through increased funding and capacity.

The handling of waste and materials is an additional contributor of GHGs in Vermont, and while Vermont's Universal Recycling and Composting Law has made significant advancements in reducing emissions from this sector, there are opportunities for more mitigation-focused related to waste reduction and management. The EPA estimates that wasted food generates nearly 60% of methane emissions from landfills. Reducing the amount of food wasted and improving food scrap diversion programs at schools, hospitals, nursing homes, and other institutions will have a meaningful impact. Additional non-energy measures beyond waste management include addressing high global warming potential refrigerants in two ways. Vermont plans to increase the rate of recovery of refrigerants from systems and appliances at the end of their life and replace refrigeration equipment with technology that utilizes non "f-gas" or natural refrigerants.

This priority plan lays out the critical measures that will leverage federal investments to accelerate Vermont's climate mitigation activities and make sustainable emissions reductions throughout the economy. As this work advances, we envision robust engagement with Vermonters to realize the transformative changes needed to meet both the challenges and opportunities of climate change.

Acronyms and Abbreviations

AAFM	Vermont Agency of Agriculture, Food, and Markets
ACCD	Vermont Agency of Commerce and Community Development
AEV	All electric vehicle
AMI	Area median income
ANR	Vermont Agency of Natural Resources
AR4	IPCC Fourth Assessment Report
ARPA	American Rescue Plan Act
BAU	Business as usual
BGS	Vermont Department of Buildings and General Services
CAO	Climate Action Office
CAP	Criteria Air Pollutant
CCAP	Comprehensive Climate Action Plan
CEAP	Capital equipment assistance program
CEJST	Climate and Economic Justice Screening Tool
CEP	Comprehensive Energy Plan
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
CPRG	Climate Pollution Reduction Grant
CREP	Conservation reserve enhancement program
CSAF	Climate smart agricultural and forestry practices (NRCS)
DCFC	Direct current fast charger
DERA	Diesel Emission Reduction Act
DEV	Drive Electric Vermont
DHCD	Department of Housing and Community Development
DOE	Department of Energy
DSIRE	Database of state incentives for renewables and efficiency
EJ	Environmental Justice
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
EVT	Efficiency Vermont
FAP	Farm agronomic practices
GHG	Greenhouse Gas
GWFS	Grassfed waterway and filter strip program
GWP	Global warming potential
GWSA	Global Warming Solutions Act
HAP	Hazardous Air Pollutant
HFCs	Hydrofluorocarbons
IAAB	Interagency Advisory Board to the Climate Action Office
IPCC	Intergovernmental panel on climate change
IRA	Inflation Reduction Act

LIDAC	Low income and disadvantaged community
LULUCF	Land use, land-use change and forestry
MAP	Measuring and Assessing Progress Tool
MERP	Municipal Energy Resilience Program
MHD	Medium- and Heavy-duty
MMTCO2e	Million metric- tons of carbon dioxide equivalent
MSRP	Manufacturer Suggested Retail Price
MTAP	Municipal Technical Assistance Program
MUD	Multi-unit dwelling
N2O	Nitrous oxide
NEI	National emissions inventory
NF3	Nitrogen trifluoride
NOx	Nitrogen oxides
NRCS	Natural Resource Conservation Service
PCAP	Priority Climate Action Plan
PFCs	Perfluorocarbons
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate matter
PSD	Vermont Public Service Department
PSWF	Pasture and surface water fencing program
RBES	Renewable building energy standard
RCI	Residential, Commercial and Industrial Sector (Buildings Sector)
RES	Renewable Energy Standard
RPC	Regional planning commission
SF6	Sulfur hexafluoride
SIT	EPA State Inventory Tool
SO2	Sulfur dioxide
STEM	Science, Technology, Engineering, and Mathematics
SWME	Solid Waste Management Entity
TRU	Transport refrigeration unit
USFWS	U.S. Fish and Wildlife Service
VAPDA	Vermont Association of Planning and Development Agencies
VCC	Vermont Climate Council
VCCC	Vermont Clean Cities Coalition
VDH	Vermont Department of Health
VEIC	Vermont Energy Investment Corporation
VFPR	Vermont Department of Forests, Parks, and Recreation
VFWD	Vermont Fish and Wildlife Department
VHCB	Vermont Housing and Conservation Board
VLCT	Vermont League of Cities and Towns
VMT	Vehicle miles traveled
VOC	Volatile organic compound
VT CAP	Vermont Climate Action Plan
VTrans	Vermont Agency of Transportation
VWFW	Vermont Works for Women

WMA	Wildlife Management Area
WWTF	Wastewater Treatment Facility
ZERH	Zero emission ready home

Introduction

Motivated by the feelings of both urgency and responsibility, Vermonters have been demonstrating leadership in mitigating climate change by transforming how we use and source energy, adapting our communities and built environment to the warming planet, protecting our natural and working lands from the damage created by climate change, and supporting and enhancing the resilience of Vermont's land and communities. Climate change represents an existential threat both for people and for the natural systems upon which we depend for our health and well-being. We see the devastating impacts of climate change in Vermont every day. To create a habitable future, it is critical that we become more resilient and adaptive to climate change and that we do more to reduce the emissions that have brought us to this point.

Climate Pollution Reduction Grants

The Climate Pollution Reduction Grants (CPRG) program provides $5 billion in grants to states, local governments, tribes, and territories to develop and implement ambitious plans for reducing greenhouse gas emissions and other harmful air pollution. Authorized under Section 60114 of the Inflation Reduction Act, this two-phase program provides $250 million for noncompetitive planning grants, and approximately $4.6 billion for competitive implementation grants.

The Vermont Agency of Natural Resources (ANR) has partnered with the Vermont Agency of Transportation, the Public Service Department, the Department of Buildings and General Services, the Department of Health, the Agency of Commerce and Community Development, and the Agency of Agriculture Food and Markets and many other stakeholders and partners to adopt this priority climate action plan (PCAP) in support of the investment in policies, practices, and technologies that reduce pollutant emissions, create high-quality jobs, spur economic growth, and enhance the quality of life for all Vermonters. This PCAP has been developed with support from the United States Environmental Protection Agency (EPA) under assistance agreement 5D-00A01253 to the Vermont Department of Environmental Conservation. The contents of this document do not necessarily reflect the views and policies of the EPA, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

Overview of Vermont's Climate Planning

This PCAP is not the beginning of climate mitigation planning in Vermont. Rather, it is the next chapter in a continuing story of Vermont's participation in the global effort to reduce greenhouse gas emissions. In 2020, the Vermont legislature adopted the Vermont Global Warming Solutions Act (GWSA), created the Vermont Climate Council (the Council), and charged the Council with adopting, and subsequently updating, a Climate Action Plan. The Global Warming Solutions Act requires Vermont to reduce its GHG emissions by no less than 26% below 2005 GHG emission levels by January 1, 2025; by no less than 40% below 1990 GHG emission levels by January 1, 2030; and no less than 80% below 1990 GHG emission levels by January 1, 2050.

The Initial Vermont Climate Action Plan (VT CAP) was adopted on December 1 of 2021 and includes 234 unique actions to mitigate, adapt to, or improve resilience to climate change. The actions are organized by Pathways, which are further defined by specific strategies to achieve the requirements of the GWSA. The VT CAP is supported by the Vermont Pathways Analysis, the Social Cost of Carbon, the Vermont

Greenhouse Gas Inventory, and the Vermont Carbon Budget, and is informed by numerous other studies and analyses that led to development of the 234 actions.

As outlined in the GWSA, the objectives of the pathways, strategies, and actions in VT's CAP are to:

- Prioritize the most cost-effective, technologically feasible, and equitable GHG emissions reduction pathways, adaptation and preparedness strategies;
- Provide for GHG emissions reductions that reflect the relative contribution of emissions from different sectors;
- Minimize negative impacts on marginalized and rural communities and individuals with low and moderate incomes;
- Ensure that all regions of the state benefit from GHG emissions reductions;
- Support economic sectors and regions of the state that face the greatest barriers to emissions reductions, especially rural and economically distressed regions and industries;
- Support industries, technology, and training that will allow workers and businesses in the state to benefit from GHG reduction solutions;
- Support the use of natural and working lands to reduce GHG, sequester carbon and increase resilience; and
- Maximize the state's involvement in interstate and regional initiatives and programs designed to reduce GHG emissions, and build upon state, national, and international partnerships and programs.

Additionally, the development of the VT CAP coincided with the development of an update to Vermont's Comprehensive Energy Plan (CEP). As described above, the VT CAP is an Action Plan for greenhouse gas mitigation, sequestration, and adaptation strategies in the face of climate change. The CEP is a mechanism to implement statutory energy policy based on a comprehensive analysis of challenges and opportunities in Vermont. While the VT CAP and the CEP have considerable areas of overlap, they remain distinct planning requirements, with different objectives.

The CEP reviews energy system planning in ways that are beyond the scope of the GWSA. For example, it focuses on planning for reliability of the electric system given the pathways necessary to meet our climate goals. In addition, it must include recommendations for regional and municipal energy planning. In turn, the VT CAP looks at the impacts of climate change beyond the scope of the CEP, addressing resilience in the natural and built environment, adaptation, sequestration, and non-energy mitigation. It is important that the process for the VT CAP and CEP align. Thus, the Public Service Department in its role developing the CEP and the Agency of Natural Resources in its role supporting the development of the VT CAP closely coordinated these two required plans.

Notably, public engagement efforts were aligned for both planning processes, so that targeted outreach to both Vermonters and technical experts was coordinated. In addition, the Vermont Pathways Analysis was initiated for purposes of the CEP but reviewed, modified, and adopted for the VT CAP, ensuring there is one set of energy related assumptions on which the two plans were based. The CEP is required

to be consistent with the requirements of the GWSA and the VT CAP. At the same time, the VT CAP is required to be informed by the CEP. These requirements to closely coordinate the efforts – even if the resulting actions are not necessarily identical, the basis on which they are formed was efficient and practical – allow for clearer consideration of the issues and a chance now to align their implementation.

Scope of Vermont's Priority Climate Action Plan for the Climate Pollution Reduction Grant

This PCAP is rooted in the extensive, thoughtful, and ongoing work and builds on the VT CAP and further aligns actions with the priorities in the CEP. To develop the PCAP, ANR revisited and reevaluated recommended actions in the VT CAP and CEP and also considered new actions.

This PCAP supports EPA's Fiscal Year (FY) 2022-2026 Strategic Plan Goal 1 (Tackle the Climate Crisis); Objective 1.1 (Reduce Emissions that Cause Climate Change). Objective 1.1 describes the environmental results of the measures in terms of well-defined outputs and, to the maximum extent practicable, well-defined outcomes that will demonstrate how the PCAP will contribute to the EPA Strategic Plan priorities.

Since the adoption of VT CAP in December of 2021, State and Local government, businesses, and individuals have demonstrated leadership and innovation in making significant progress towards meeting the requirements of the GWSA. Vermont has implemented bold and meaningful programs to reduce emissions in the Transportation and Buildings Sectors, built the framework within the administration to facilitate, coordinate, and communicate climate work at every level of government. These systems and structures are prepared to implement the action items described in this PCAP. Much work remains in order to achieve emissions reductions across more sectors of the Vermont economy, especially in a way that allows all Vermonters to participate in the transition to cleaner technologies that emit less and save money. The measures outlined in this PCAP represent further bold and innovative climate action that will meaningfully accelerate Vermont's role in lessening the impacts of climate change.

This PCAP should be construed as broadly available to any entity in the state eligible for receiving funding under the EPA's Climate Pollution Reduction Implementation Grants (CPRG) and other funding streams, as applicable.

Public Engagement and Outreach

Inter-agency coordination

Vermont is well-positioned to develop this plan through its newly formed Climate Action Office (CAO). The policies, programs and tools needed to implement climate mitigation, adaptation, and resilience strategies require a long-term intergovernmental structure to coordinate and manage this statewide effort. The CAO is responsible for coordination of state-led climate initiatives, as well as the monitoring, assessment and tracking of climate adaptation, mitigation, and resilience activities necessary to evaluate progress over time in achieving the requirements of the GWSA through implementation of the VT CAP. To carry out this work, the Office works closely with staff across ANR, other state Agencies, the state climatologist, and key stakeholders.

As the lead implementing agency, ANR worked closely with other state agencies, primarily through the pre-existing structure of the Interagency Advisory Board (IAAB) to the Climate Action Office. The IAAB includes the Vermont Public Service Department, Vermont Agency of Transportation, Vermont Agency of Commerce and Community Development, Vermont Department of Health, Vermont Department of Buildings and General Services, Vermont Agency of Human Services, Vermont Department of Emergency Management, Agency of Agriculture, Food and Markets and the Office of the State Climatologist. The IAAB's role is to provide an intergovernmental structure that sets State policy direction and promotes coordination of the policies, programs, and tools needed to implement climate change adaptation, mitigation, resilience strategies and carbon sequestration over the long-term. The IAAB meets regularly, and informed and coordinated the measures being put forward in this PCAP.

Engaging Regional and Local Entities

To consider the interests and needs of eligible municipalities to ensure "coverage" under the PCAP, ANR coordinated directly with the Vermont League of Cities and Towns (VLCT) in their capacity as representing Vermont's villages, towns and cities, and the Vermont Association of Planning and Development Agencies (VAPDA) in their capacity as representing Vermont's Regional Planning and Development Commissions. These are well established and organized entities that represent a broad and diverse group of government entities. ANR already engaged with these entities in other work of the Climate Action Office, so points of contact and channels for meaningful dialogue were already in place. Additionally, RPCs adopt regional energy plans, and assist municipalities in adopting local energy plans. ANR worked closely with RPCs and municipalities to incorporate them by reference into the PCAP and further prioritize the actions in them.

Finally, Vermont's Air Pollution Control Agency is the Air Quality and Climate Division which is housed within ANR. The CAO coordinated closely with the Vermont Air Quality and Climate Division to maximize co-benefits of greenhouse gas emissions mitigation and air contaminant reductions, and to coordinate CPRG funding with other air quality-related funding in the Inflation Reduction Act.

Engagement and Outreach Planning

Climate Action Office Community Engagement Plan 2023-24

Outreach for the Priority Climate Action Plan of the Climate Pollution Reduction Grant application was conducted within the broader context of the Climate Action Office's overall 2023-24 Community Engagement Plan.

The Engagement Plan strives to achieve the following goals:

- **Provide information and knowledge** that helps people prepare for climate impacts, take action, and access programs that can benefit them.
- **Lift up the voices and viewpoints of communities** into the implementation of climate-related initiatives and the ongoing work of the Vermont Climate Council, so that a diverse group of Vermonters can influence these efforts.
- **Build relationships and communication channels** that will help Vermonters work collaboratively on future climate action.

The engagement methods used to achieve these goals are:

1) **Public Meetings** focused on the substantive areas of ongoing work to inform the implementation of the Initial Climate Action Plan, anticipated legislative priorities, preparing for a revision to the Climate Action Plan. *(Ongoing)*
2) **Partner engagement and direct community engagement** to create conversations that can be sustainable over time around climate action issues.
    a. Develop and sustain partnerships with key organizations. *(Being implemented)*
    b. Conduct targeted focus groups for those whose first language is not English, working with cultural brokers to convene those who are often left out of these conversations due to language barriers. *(Being implemented)*
    c. Meet frontline communities where they are; be a continual, consistent presence to build trust and increase depth of conversations. *(Being implemented)*
    d. Convene a climate engagement alliance of frontline organizations *(Not yet begun)*

The Quarter 4 report on engagement activities outlines our most recent community engagement activities and approaches, and spotlights themes of Vermonters' concerns, ideas, and feedback. concerns, ideas, and feedback.

This ongoing engagement covers broad topics. Through these ongoing efforts, we include specific questions and prompts that solicit feedback that informs the State's climate action priorities, including those listed here in the Priority Climate Action Plan.

Climate Pollution Reduction Grants Engagement Summary

Vermont's Climate Action Office (CAO) held two virtual public meetings in December to receive initial feedback on the measures the state plans to include in its application for federal funding under the Climate Pollution Reduction Grant. The CAO also briefed Vermont's Climate Council to receive additional input.

59 people participated in the interactive public meetings. Another 25 attended the Council briefing, which was also open to the public. At these sessions, the CAO gave an overview of the Climate Pollution Reduction Grant (CPRG) and outlined the specific climate actions that the office proposes to include for funding. The Climate Action Office described the criteria that state agencies used to prioritize actions for the grant. After the initial presentation, participants engaged in a facilitated discussion. Videos are publicly available on the Agency of Natural Resources YouTube channel and the Climate Action Office website.

The measures in the grant application were selected from actions within Vermont's Initial Climate Action Plan, or they complement the Plan. The Plan was adopted December 2021 after a participatory process that included involvement from 1,600 Vermonters through events, surveys, direct conversations, and public comment form. The 2021 Public Engagement Findings report outlines engagement activities and summarizes resulting input for the Climate Action Plan. This input directly influenced the Climate Action Office's initial selection of measures to put forward for Climate Pollution Reduction Grant funding.

The CAO also encouraged written input on the proposed measures using a press release, social media posts, community event calendars, personal email invitations, and the CAO website to alert Vermonters to the public meetings and the opportunity to provide written comment. Nineteen people sent emails.

Overcoming barriers

The Climate Action Office's community engagement plan was designed in partnership with the Agency of Natural Resources Environmental Justice (EJ) Unit. The EJ Unit supports the implementation of Vermont's environmental justice law. Act 154 was adopted in 2022 and requires Vermont to "provide the opportunity for the meaningful participation of all individuals with particular attention to environmental justice focus populations, in the development, implementation, or enforcement of any law, regulation, or policy."

The EJ Unit is also responsible for establishing a new mapping tool that would identify communities where environmental burdens have disproportionate impact on Vermonters. ANR expects the requirements of Act 154 and the forthcoming mapping tool will aid in developing the analytical approaches and metrics for estimating benefits flowing to low income and disadvantaged communities as a result of the CPRG funding. While these deliverables will be forthcoming and developed in parallel to this work, the first deliverable was the principles of community engagement which informed the development of the CAO's community engagement plan described above. By implementing a Plan built on these principles, Vermont hopes to overcome the historic barriers to frontline and impacted communities' engagement with the state about policies that affect them. Continuing to evaluate the effectiveness of our engagement in this area will be critical to ensure we are doing our best to meet people where they are and lift up their voices into decision-making at the state level.

Outreach Documentation

Date	Topic	Organizations Involved	Outreach Method	Outcome(s)	Notes/Links
July – Oct. 2021	Initial Climate Action Plan Engagement	Vermont Climate Council, Climate Action Office, RISE Consulting, Climate Access Consulting	Interviews, Roundtables, Events, Opinion Survey, Comment Form	1,602 Vermonters engaged to influence the Initial Climate Action Plan	Public Engagement Findings report
August – Sept. 2023	Ongoing Community Engagement	Climate Action Office, Consensus Building Institute	Tabling and attending in-person events	7 events attended	Quarter 3 Vermont Voices on Climate report

Oct. – Dec. 2023	Ongoing Community Engagement	Climate Action Office, Consensus Building Institute	Tabling and attending in-person events, virtual gathering of community-based organizations	8 events attended; 10 community-based organizations engaged	Quarter 4 Vermont Voices on Climate report
11/30/23	Vermont's Climate Action Office Asks for Public Input on Federal Funding Opportunity for Climate Solutions	Vermont Agency of Natural Resources	Press Release sent to statewide news media, plus Vermont League of Cities & Towns and Vermont town clerks	Registrants for 12/11 & 12/12 events	Vermont Public article and podcast/radio spot Vermont Business Magazine article Agency of Natural Resources press release
11/28/23	Community calendar event listings	Climate Action Office	News media	Registrants for 12/11 & 12/12 events	Submitted events to local papers statewide. Events were posted in Burlington Free Press, Times Argus, Brattleboro Reformer, Newport Daily Express, Rutland Herald, Bennington Banner.
11/28-11/30/23	Front Porch Forum posts	Climate Action Office	Community list serves in Montpelier, Waterbury, Berlin, and Woodbury	Registrants for 12/11 & 12/12 events	Example of post
12/1-12/6/23	Invitations to join 12/11 & 12/12 events	Climate Action Office, Consensus Building Institute, Regional Planning Commissions, Vermont League of Cities & Towns, Vermont Energy & Climate Action Network, Public Service Department, Conservation	Email	Registrants for 12/11 & 12/12 events	Example of email invitation

		Commissions, Vermont Climate Council and subcommittees			
12/11/23	Vermont's Opportunity for Federal Climate Funding (virtual Zoom meeting)	Climate Action Office, Consensus Building Institute	Virtual interactive event	Received substantive public input and feedback.	Recording
12/12/23	Vermont's Opportunity for Federal Climate Funding (virtual Zoom meeting)	Climate Action Office, Consensus Building Institute	Virtual interactive event	Received substantive public input and feedback.	Recording
12/20/23	Follow-up Email to Event Registrants and Attendees	Climate Action Office	Email	Additional public comments received by email. Additional views of 12/11 and 12/12 presentations.	Example of follow-up email
2/17/23	Attended Northeast Organic Farming Association-VT's annual conference	Climate Action Office, Consensus Building Institute	Conference	Asked farmers and other working lands professionals about the barriers they experience when trying to access agricultural climate action programs.	https://www.nofavt.org/events/2024-nofa-vt-winter-conference
Planning in progress	Speak with low-income Vermonters who have benefitted from State-incentivized weatherizing programs	Climate Action Office, Community Action Agencies	Interviews	**Goal:** understand the barriers to accessing these programs and explore what can be improved and where funding is most needed	

Vermont's Greenhouse Gas Emissions

Greenhouse Gas Emissions Inventory

The Vermont Greenhouse Gas Emissions Inventory and Forecast (GHG Inventory) reports[Error! Bookmark not defined.] provide estimates of the amount of human caused (anthropogenic) greenhouse gas emissions produced within the state of Vermont in units of million metric tons of carbon dioxide (CO_2) equivalent ($MMTCO_2e$). It includes emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The GHG Inventory estimates and tracks the levels of these greenhouse gases by sector as accurately and consistently as possible through time; reports are currently available from 1990 – 2020. The most recent publication of the Vermont GHG Inventory (Appendix A) uses the 100-year global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). In the next iteration of the inventory the GWP values will be updated to use 100-year GWP values from the IPCC Fifth Assessment Report (AR5) as is now required for the national GHG Inventory by the UNFCCC.

The GHG Inventory is required pursuant to Vermont statute 10 V.S.A. § 582 and includes quantifications of historic 1990 and 2005 baseline GHG levels. It is the metric for determining progress toward the state's greenhouse gas reduction requirements in 10 V.S.A. § 578, which were updated with the passage of the GWSA (Act 153) in 2020 to be mandatory greenhouse gas levels that must be achieved rather than aspirational targets.

Total GHG emissions in $MMTCO_2e$ by sector and subsector have been provided for specific years in Table 1 below. Emissions estimates in the Vermont GHG Inventory are organized by these economic sectors: Electricity; Residential/Commercial/Industrial Fuel Use; Transportation/Mobile Sources; Fossil Fuel Industry; Industrial Processes; Waste Management; Agricultural.

Emissions totals in the VT GHG Inventory are calculated using methodologies largely based on methods used in, or developed for, the Final Vermont Greenhouse Gas Inventory and Reference Case Projections, 1990-2030 report and are compatible with IPCC GHG inventory guidelines. These methodologies mainly rely on the EPA State Inventory Tool (SIT) and applicable modules by sector. Local data is incorporated into the SIT modules where it is available and appropriate. Certain sectors and subsectors utilize alternative methodologies, generally where a detailed Vermont specific dataset is available that does not fit within the framework of the SIT (e.g. reported landfill gas data in the solid waste sector). For these cases a determination has been made that the alternative data and method will produce a more accurate emission estimate and will either reach back, or be projected back with a high degree of confidence, to the 1990 baseline. In several cases, such as the land-use, land use change and forestry (LULUCF) sector, data has been incorporated into the inventory from state level GHG emissions estimates that have been calculated by EPA through the disaggregation of the National Inventory of U.S. Greenhouse Gas Emissions and Sinks reports. Details on the specific methodologies and datasets used in the Vermont GHG Emissions Inventory and Forecast reports by sector are available in the Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies companion document (Appendix B).

Table 1: Vermont Historic Greenhouse Gas Emissions by Sector

Sector	Million Metric Tons CO_2 Equivalent: $MMTCO_2e$							
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**
Electricity Supply & Demand (consumption based)	**1.09**	**0.77**	**0.43**	**0.64**	**0.43**	**1.00**	**0.25**	**0.18**
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.00	0.01	0.02	0.00	0.00
Oil	0.01	0.01	0.06	0.01	0.04	0.01	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.62	0.36	0.96	0.24	0.16
Residential / Commercial / Industrial (RCI) Fuel Use	**2.54**	**2.51**	**3.02**	**3.06**	**2.56**	**2.94**	**3.00**	**2.87**
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.31	0.37	0.50	0.45	0.45	0.64	0.76	0.71
Oil, Propane & Other Petroleum	2.14	2.05	2.45	2.53	2.02	2.20	2.15	2.08
Wood (CH_4 & N_2O)	0.07	0.07	0.06	0.07	0.08	0.09	0.10	0.09
Transportation/Mobile Sources	**3.25**	**3.85**	**3.80**	**4.05**	**3.58**	**3.50**	**3.34**	**2.85**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	2.77	3.03	3.14	2.68	2.55	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.85	0.54	0.65	0.73	0.79	0.71	0.65
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.13	0.07	0.08	0.07	0.06
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01
All Mobile (CH_4, N_2O)	0.13	0.15	0.14	0.12	0.08	0.05	0.04	0.04
Fossil Fuel Industry	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**
Natural Gas Distribution	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas Transmission	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Industrial Processes	**0.21**	**0.40**	**0.53**	**0.44**	**0.47**	**0.62**	**0.63**	**0.65**
ODS Substitutes	0.00	0.05	0.13	0.18	0.25	0.32	0.36	0.37
Electric Utilities (SF_6)	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.16	0.28	0.34	0.21	0.18	0.26	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.03	0.02	0.03	0.03	0.03
Soda Ash Use	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**0.27**	**0.33**	**0.36**	**0.35**	**0.29**	**0.17**	**0.16**	**0.16**
Solid Waste	0.21	0.27	0.30	0.28	0.21	0.10	0.08	0.08
Composting	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Wastewater	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07
Agriculture	**1.24**	**1.16**	**1.24**	**1.27**	**1.28**	**1.42**	**1.38**	**1.26**
Enteric Fermentation	0.70	0.67	0.69	0.63	0.62	0.63	0.63	0.61
Manure Management	0.18	0.19	0.26	0.33	0.33	0.34	0.35	0.33
Agricultural Soils	0.36	0.31	0.28	0.30	0.33	0.40	0.37	0.29
Liming and Urea Fertilization	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.03
TOTAL GROSS EMISSIONS	**8.61**	**9.03**	**9.39**	**9.83**	**8.62**	**9.66**	**8.79**	**7.99**
Land-use, Land Use Change, and Forestry (LULUCF)	**-9.14**	**-8.52**	**-7.83**	**-7.24**	**-6.84**	**-6.27**	**-5.94**	**-5.92**
Estimated Net Emissions Total	**-0.53**	**0.52**	**1.56**	**2.59**	**1.78**	**3.39**	**2.86**	**2.07**

Greenhouse Gas Emissions Projections and Targets

ANR has developed near-term (2030) long-term (2050) projections of GHG emissions that would occur in a "business-as-usual" (BAU) scenario. This scenario was updated in 2023 and accounts for the emissions impacts of all known state and federal programs currently applicable to Vermont and available to Vermonters to mitigate GHG emissions. Table 2 lists base year GHG emissions and near-term and long-term GHG emissions projections for Vermont under the BAU and as compared to the GHG reductions requirements of the Vermont GWSA. The GWSA requirements for Vermont are 40% below 1990 GHG emission levels by January 1, 2030; and 80% below 1990 GHG emission levels by January 1, 2050. The GWSA required emissions are shown here based on the most recent Vermont GHG Inventory report.

Table 2 indicates that Vermont needs to implement further mitigation measures to meet our required emissions requirements.

Table 2: Vermont Modeled Business as Usual and GWSA Target Emissions in Metric Tons

Scenario	**2030**	**2050**
BAU	6,420,000 MT CO_2e	4,880,000 MMT CO_2e
GWSA Requirements	5,170,000 MT CO_2e	1,720,000 MT CO_2e

The estimated emissions reductions from implementation of measures in this PCAP are expected, cumulatively, to be 1,223,484 MTCO_2e by the year 2030 and 6,760,633 MTco2e by the year 2050, and would therefore enable Vermont to get closer to meeting the requirements of the GWSA. Further detail on the mitigation potential of each measure is included in each measure description.

Table 3: Estimated Cumulative Reductions of PCAP Measures in Metric Tons

	2025 – 2030	**2025 - 2050**
Estimated Cumulative Reductions of PCAP Measures	1,223,484 MT CO_2e	6,760,633 MT CO_2e

Measuring and Tracking Progress

Vermont is required to measure and track progress related to greenhouse gas emissions reductions to determine compliance with the GWSA. As mentioned previously, the official indicator of compliance with the law will be the Vermont Greenhouse Gas Emissions Inventory and Forecast report, however, given the nature of a statewide inventory and the somewhat coarse tools, datasets, and methodologies available to calculate such an inventory it is also important to track more specific and granular actions and metrics to help understand progress in a different way and on a different scale. The Vermont ANR is advancing the implementation of a two-phase project to design and build a Measuring and Tracking Progress (MAP) tool that will contain such metrics and indicators. In Phase 1 of the project a contractor, in collaboration with Vermont ANR and a data governance team, will determine which measures to track and the appropriate metrics or indicators within the measure as well as existing or necessary datasets to inform those metrics (e.g. the number of electric vehicle (EV) registrations in the state as well as the amount of electric vehicle supply equipment (EVSE), residential electrical panel upgrades to enable EV home charging, etc.). The MAP tool will be as comprehensive as possible in the measures and metrics being tracked with available datasets to provide valuable information for policy makers and the public related to where progress is being made and where additional efforts are required to enable the success of an action or measure.

ANR is planning to incorporate the measures from the PCAP, and outputs and outcomes from those measures, into the MAP tool to enable tracking of those measures and metrics through time. This will be important to determine the success of each measure, as well as allowing for more project specific GHG emissions reductions calculations as needed. Data will be collected from measure administrators and participants to inform the metrics tracked with the MAP tool. Examples of metrics that can be tracked to determine progress and performance of each measure include, but are not limited to:

1. Number of medium- and heavy-duty incentive program participants, including type of vehicles deployed;
2. Number and type of idle reduction solutions deployed;
3. Number of programs that have included a clean transportation curriculum, and the number of students who complete the program;
4. Number of electric passenger cars and light duty trucks deployed in relation of the sales requirements of Advanced Clean Cars II;
5. Number of consumers that engage with the Drive Electric Vermont programs;
6. Number of households, disaggregated by household income and location, that participate in the Energy Navigator program;
7. Number of thermal efficiency projects deployed, including specific data and details from efficiency utilities and weatherization program provider;
8. Number of acres of agricultural land enrolled in land-use and carbon sequestration program activities;
9. Number of acres of wetland area restored;
10. Number of forest carbon management projects deployed, and the impacted acreage, and the specific practices being deployed for each project;
11. Number of land acquisition projects completed, and associated acreage restored by the acquisition;
12. Number of institutions that implement food waste reduction strategies, and the number of tons of waste reduced as a result;
13. Number of appliances from which refrigerants are recovered, and the number of entities that deploy new systems using natural refrigerants;
14. Number of Electric Vehicle Supply Equipment ports installed;
15. Number of housing units that exceed the Renewable Energy Building Standard;
16. Number of mitigation projects at Solid Waste Management Entities and their respective emissions reduction impacts; and
17. Number of GHG mitigation projects, with more specific outputs measured, implemented in municipalities with a high energy burden.

Measures for prioritization in the CPRG Program

The Vermont Global Warming Solutions Act defines "mitigation" as the reduction of greenhouse gas emissions caused by humans, as well as the preservation and enhancement of natural systems to sequester and store carbon, in order to stabilize and reduce greenhouse gas emissions in the atmosphere. The measures included in this PCAP, when implemented, will be a significant step forward in Vermont's efforts to reduce greenhouse gas emissions, and will write the next chapter in the ongoing story of climate solutions in Vermont.

The proposed measures have been organized by the sector in which the emissions occur.

Transportation

Greenhouse gas emissions from the transportation sector have consistently been higher than any other sector. Only during the COVID pandemic did emissions from this sector fall short to the Buildings (RCI) Sector. The state has implemented law and policy aimed at requiring manufacturers to deliver for sale cleaner vehicles to the market, and the legislature has authorized and funded programs to incentivize the purchase and use of these vehicles in Vermont, as well as expand and accelerate other transportation solutions the reduce reliance on the single occupancy vehicle. The success of these policies and programs in driving innovation in the automobile industry to produce cleaner technologies, coupled with the recent development of more robust state vehicle purchase incentives and investments in electric vehicle charging stations has yielded a slow but steady increase in electric vehicles in the Vermont fleet. As of January 2024, there were 12,574 plug-in hybrid or battery electric vehicles registered in Vermont. However, modeling shows that our current rate of EV adoption and number of EVs on the road is not nearly enough to achieve the reductions in this sector required by the GWSA. The medium- and heavy-duty vehicle sector is particularly lagging, as the suite of programs to support this class of vehicle adoption do not yet exist. The measures in this sector represent the next step in complementing the rules, programs, and policies that will accelerate EV adoption through a variety of approaches aimed at sparking market innovation and transformation in vehicle manufacturing, coordinating emission reductions and investments at the regional level, designing more robust vehicle purchase incentives that mitigate the high up-front costs of electric vehicles, creating more transportation options and helping ensure these choices are accessible to all Vermonters, no matter their income or business model.

Acceleration of electric vehicle adoption is a cost-effective, and necessary approach to achieving emission reductions. These measures also recognize the importance of reducing Vehicle Miles Traveled (VMT). VMT reduction in a largely rural state presents a significant challenge. However, through programs and policies that facilitate settlement of Vermonters in areas that allow for less dependence on the personal vehicle, and make vehicle alternatives an easier choice, our approach to transportation sector emission reductions can expand beyond electrification.

Heating and Cooling

Many of Vermont's residential and commercial building spaces are poorly insulated and heated using carbon intense fossil fuels. Given the duration and intensity of Vermont's cold-weather seasons, it is not surprising then that this sector has traditionally been the second highest emitter of greenhouse gases in Vermont. Most homes were built before 1975, with a significant portion older than 1939. Measures

aimed at reducing emissions in this sector are two-fold: improving thermal efficiency of Vermont's buildings through weatherization and related activities and switching heating sources to lower carbon alternatives. These measures need to be closely coordinated to achieve maximum efficiency and to overcome the equity and cost challenges associated with the necessary approaches. This work also incorporates an opportunity to keep more energy dollars in-state by replacing fossil fuel use with electricity for heating needs while also employing an increased workforce of weatherization and home heating technicians. Progress made, however, must align with policies and programs that prioritize those who struggle with the costs associated with housing and energy use.

Agriculture

Gross emissions from the agricultural sector in Vermont account for approximately 16% of greenhouse gas emissions in the state, making up our third largest emitting sector, however many of the pathways to reduce agricultural emissions in Vermont's Initial CAP have not advanced to implementation. Many Vermont farmers have already elevated climate change mitigation as a goal in managing their agricultural enterprises. Emissions from agriculture are technically a non-energy source of emissions, however reduction measures are discussed separately from the non-energy emissions sector for the purposes of this PCAP. Measures in this sector include improving management practices, such as no-till or cover cropping, to prevent emissions of carbon currently stored in soils into the atmosphere, while also increasing the sequestration of carbon from the atmosphere through land use and management decisions on farms. Maintaining and improving soil health as a climate change mitigation strategy also has numerous co-benefits, such as resilience to extreme weather events and improved water quality. In fact, there is an opportunity to leverage existing water quality programming and funding to implement emission-reducing management tools, making pathways in this sector uniquely cost-effective.

Industry and Waste Management

Measures related to non-energy emissions address work needed to reduce greenhouse gas emissions from industrial processes and management of solid waste and wastewater. This sector represents around 8% of total emissions statewide, but many of the greenhouse gases emitted are gases other than CO_2 that have high GWP but are short-lived in the atmosphere. Because of the short atmospheric lifetimes of these gases, prioritizing further emission reductions from this sector is important for near term impacts. Emissions reductions already made from the solid waste sector will further benefit from the continued implementation of Vermont's Universal Recycling Law, however measures in this plan will facilitate waste reduction and management in a way that will significantly further the progress Vermont has made. Measures related to the treatment of wastewater and the use of high GWP refrigerants are also ripe for emission reductions in this sector.

Electricity

Greenhouse gas emissions from the electricity sector in Vermont have been variable over time, but have been declining in recent years due to the adoption and implementation of the Renewable Energy Standard (RES) and utility commitments. As a result, contributions of greenhouse gas emissions from the electricity sector are currently low. However, because pathways used to reduce emissions from other sectors will rely significantly on electrification, it is important that the low emissions levels in this sector be maintained and improved upon, even as the overall electricity load increases. This must be done

while also keeping Vermont's electric supply reliable and affordable. Increased reliance on electricity to meet transportation and building heating needs also means ensuring resilient and adapted electric infrastructure, by upgrading distribution and transmission infrastructure, increasing load management and coordination capabilities, upgrading homes and businesses to enable the transition to electric technologies, and making distributed energy resource programs and services widely and equitably available to all Vermonters. Given the small contributions to emissions from this sector, and the significant investments that are being made to facilitate transmission and electric infrastructure upgrades via other federal funding sources, ANR has declined to focus measures in this PCAP directly on the electricity sector.

There is no single measure or strategy that will ensure the necessary transitions required to drastically reduce our emissions. Action must be taken on multiple fronts to reach the required emission reductions in the GWSA. Most importantly, the policies and programs outlined in each of the measures included in this PCAP represent a coordinated and continuing approach to mitigating greenhouse gas emissions, emphasizing approaches that are equitable and seek to ensure accessibility for all Vermonters.

The measures in this section have been identified as "priority measures" for the purposes of pursuing funding through CPRG implementation grants. This list is not exhaustive of Vermont's priorities. Instead, the selected priority measures included in this PCAP meet the following criteria:

- **The measure is ready to be implemented.** The design work for the policy, program, or project is complete enough that a full scope of work and budget can be included in a CPRG implementation grant application.
- **The measure can be completed in the near term.** All funds will be expended, and the project completed, within the five-year performance period for the CPRG implementation grants.
- **The measure advances the following state priorities**:
    - Measurable impact to climate mitigation
    - Cost-effective emission reduction
    - Broad and varied co-benefits to Vermonters
    - Technical feasibility
    - Consistency with the Guiding Principles for a Just Transition (see "Low Income and Disadvantaged Community" Section)

This section discusses the following information for each measure:

1) Measure Summary and Approach
   a) Description of the measure
   b) Demonstration of the Funding Need
   c) Transformative Impact
2) Impact of GHG Reductions
   a) Magnitude of GHG reductions from 2025 – 2030
   b) Magnitude of GHG reductions from 2025 – 2050
3) Environmental Benefits – Outputs, Outcomes, and Administration
   a) Expected Outputs and Outcomes
   b) Authorities and Implementation
4) LIDACs

a) Community benefits
b) Community Engagement

Other sections of this PCAP describe information that is generally applicable to each sector and measure:

- Metrics for measuring and tracking progress (See "Measuring and Tracking Progress", p.21)
- Authority to implement (See "Authority to Implement Priority Measures", p. 86)
- Workforce needs (See "Climate Workforce Planning in Vermont", p.88)

Vermont's Priority Measures Summary

Table 4 below describes generally the priority measures, organized by sector, the GHG reductions estimated, the implementing agency or agencies. Note that the geographic scope of all the measures listed in this PCAP is **state-wide**.

Table 4: Priority Measure Summary

Priority Measure	**Cumulative GHG emission reductions (MT CO_2e)**		**Implementing Agency or Agencies**
	2025–2030	**2025–2050**	
Transportation Measures			
1. Medium- and Heavy-Duty fleet EV point of sale purchase and EVSE incentive, including infrastructure, technical assistance, and training	21,324	130,600	ANR and VTrans
2. Idle-reduction technology deployments for all vehicle weight classes	10,457	62,741	ANR
3. Clean Transportation educational programming	10,920	55,802	ANR
4. Passenger Electric Vehicles Incentives – Point-of-sale Purchase Incentive, Replace your Ride, Mileage Smart, E-Bike, and electrical panel upgrades	87,636	448,580	VTrans
5. Charge Vermont – Vermont's Electric Vehicle Supply Equipment Grant Program	4,018	24,109	ACCD
Buildings and Thermal Sector (RCI) Measures			
6. Centralized thermal efficiency clearinghouse and energy coaching program, mini-grants to Community-action agencies to bridge gaps in funding needs for Low Income Households	22,087	148,300	PSD
7. Low to Moderate Income thermal efficiency program expansion	440,000	1,720,000	PSD

Natural and Working Lands Measures			
8. Enhanced carbon sequestration and emissions reduction on farms	579,497	3,890,908	AAFM
9. Enhanced Carbon Sequestration through Wetland Restoration and Acquisition	1,681	10,085	ANR
10. Enhanced Carbon Sequestration through Land Acquisition	26,766	158,491	ANR
11. Enhanced Forest Sequestration	4,719	28,314	ANR
Non-Energy Measures			
12. Institutional Waste Reduction, Recycling, and Composting Initiative	1,032	7,914	ANR
13. Expanded High GWP refrigerant mitigation program	4,373	17,820	ANR
Multi-Sector Measures			
14. Mitigation activities at Wastewater Treatment Facilities and Solid Waste Management Entities in Vermont	288	1251	ANR
15. Climate focused housing	2,356	14,139	ACCD
16. Expansion of the Municipal Energy Resilience Program and the Municipal Technical Assistance Program	6,429	38,579	ANR and BGS

Transportation Sector Measure Details

1. *Medium- and Heavy-duty Electric Vehicle Incentive Program*

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to accelerate the successful deployment of electric trucks in Vermont. This measure includes a comprehensive point-of-sale purchase incentive for electric medium- and heavy-duty (MHD) vehicles, a corresponding electric vehicle supply equipment (EVSE) purchase and installation incentive, and pre- and post-incentive technical and advisory support and training for fleets. The program will include the tools and financial assistance that vehicle and fleet owners need to transition to electric vehicle technology, including pre-application support and guidance on vehicle selection, outreach to electric utilities and other stakeholders, EVSE and infrastructure design, a point of sale rebate that will be scaled to support different vehicle weight class purchases and designed to be stacked with other federal funding sources to cover the full incremental cost of the vehicle, and post-deployment support and training related to vehicle operation and maintenance. Transit and School buses will not be

eligible for the purchase incentive, but may be eligible to participate in the technical advisory and training programs associated with the comprehensive program.

With the passage of the Advanced Clean Trucks, Low NOx Omnibus, and Phase 2 Greenhouse gas rules in Vermont, it is critical that the requirements related to supply of electric trucks be met with the demand that is needed to ensure lower emitting vehicles are deployed at pace with or beyond the regulatory requirements. ANR and other state agencies have learned from the implementation of the Vermont Passenger car electric vehicle purchase incentive program, as well as the grant programs administered through the Diesel Emissions Reduction Act and Volkswagen Settlement funding, that the most impactful incentive opportunities include a point-of-sale incentive and robust technical support and assistance to ensure a successful vehicle deployment. A comprehensive incentive and advisory program for electric trucks will be critical to ensuring the emissions reductions of greenhouse gases and criteria air pollutants from the transportation sector in Vermont.

ii. Demonstration of the Funding Need

The IRA contains several other tax benefit provisions and grant programs to support the deployment of electric trucks. These include the Commercial Clean Vehicle Tax Credit, the Alternative Fuel Vehicle Refueling Property Tax Credit, and the Clean Heavy Duty Vehicle Program. While the level of funding accessible through these programs is supportive of the transition to electric trucks, our data analysis shows that these amounts will not be sufficient to cover the incremental cost of the electric truck and fueling infrastructure as compared to a comparable gasoline or diesel vehicle. In order to meaningfully impact behavioral changes and decision-making in fleet vehicle purchasing, incentives must cover the full incremental cost of the vehicle purchase, along with robust technical support and training. The incentive program will be designed to cover the average additional incremental cost of the truck purchase, with the incentive amount varying across weight classes, the incremental cost of the fueling infrastructure required, and the technical support and training, pre-and post-vehicle deployment, to ensure successful operation of the vehicle and prevent stranded assets.

iii. Transformative impact

In implementing a comprehensive program that supports not only the purchase of the vehicle, but the planning, design, and deployment as well, this program will accelerate electric truck deployment to first demonstrate the feasibility and applicability of electric truck technology in Vermont and then normalize the use of electric truck technology as part of a fleet. While technology-forcing regulations are a key component of a comprehensive and transformational program, we also need complementary programs to increase consumer demand for vehicles.

B. Impact of GHG Reductions

The estimated emission reductions from this measure were quantified using outputs from MOVES and EMFAC modeling used in a Vermont specific study on impacts of heavy-duty vehicle emission rules, as well as emission factors and assumptions from EPA, the Annual Energy Outlook, and vehicle miles traveled data from various sources.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 21,324 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 130,600 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The primary output of this measure will be a program to support the purchase and successful deployment of electric trucks in Vermont. Table 5 below includes the expected outputs in terms of vehicles deployed across the weight classes, which corresponds to the expected emissions reductions described above.

Table 5: Expected outputs of the MHD Vehicle Incentive Program

Weight Class	2025	2026	2027	2028	2029
2b-3	21	22	24	26	27
4-5	6	6	7	8	8
6-7	13	13	14	15	16
8a-8b	6	7	7	7	7
Total vehicles deployed	46	48	52	56	58
Grand total	**260**				

The expected outcomes of this measure include:

- reduction in cumulative GHG emissions, as outlined above;
- reduction in CAP and HAP emissions and reduced exposure to hazardous air pollution or unhealthy ambient air quality in LIDACs by 2030. Reducing gasoline and diesel emissions in turn reduces: 1) volatile organic compounds (VOCs) and nitrogen oxides (NOx), which combine to form ground level ozone that triggers asthma attacks, damages lung tissue, and damages forests and crops, 2) fine particulate matter (PM), which causes respiratory and cardiovascular damage, and leads to haze that limits visibility, 3) sulfur dioxide (SO2), which aggravates lung disease and other breathing problems, and 4) toxic and carcinogenic compounds such as benzene, aldehydes and butadiene, carbon monoxide (CO), which interfere with the delivery of oxygen to the body's organs and tissues;
- lower energy demand and therefore lower commercial energy expenditures on diesel and gasoline fuel;
- increased staff capacity to implement GHG reduction measures;
- and the creation of high-quality jobs throughout Vermont to ensure the successful transition to electric vehicle technology.

ii. Authorities and Implementation

This measure will be implemented jointly by ANR and VTrans, as these two agencies currently deploy funds to incentivize electric vehicle technology across all weight classes. VTrans also partners with key stakeholders, including Drive Electric Vermont, which currently administers a program to provide technical assistance and coaching to commercial entities exploring vehicle electrification. This kind of partnership could be expanded to more broadly offer necessary pre- and post-deployment technical advice. Solicitation for an entity to administer the technical assistance component of the measure would be via a competitive procurement process.

The measure is authorized to be implemented by ANR pursuant to 10 V.S.A §554(15), and by VTrans pursuant to 19 V.S.A. §7(f)(2) and 5 V.S.A. §206(b).

D. LIDACs

i. Community benefits

Reducing emissions from trucks will result in air quality and public health improvements, especially in LIDACs. Expected benefits of truck electrification include:

- improved public health resulting from reductions in co-pollutants (ozone, PM2.5 and hazardous air pollutants) such as reductions in new asthma cases and reductions in hospital admissions and emergency department visits;
- decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources;
- reduced noise pollution;
- and increased access to transportation alternatives.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

Members of the public expressed an interest in better access to technical information, support, and charging infrastructure for all vehicle types, including trucks. While many members of the public expressed an interest in expanding public transit options and innovative programs, especially in rural parts of the state, we have not included this measure in the PCAP because funding for electric transit related projects already exists via the Low or No Emission Grant Program, the Clean School Bus Program, and the Congestion Mitigation and Air Quality Improvement Program. Even though funding is available from these sources, the technical advisory program developed in relation to and in support of this measure will be made available to all deployments of medium- and heavy-duty vehicles, including school and transit buses to the extent that support is not offered via other funding and programming.

The State's process for development of a Carbon Reduction Strategy, required under the Federal Highway Administration's Infrastructure Investment and Jobs Act Carbon Reduction Program, also included a public engagement and stakeholder process. As it relates to electrification of the Medium and Heavy-Duty fleet, comments from the Feight and Rail and Business stakeholder groups were most relevant. Overall, there is hesitation from these stakeholders in moving forward too quickly with any regulatory approaches to electrification. This was particularly noted by those representing the Freight industry for larger trucks. Some entities representing Businesses stakeholder group are more proactive and open to the potential transitioning of fleets. However, the overall sentiment was that at this early stage in the alternatives fueling transition, incentives to aid in the upfront cost of purchases was much preferred and deemed a more efficient pathway to any consideration of a regulatory or mandated approach.

2. Idle Reduction Incentive Program

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to reduce emissions from vehicles by reducing the amount of time they are idling. This is especially important for freight trucks and police vehicles that must run their engines while parked in order to operate auxiliary equipment, such as refrigeration or computer systems. This measure will be available to all vehicle weight classes, including light-duty fleets, and will provide an emissions reduction opportunity for trucks that have a long remaining useful life and currently must use an engine to power their auxiliary equipment.

An incentive program will support either the purchase and installation of software designed to reduce vehicle idling, or the purchase and installation of power systems that are not fossil fueled so that auxiliary equipment can be run without idling. These technology solutions can be on-board the subject vehicle, or they could be fixed equipment where a vehicle is dwelling for a period of time (such as rest stops for freight trucks). The Department of Energy's (DOE) IdleBox Toolkit as well as EPA's SmartWay Technology Program will be used to identify the appropriate and recommended idle reduction technology to meet the needs of the subject vehicle while maximizing emission reductions. Incentive levels will vary based on the application of the technology and the vehicle weight class.

This measure will meet the goals of the CPRG program by achieving emission reductions within a category of vehicles or fleets that are some of the last to transition to electric technology given their long remaining useful life and/or potential infeasibility of electric technology to meet the vehicle's the intensive auxiliary power needs. These reductions will be likely to achieve reduction of CAPs and HAPs and are likely to have community benefits given that idling often exacerbates local exposure to these pollutants. This measure presents an innovative solution to achieve reductions from fossil-fuel vehicles that may be slower to transition to electric technology, and therefore could be scaled up and evolve as technology and vehicle use changes.

ii. Demonstration of the Funding Need

The Diesel Emissions Reduction Act (DERA) Grant Program provides some financial support for verified idle reduction technologies such as auxiliary power units, fuel operated heaters, shore connection systems, transport refrigeration unit (TRU) electrified parking spaces, and truck stop electrification technologies. However, the eligibility for this program is restricted to a small subset of project types, and the cost share requirements have resulted in limited use of this funding opportunity in Vermont. Therefore, additional resources are necessary to realize this opportunity for emission reductions as applied to all vehicle weight classes, including light duty.

iii. Transformative impact

This measure has the potential to transform the impacts of idling activity, and therefore reduce GHG, CAP, and HAP emissions from all types of vehicles when they need a power source while not driving. It will also help to offer a bridge solution to reduce emissions on existing fossil fuel powered vehicles that are not prime candidates for electrification.

B. Impact of GHG Reductions

The emission reduction estimates for this measure were estimated using a data the U.S. Department of Energy (DOE) Vehicle Technologies Office, EPA, and the Vermont Clean Cities Coalition.

i. **Magnitude of GHG reductions from 2025 – 2030 -** 10,457 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 62,751 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The primary output of this measure will be a program to support the purchase and successful deployment of idle reduction technology and infrastructure in Vermont. Table 6 below includes the expected outputs in terms of idle reduction solutions deployed across the weight classes, which corresponds to the expected emissions reductions described above.

Table 6: Expected outputs of Idle Reduction Measure

Technology	Number of vehicles	Measure
Auxiliary Power Unit (APU)	20	Passenger Car (Ford Crown Vic)
APU	5	Medium Heavy Truck (class 6)
APU	5	Delivery Truck (class 5)
APU	5	Medium Heavy Truck (class 6-7)
APU	5	Combination Truck (class 7)
APU	5	Tractor-Semitrailer (class 8)
Auto engine start/stop	75	Passenger Car (Ford Crown Vic)
Auto engine start/stop	6	Medium Heavy Truck (class 6)
Auto engine start/stop	6	Delivery Truck (class 5)
Auto engine start/stop	6	Medium Heavy Truck (class 6-7)
Auto engine start/stop	6	Combination Truck (class 7)
Auto engine start/stop	6	Tractor-Semitrailer (class 8)
Truck stop electrification	6	Tractor-Semitrailer (class 8)

The expected outcomes of this measure include:

- reduction in cumulative GHG emissions, as outlined above;
- reduction in CAP and HAP emissions and reduced exposure to hazardous air pollution or unhealthy ambient air quality in LIDACs by 2030. Reducing gasoline and diesel emissions in turn reduces: 1) volatile organic compounds (VOCs) and nitrogen oxides (NOx), which combine to form ground level ozone that triggers asthma attacks, damages lung tissue, and damages forests and crops, 2) fine particulate matter (PM), which causes respiratory and cardiovascular damage, and leads to haze that limits visibility, 3) sulfur dioxide (SO2), which aggravates lung disease and other breathing problems, and 4) toxic and carcinogenic compounds such as benzene, aldehydes and butadiene, carbon monoxide (CO), which interfere with the delivery of oxygen to the body's organs and tissues;
- lower energy demand and therefore lower commercial energy expenditures on diesel and gasoline fuel;

- increased staff capacity to implement GHG reduction measures;
- and the creation of high-quality jobs throughout Vermont to ensure the successful transition to electric vehicle technology.

ii. Authorities and Implementation

This measure will be implemented by ANR, in partnership with entities like the Vermont Clean Cities Coalition (VCCC). VCCC provides critical support to fleets to reduce idling. VCCC uses the DOE's IdleBox Toolkit's print materials, templates, presentations, and informational factsheets to assist light- and medium-duty fleets with idle reduction projects. IdleBox tools can be used to educate and engage policymakers, fleet managers, drivers, and other decision makers about the benefits of reducing idling. ANR will design and implement the incentive program and will engage with partners like the VCCC to provide technical support and conduct fleet outreach to encourage use of idle reduction technologies via the program.

The measure is authorized to be implemented by ANR pursuant to 10 V.S.A §554(15).

D. LIDACs

i. Community benefits

i) Expected benefits to LIDAC from measure

Reducing idle emissions from vehicles will result in air quality and public health improvements, especially in LIDACs. Expected benefits of idle reduction include:

- improved public health resulting from reductions in co-pollutants (ozone, PM2.5 and hazardous air pollutants) such as reductions in new asthma cases and reductions in hospital admissions and emergency department visits;
- decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources; and
- reduced noise pollution.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs. Generally, ANR received comments favoring vehicle electrification across Vermont's transportation fleet, with idle reduction being a key component of the strategy to reduce transportation emissions.

3. Clean Transportation Outreach and Education

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to increase the deployment of electric vehicle (EV) technology and reduction of vehicle miles traveled (VMT) by incorporating relevant subject matter into science, technology, engineering, and mathematics (STEM) and driver education curricula. This measure would implement a

broader clean transportation education and outreach program intended to deliver presentations for high school-level STEM educators, students and/or driver's education students to assist drivers in making informed decisions regarding their options for transportation. To advance a key strategy of Vermont's Climate Action Plan to educate drivers on the benefits of electrification and other transportation options to reduce VMT, ANR's Department of Environmental Conservation has recently deployed a Clean Transportation Outreach and Education pilot program. This measure would be a significant expansion of the recent program.

While EV technology is still in the early adopter phase and strategies to reduce VMT are not yet mainstream, reaching first-time drivers is critical to broadening EV adoption and normalizing behavior that reduces VMT. Transitioning to electric vehicles also means changing how we fuel our vehicles and how we drive; encouraging these behavior changes early in a driver's life is critical to broadening public support for and engagement in electrification of transportation.

The pilot program included development of a comprehensive overview of clean transportation topics that could be incorporated into high school-level STEM and/or driver's education curricula, including, but not limited to, the following topic areas:

1) The environmental and public health impacts associated with emissions from conventional internal combustion engines, including:
    a. an overview of the types of pollutants emitted by mobile sources in the transportation sector and the impacts associated with each pollutant and
    b. a discussion of environmental justice and how transportation sector air pollution can disproportionately affect overburdened and underserved communities.
2) An overview of zero tailpipe emission vehicles, including:
    a. an overview of different low and zero emission vehicle options (battery electric, hybrids, fuel cell-powered, etc.), charging infrastructure, cost of ownership and maintenance, features, and benefits and
    b. a summary of Vermont's emissions reduction goals and how alternative fuel vehicles will help the state reach these goals.
3) A discussion around other means of transportation as an alternative to personal vehicle use (e.g., conventional bikes, eBikes, motor pool, public transit) and applicable state programs (e.g., Go! Vermont).
4) Coordination with and promotion of relevant statewide incentive programs (e.g., Incentive Program for New Plug-in Electric Vehicles, MileageSmart, Replace Your Ride, and the Electric Bike Incentive Program), utility incentives, and charging equipment/infrastructure incentive funding.

The pilot program also included an end-of-course evaluation component, allowing program participants (i.e., presentation audience members) to provide feedback and constructive criticism. The post-pilot program will use the curriculum developed in the pilot, and will expand the scope and scale of the use of the developed materials to be integrated into Vermont's driver's education curriculum state-wide.

Therefore, this measure meets the goals of the CPRG program by complementing and measurably improving the effectiveness of other transportation emission reduction measures aimed at reducing GHG, CAP, and HAP emissions. This program capitalizes on previous investments made in the pilot stage of the program to develop an impactful curriculum, however more funding is needed to expand the benefits of this program state-wide.

ii. Demonstration of the Funding Need

Funding for the pilot program was from miscellaneous air quality settlement payments to which the State of Vermont was a party. Those were one-time funds that have since been exhausted. No other funding source has been identified or authorized to broaden this program beyond the pilot stage. Therefore, CPRG funding is critical to advance this important work to improve uptake of emissions reduction programs state-wide.

iii. Transformative impact

Education and outreach related to EV technology and VMT reduction increases the uptake in EV adoption and behaviors that can lead to reduction in VMT. The implementation of this program state-wide, and as a routine component of drivers' education, would improve the awareness and effectiveness of transportation emissions reduction programs in Vermont.

B. Impact of GHG Reductions

The emissions reduction estimates for this measure were informed by various studies and research reports about financially incentivized behavior changes related to energy efficiency.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 10,919 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 55,802 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The output of this measure will be the implementation of a state-wide clean transportation educational curriculum. Specific outputs will be the number of driver's education curriculums including the program, and the number of students completing the training as part of the program.

The expected outcomes of this measure include:

- reduction in cumulative GHG emissions, as outlined above;
- reduction in CAP and HAP emissions and reduced exposure to hazardous air pollution or unhealthy ambient air quality in LIDACs by 2030. Reducing gasoline and diesel emissions in turn reduces: 1) volatile organic compounds (VOCs) and nitrogen oxides (NOx), which combine to form ground level ozone that triggers asthma attacks, damages lung tissue, and damages forests and crops, 2) fine particulate matter (PM), which causes respiratory and cardiovascular damage, and leads to haze that limits visibility, 3) sulfur dioxide (SO2), which aggravates lung disease and other breathing problems, and 4) toxic and carcinogenic compounds such as benzene, aldehydes and butadiene, carbon monoxide (CO), which interfere with the delivery of oxygen to the body's organs and tissues;
- lower energy demand and therefore lower commercial energy expenditures on diesel and gasoline fuel;
- increased staff capacity to implement GHG reduction measures;
- and the creation of high-quality jobs throughout Vermont to ensure the successful transition to electric vehicle technology.

ii. Authorities and Implementation

This measure will be implemented by ANR and its Department of Environmental Conservation, in partnership with an entity that will be selected via competitive procurement to implement the developed curriculum and work cooperatively and collaboratively with institutions and other programs to deploy the curriculum.

ANR has the authority to implement this program pursuant to 10 V.S.A §554(15).

D. LIDACs

i. Community benefits

Broadening the opportunity to educate drivers about electric vehicles and transportation alternatives will result in air quality and public health improvements, especially in LIDACs. Expected benefits of clean transportation education include:

- improved public health resulting from reductions in co-pollutants (ozone, PM2.5 and hazardous air pollutants) such as reductions in new asthma cases and reductions in hospital admissions and emergency department visits;
- decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources;
- reduced noise pollution;
- and increased access to transportation alternatives.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

Beyond engagement on the PCAP specifically, ANR solicited feedback from the public during its recent rulemaking process for the Advanced Clean Cars and Trucks rules, which were adopted by Vermont in 2022. Engagement on the rulemaking took place in six locations across Vermont, including virtually, and in LIDACs. During public engagement for the PCAP and during the rulemaking process, commenters expressed an interest in broader access to clean transportation technical resources related to vehicle electrification, but also better access to public transportation alternatives.

4. Passenger Electric Vehicle Incentive Programs Including Consumer Education and Outreach

A. Measure Summary and Approach

i. Description of the measure

Incentives to increase adoption of passenger electric vehicles are critical to meeting Vermont's GHG reduction requirements and for the transition to a fully electric transportation fleet. Climate smart transportation incentive programs help income-qualified Vermonters reduce their transportation-related emissions. VTrans works with partners including Drive Electric Vermont and Capstone Community

Action to offer programs that replace internal combustion vehicles with new or used efficient and electric vehicles, bicycles, or other clean transportation options.

The Vermont Legislature has authorized four statewide vehicle incentive programs for income-qualified Vermonters, including:

1. Plug-in Electric Vehicle (PEV) Incentive Program: for the purchase or lease of a new plug-in electric vehicle;
2. MileageSmart: for the purchase of a high fuel-efficiency used vehicle;
3. Replace Your Ride: retires 10+ year old internal combustion engine vehicles and provides funds for cleaner transportation alternatives;
4. Electric Bike (eBike) Incentive Program: for the purchase of a new electric bicycle.

The authorization for this funding is set to expire with the exhaustion of the currently allocated funding, leaving a significant gap in the support available to help Vermonters transition to electric vehicles. This measure will further refine and implement these important programs with the following design elements and priorities:

PEV Incentive Program: Incentives will be available for the purchase or lease of a new plug-in all-electric vehicle (AEV) on a first-come, first-served basis for low income-qualified individuals. Incentives will be limited to AEVs with a base MSRP of $50,000 or less and may be combined with additional incentives from electric utilities and federal tax credits. Eligible customers may receive the incentive directly from a participating car dealer in the form of a reduced purchase or lease price, or they may receive a direct cash reimbursement from the state's incentive administrator, which would be selected pursuant to the state's competitive procurement process.

MileageSmart: The program will provide financial assistance to income-eligible Vermonters (80% of State Median Income, based on household size) at the point-of-sale to purchase used plug-in hybrid electric vehicles (PHEVs) or AEVs. MileageSmart can contribute up to 25% of the vehicle purchase price, with a maximum of $5,000. It can be used in combination with the other incentive programs the state administers, as well as federal incentives.

Replace Your Ride: The Replace Your Ride program encourages owners of older internal combustion engine vehicles to switch to cleaner transportation options by offering an incentive of up to $5,000 to scrap the high polluting vehicle. Eligible applicants must either meet the lower-income thresholds of the PEV incentive program or meet the income criteria for the MileageSmart program (80% of State Median Income, based on household size).

The program would offer two options on how to use the incentive:

1. Participants may apply their voucher towards the purchase or lease of a new or used PEV;
2. Participants seeking a more flexible option may apply their voucher towards active or shared mobility options including a bicycle, electric bicycle, or fully electric motorcycle; and/or shared mobility services that reduce the need for vehicle ownership (such as public transit fares, carsharing or bike sharing). Participants who chose the latter option will receive a clean mobility

card, which is a pre-paid debit card that can be used at eligible businesses that help reduce or avoid vehicle miles traveled in single occupancy automobiles.

Incentives through this program may be combined with MileageSmart, PEV Incentive Program, and Electric Bike Incentive Program.

Electric Bike Incentive Program: The Vermont eBike Incentive Program has been a limited-time offering available to income-eligible Vermonters on a first-come, first-served basis. Funding for this incentive program ran out quickly because of its tremendous popularity.

The program would be restricted to serve only households with lower incomes and high transportation needs. Eligible eBikes must meet minimum safety standards and cannot exceed maximum price levels of a base MSRP of $4,000 for standard electric bikes and $5,000 for electric cargo bikes. eBike purchasers must first apply for and receive a pre-paid debit card that can be applied at the point-of-sale at participating bike shops. eBike incentives can be combined with offers from Vermont electric utilities to further reduce the cost of electric bikes.

Consumer support and technical assistance: Vermonters that are unfamiliar with EVs and the incentives available may access consumer information from the robust and intuitive support that is available through the Drive Electric Vermont (DEV) program. To ensure the continued success of these refocused programs, DEV will remain a critical component of this program suite that will be supported by this measure. DEV partners with stakeholders to address knowledge gaps and provide opportunities to experience EV technology. DEV also works with partners to identify communities presently underserved by charging infrastructure and electric vehicle adoption. Resources are currently being developed to cultivate community connections and increase awareness of EVs.

Residential and multi-unit dwelling electrical panel upgrades: This proposed measure includes financial support for EV owners who need to upgrade their residential electrical service to charge their EV at home. Vermont's largest electricity distribution utility estimates that about half of Vermont households require an upgrade to 200A service in order to support at-home EV charging. While current and future home weatherization and fuel switching incentive programs provide some support for panel upgrades, an EV purchase is not a qualifying event for those programs. With CPRG funding, this new measure would mean that purchasing an EV qualifies a homeowner to receive incentives for panel upgrades.

Refining and enhancing Vermont's PEV incentives can serve as an innovative example for other jurisdictions seeking a program design that increases uptake in EV technology and provides critical assistance to ensure that all Vermonters can participate in the transition to an electric fleet. This measure prioritizes LIDACs with higher incentive amounts for low-income households, plus the ability to stack funding sources. Because lower income households are more likely to purchase a used vehicle, these programs also incentivize the purchase of used EVs. The MileageSmart program is currently administered by Vermont's community action agencies, which offer primary support for Vermonters who are living in poverty in both rural and urban areas. A robust incentive program that increases EV adoption for all Vermonters also yields improvements to air quality and public health benefits along high traffic corridors, and lowers transportation costs related to vehicle fueling and maintenance. In addition to the financial support, the DEV program will continue to enhance the incentive programs by identifying communities that can benefit from additional engagement.

ii. Demonstration of the Funding Need

With the passage of the Advanced Clean Cars rules in Vermont, it is critical that the requirements related to supply of electric cars and trucks be met with the demand that is needed to ensure lower emitting vehicles are deployed at pace with or beyond the regulatory requirements. ANR and other state agencies have learned from the previous implementation of the Vermont PEV purchase incentive program that impactful, successful incentive programs must include a point-of-sale incentive and robust technical support and assistance. Comprehensive, enhanced incentive programs for passenger cars will continue to be critical to ensuring the emissions reductions of greenhouse gases and criteria air pollutants from the transportation sector in Vermont.

The IRA contains several other tax benefit provisions and grant programs to support the deployment of new and used electric passenger cars and light duty trucks. These include the New and Used Clean Vehicle Tax Credit and the Commercial Clean Vehicle Tax Credit. While the level of funding accessible through these programs is supportive of the transition to electric cars, our data analysis shows that these amounts will not be sufficient to cover the incremental cost of the electric car and fueling infrastructure when compared with gasoline-powered cars. Research and survey data show that in order to meaningfully impact consumer behavior changes when purchasing a vehicle, incentives must cover or exceed the full incremental cost of the vehicle purchase. This is especially true when considering the ability of lower-income Vermonters to participate in the transition to electric vehicles. Therefore, Vermont must continue to invest in a state incentive program that can be stacked with available federal funding to make the most impact in emission reductions, and to generate the demand needed to meet and exceed the supply of EVs that will be delivered to Vermont pursuant to the Advanced Clean Cars rules.

While Vermont plans to mitigate emissions in the transportation sector using Carbon Reduction Program (CRP) funding authorized under the IIJA, CRP funds are not eligible to be spent on vehicle incentive programs.

Ebike incentives are not otherwise available or authorized with existing federal funding, such as tax credits. Ebikes remain a solution to reducing emissions and vehicle miles traveled in Vermont, so further funding this incentive program is critical to increasing clean transportation alternatives. All of the other purchase incentive programs described above are currently supported by state funds appropriated in various authorities originally adopted in FY2023, and subsequently carried over to future fiscal years. Funding for the incentive programs is expected to be exhausted between now and the end of calendar year (CY) 2025, making the CPRG funds ripe for continuing and enhancing these programs. Similarly, the consumer education and technical support programming currently offered by Drive Electric Vermont will be exhausted mid-way through CY2025 and is not expected to be renewed. Therefore, this complimentary program would also be able to continue thanks to CPRG funding.

iii. Transformative impact

While technology-forcing regulations are a key component of a comprehensive and transformational program, we also need complementary programs to increase consumer demand for vehicles. Such complementary programs, like purchase incentives and consumer education and support, are critical to generating the demand necessary to accelerate EV deployment and thereby reduce GHG emissions.

B. Impact of GHG Reductions

The emission reductions for this measure were estimated using historical incentive data collected by VTrans and per gallon fuel emission factors from EPA.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 87,636 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 448,580 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The primary output of this measure will be a program to support the purchase and successful deployment of electric passenger cars and light trucks in Vermont. Table 7 below includes the expected outputs in terms of incentives deployed within each program, which corresponds to the expected emissions reductions described above.

Table 7: Expected outputs of passenger car incentive programs

	Number of Annual Incentives		
Program Year	2025	2026	2027
Incentives for New PEVs	800	1,000	1,250
MileageSmart	336	420	525
Replace Your Ride	180	240	300
eBike Incentive Program	1,000	1,000	1,000

The expected outcomes of this measure include reduction in cumulative GHG emissions, as outlined above, and:

- reduction in CAP and HAP emissions and reduced exposure to hazardous air pollution or unhealthy ambient air quality in LIDACs by 2030. Reducing gasoline and diesel emissions in turn reduces: 1) volatile organic compounds (VOCs) and nitrogen oxides (NOx), which combine to form ground level ozone that triggers asthma attacks, damages lung tissue, and damages forests and crops, 2) fine particulate matter (PM), which causes respiratory and cardiovascular damage, and leads to haze that limits visibility, 3) sulfur dioxide (SO2), which aggravates lung disease and other breathing problems, and 4) toxic and carcinogenic compounds such as benzene, aldehydes and butadiene, carbon monoxide (CO), which interfere with the delivery of oxygen to the body's organs and tissues;
- lower energy demand and therefore lower commercial energy expenditures on diesel and gasoline fuel;
- increased staff capacity to implement GHG reduction measures;
- and the creation of high-quality jobs throughout Vermont to ensure the successful transition to electric vehicle technology.

ii. Authorities and Implementation

This measure will be implemented by VTrans as an agency that currently deploys funds to incentivize electric vehicle technology. VTrans also partners with key stakeholders, including Drive Electric Vermont, which currently administers a program to provide educational assistance and outreach to increase awareness of and participation in the transition to EVs. This kind of partnership could be continued within the scope of this measure.

The measure is authorized to be implemented by VTrans pursuant to 19 V.S.A. §7(f)(2) and 5 V.S.A. §206(b).

D. LIDACs

i. Community benefits

Reducing emissions from passenger cars and light duty trucks will result in the outcome of air quality and public health improvements, especially in LIDACs. LIDACs will also be prioritized for EV purchase opportunities through increased incentive amounts for income-qualifying households. Expected benefits of vehicle electrification include:

- improved public health resulting from reductions in co-pollutants (ozone, PM2.5 and hazardous air pollutants) such as reductions in new asthma cases and reductions in hospital admissions and emergency department visits;
- decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources;
- reduced noise pollution;
- and increased access to transportation alternatives.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

Members of the public expressed an interest in continuing and expanding purchase incentive programs to be applicable to new and used EVs, which this measure would support by refocusing programs to prioritize equity and plug-in technologies. During the public engagement ANR conducted for the Advanced Clean Cars rulemaking, the public expressed interest in the total cost savings of EV ownership but highlighted the high up-front cost as a critical barrier to purchasing an EV. Therefore, point-of-sale incentive programs are critical to overcoming this barrier, both in the new and used EV markets.

5. Expansion and enhancement of the Charge Vermont Program

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to enhance and expand the State of Vermont's existing Charge Vermont program, which has invested significantly in Electric Vehicle Supply Equipment (EVSE). Since 2014, the State of Vermont has invested more than $3.5M in public EV charging stations, installing 41 fast charging

stations and 89 Level 2 charging stations across all 14 counties. Recent investments to bolster the EVSE network have positioned Vermont as #1 in the nation for the number of EV charging stations per capita, with 114 public charging stations per 100,000 people. Electric cars are spreading across the state and are now present in 92% of Vermont communities. This measure will enhance and expand the existing EVSE program to continue State investments in public charging stations as well as investments in home and workplace charging to ensure EV drivers have a reliable place to charge their vehicles.

This measure would support EV charging solutions that can meet the needs of multiunit properties, where many renters reside. These options have been slower to develop and tend to cost more than solutions available to owner-occupied housing with dedicated parking garages. Specifically, the incentives for multiunit property owners would help to overcome the cost and other barriers to installing EV charging in multiunit properties.

This measure would also support workplace charging, which is a particularly important solution for renters and residents of multiunit properties who don't have access to home charging. It provides another source of charging that may be more convenient and affordable than relying entirely on public charging, which tends to have high fees and reliability challenges, especially direct current fast charging (DCFC).

ii. Demonstration of the Funding Need

Vermont has a goal to have 126,000 EVs registered by 2030. According to EVI Pro Lite tool, supporting this level of EV adoption will require 3,857 shared private charging ports (989 multiunit Level 2 ports, and 534 multiunit Level 1 ports and 2,334 workplace ports).

VT has been making investments to build out the charging infrastructure needed to support the State's EV adoption goals, focusing on investments in shared private charging ports that provide more equitable access for Vermonters living in multiunit properties.

Roughly 33% of Vermont housing units are in multiunit buildings or properties. Residents of multiunit properties, particularly renters, face disproportionately high barriers to accessing convenient and affordable home charging for electric vehicles. This limits their ability to participate in the market transformation to electric vehicles, including making use of funding incentives for electric vehicles.

A successful pilot program in 2022 awarded $1M to affordable housing providers to install EV charging in 34 locations across the State, providing new home EV charging access to more than 6,000 residents of multiunit properties. The State increased funding for the pilot program, and in 2023 launched a re-branded $4.8M program for Level 1 and Level 2 EVSE that expanded eligibility to include market rate multiunit housing, workplace charging, and charging at community attractions.

In the first 6 months of the program, the demand for funds has exceeded the funding available by about $3.5M. There are currently $8.4M worth of projects in the program pipeline, representing over 1,000 ports in 330 locations across Vermont. This measure would help to meet this demand through a refined program that further targets the best public investments in EVSE to equitably meet the needs of Vermonters.

iii. Transformative impact

A safe, reliable, and efficient EVSE charging network is critical to advancing vehicle electrification in Vermont. It is by far the most important complementary policy to Vermont's existing regulatory and incentive programs targeting an increase in EVS, and eventually transitioning away from fossil fuel vehicle technology to the extent feasible. Investments in EVSE not only facilitate a safe, equitable, and reliable experience for existing EV drivers, but they also give prospective EV drivers peace of mind in making the decision to transition to electric technology. Vermont's complementary EVSE regulatory program, currently implemented by the Department of Weight and Measures in the Agency of Agriculture, Food, and Markets, will put consumer protection measures in place to ensure a uniform and fair EVSE experience for all drivers using public charging.

B. Impact of GHG Reductions

The emissions reductions for this measure have been estimated using the California Climate Investment Program's benefits quantification tools.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 4,018 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 24,108 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this program are the expansion of a direct incentive program for EVSE installations that would support 680 EVSE charging ports in Vermont.

The outcomes of this measure are:

- reduction in cumulative metric tons of GHG emissions as detailed above, as well as the associated CAP and HAP emissions from avoided combustion of fossil fuel in conventional vehicles;
- lower energy demand for EV drivers will yield significant cost-of-ownership reductions in fueling and maintenance costs;
- enhanced community access to EVSE especially in communities where most drivers reside in multi-unit dwellings or rely on workplace charging solutions to regularly fuel their vehicle;
- and increased capacity at the Department of Housing and Community Development to enhance and expand their current "Charge Vermont" program.

ii. Authorities and Implementation

The Department of Housing and Community Development (DHCD) will implement and administer this measure through the expanded and enhanced Charge Vermont program in consultation with the existing Interagency EVSE Working Group, which includes members from ANR, PSD, VTrans, BGS, and the Vermont Department of Health. DHCD has the authority to implement this measure pursuant to 3 V.S.A. §2453(3).

D. LIDACs

i. Community benefits

The benefits of the Charge Vermont program will specifically impact LIDACs where most individuals and families rent their home. Renters typically have increased challenges in charging their EV at their dwelling, which is the most cost effective and convenient way to charge an EV. This program would prioritize investments in EVSE at multiunit dwellings. Having access to an at-home charger will also save fuel costs because those who benefit from the program will not have to rely on more expensive public charging options.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in Section 10 of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

Feedback received during public engagement for the PCAP pointed specifically to the need to increase access to all types of EVSE, and especially those in multiunit dwellings where at-home charging can be a challenge and barrier to accessing the benefits of EV ownership.

Buildings and Thermal Sector (RCI) Measure Details

6. Energy Navigator Services

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to create five "energy navigator" jobs. These Navigators will work directly with low to moderate income families to provide direct support to change home energy systems to cleaner technologies. The Navigators will be technically trained to review the current home heating system and provide recommendations for energy efficient upgrades. The Navigator will work with the family to identify issues that may need to be addressed before the new heating system is installed (e.g. repairs on foundations, remediation, and funding to do so), identify and secure contractors, schedule work with contractors, and identify and help secure funding to pay for equipment and contract work. The Energy Navigation program will also help connect families to other "wrap-around" services that help meet other pressing needs (e.g. 3SquaresVT food security benefits).

The nature of whole-home thermal efficiency projects is complex; there are multiple sources of state, federal, and utility funding available and many options for cleaner energy appliances and weatherization. Vermonters with the highest energy burden are in need of one-on-one technical support and counseling to navigate this complex landscape of funding and home improvement. This measure will facilitate efficiency projects for the families who will most benefit from cleaner, lower-cost home heating and cooling. The measure will help achieve additional emissions reductions and a more equitable transition to clean technology.

This measure meets the goals of the CPRG program by: complementing and increasing funding available to complete thermal efficiency projects for low-income households; benefitting communities by lowering the energy burden and costs and improving indoor air quality for low-income households; and advancing an innovative program that can be applied to other climate mitigation incentive frameworks.

ii. Demonstration of the Funding Need

While there are many complementary sources of funding that directly achieve emissions reductions through home weatherization and fuel-switching, this measure fills an unmet need—the opportunity to expand home efficiency incentive programs to low-income households, and to increase successful deployment of clean technologies to the families that need it most. Incentive programs complimentary to this service will include all existing sources of state and federal funds to realize GHG emission reductions from buildings. A list of current programs available to Vermonters is available at the Database of State Incentives for Renewables and Efficiency (DSIRE).

A successful Energy Coaching program currently exists within Vermont's Green Savings Smart program. However, funds for this current program are likely to be exhausted by the end of CY2024, and additional funding is not being reauthorized by the Vermont legislature. This measure will expand the current program for which funding will end, capitalizing on its success by increasing the number of navigators available to assist eligible households.

iii. Transformative impact

This measure is likely to accelerate deployment and increase uptake in clean thermal efficiency technologies in households with the highest energy burden and therefore the highest need for this transformative work. While state and federal incentive programs are critical to ensuring Vermonters can equitably participate in the transition to lower emitting buildings, if an individual or family does not have the capacity to fully realize the benefits of these incentives, they will remain reluctant to participate. Research and survey data show that to meaningfully impact behavior changes and decision-making in home efficiency, incentives must not only cover the cost of the technology, but also provide the necessary technical assistance.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using historical and program data from a current energy "coaching" program implemented by Vermont Green Savings Smart, and from data provided by the Vermont Weatherization Assistance Programs.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 22,087 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 148,299 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be the creation of five state-wide energy navigators and one energy navigator program manager. Each navigator would be expected to work with 75 households per year, totaling 375 households per year that would receive assistance from an energy navigator to implement thermal efficiency and weatherization incentive programming.

The expected outcomes of this measure include:

- reduction in cumulative GHG emissions, as outlined above;
- reduction in CAP and HAP emissions by 2030 due to the reduction in heating fuel emissions in LIDACs;

- lower energy demand and therefore lower energy expenditures on heating fuels and home energy costs;
- reduced exposure to hazardous air pollution or unhealthy ambient air quality;
- increased staff capacity to implement GHG reduction measures;
- and the creation of high-quality energy navigator jobs in Vermont to ensure the successful transition to better building efficiency.

ii. Authorities and Implementation

This measure will be implemented by the Public Service Department, who will solicit an entity to administer the Energy Navigator program on behalf of the state via a competitive procurement process.

The measure is authorized and implemented by PSD pursuant to the agency's authority to accept federal funding.

D. LIDACs

i. Community benefits

Increasing energy-efficient housing lowers energy costs which benefits LIDAC communities, especially those who are energy burdened. Specifically, this measure supports low to moderate income households becoming more energy efficient and therefore more affordable to live in. More energy-efficient housing will also provide public health benefits to LIDAC communities by improving indoor and outdoor air quality.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for this PCAP, ANR received dozens of comments recognizing the need for additional funding and support to help low-income households transition to lower-cost, cleaner heating technologies and improved building envelopes. Many commenters also suggested that community action agencies are the best place to house Energy Navigators, because they are already helping low-income Vermonters and provide their services statewide. Commenters also suggested the thermal efficiency programs be designed to better alleviate the financial and technical barriers that exist for program participation.

7. Low- to Moderate-Income Thermal Efficiency Incentive Program Expansion

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to increase the amount of funding available for low- to moderate-income Vermonters to make thermal efficiency upgrades to single households and multi-family buildings in Vermont. These upgrades include weatherization activities, fuel switching, and the complementary and make-ready work required to facilitate these projects. Current modeling indicates that, even with the

recent influx of federal funding to support weatherization and thermal efficiency work of State Energy Offices, additional measures are required to meet Vermont's 2030 GHG reduction requirements in the Thermal Sector. Based on a recent study, an estimated 90,160 homes require weatherization and 263,000 heat pumps will need to be installed to meet the thermal sector contribution to the economy-wide 2030 GHG reduction requirements. Current funding levels will not meet the estimated need, therefore additional funding is needed for existing, effective programs to support Vermonters who have the highest energy burden. In addition to weatherization and electrification, further funding for critical complementary programs, such as electric panel service upgrades, is also needed. A robust suite of efficiency and weatherization programs are currently administered by Vermont's three energy efficiency utilities (Efficiency Vermont, the Burlington Electric Department, and Vermont Gas Systems) and the Weatherization Assistance Program.

This measure will meet the goals of the CPRG program by further achieving GHG emission reductions in the buildings and thermal sector by 2030 and beyond, providing substantial benefits to low- and moderate-income Vermonters with higher energy burdens in the form of cost-savings and reduced exposure to poor air quality (indoor and ambient), and complementing existing funding and programs by capitalizing on existing administrative structures and partnerships.

ii. Demonstration of the Funding Need

While funding from ARPA, IRA, and state-funded thermal efficiency programs is expected to total nearly $700,000,000 through 2030 via the Vermont Department of Public Service, recent analysis shows that additional funding is needed to assist Vermonters in making key upgrades that will achieve the emissions reduction requirements in the Buildings and Thermal Sector. To expand the existing programs mentioned above and meet the required reductions in the buildings and thermal sector, Vermont will need to invest an additional $213,120,000 in weatherization, fuel switching, and other decarbonization measures. Current available funding cannot support this need.

Recent analyses assume that low-income households receive incentives equal to 100% of the costs for the new technologies or for weatherization, and that moderate-income households receive incentives equal to 75% of costs. These incentives for low- to moderate-income households account for approximately 60% of all potential costs (residential, commercial, and industrial). However, based on decades of experience with efficiency programs in Vermont and other states, the analysis assumes that such high incentives are necessary to ensure low-and moderate-income households participate at levels at least proportional to their share of the population and realize at least a proportional share of total energy savings as they transition off fuel oil and propane. The savings when transitioning from natural gas are less favorable, so additional incentives and programmatic support may be necessary to successfully transition households away from gas. Therefore, additional funding will be needed to increase and accelerate implementation of thermal efficiency projects in Vermont.

iii. Transformative impact

Vermont is a rural state with older housing stock and associated high energy costs. As explained above, additional funding for existing thermal efficiency programs would accelerate implementation of these projects, especially for those with a high energy burden. Recent analysis of residential customer economics indicates most customers would see annual energy bill savings and even total energy cost savings (factoring in the cost of financing new equipment, net of program and tax incentives) if they

transition from fuel oil and/or propane to electric heat pumps for space and water heating. This measure will have a statewide impact.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using outputs from the Vermont Thermal Programs Study, which uses the Low Emissions Analysis Platform to estimate costs and reductions associated with thermal efficiency programs.

i. **Magnitude of GHG reductions from 2025 – 2030 -** 440,000 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 1,720,000 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of the additional funding for existing programs will be measured in the number of thermal efficiency projects completed, including weatherization, fuel switching (electrification), and associated upgrades and make-ready work. Table 8 below includes the expected outputs from implementation of this measure:

Table 8: Table of expected outputs by 2030

MEASURE	Number of HVAC and Insulation retrofits by 2030
Retrofits/Weatherization	263,000
Heat Pumps	90,160

The expected outcomes of this measure include:

- reduction in cumulative GHG emissions, as outlined above;
- reduction in CAP and HAP emissions by 2030 due to the reduction in propane, natural gas, and heating oil emissions in LIDACs;
- lower energy demand and therefore lower energy expenditures on heating fuel;
- reduced exposure to hazardous air pollution or unhealthy ambient air quality;
- increased staff capacity to implement GHG reduction measures within current programs;
- and the creation of high-quality jobs throughout Vermont to ensure the successful transition to more thermal efficient buildings.

ii. Authorities and Implementation

This measure will be implemented by the Department of Public Service, as this Department currently manages contracts with several entities for the deployment of thermal efficiency programs across Vermont.

The measure is authorized and implemented by PSD pursuant to the agency's authority to accept federal funding.

D. LIDACs

i. Community benefits

Funding more energy-efficient housing lowers energy costs which benefits LIDAC communities, especially those who are energy burdened. Specifically, this measure supports ensuring that low- to moderate-income households will be more energy efficient and therefore more affordable to live in. More energy-efficient housing will also provide public health benefits to LIDAC communities by improving indoor and outdoor air quality. Additionally, the current program design incentivizes thermal efficiency upgrades in LIDACs, which will help low-income individuals with high energy burdens access these benefits sooner.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for this PCAP, ANR received dozens of comments recognizing the need for and supporting additional funding to help low-income households transition to lower-cost, cleaner heating technologies and improved building envelopes.

8. Climate-focused Housing Development

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to incentivize housing developers to exceed Vermont's Renewable Building Energy Standard (RBES). Vermont has recently updated its RBES and it is one of the most aggressive energy codes in the country. When affordable housing developers use certain funding sources, they are required to work with Efficiency Vermont to exceed RBES by building to their High-Performance Building standard. Recently one of the state's largest affordable housing developers, in partnership with Champlain Housing Trust, won the U.S. Department of Energy's Building Envelope Campaign Novel 40 Award for the Laurentide Apartment building in Burlington. The award was in recognition of the building's aggregate improvement of 60% in building envelope performance. The air sealing results for Laurentide exceeded Passive House standards.

Incentivizing a highly energy efficient thermal shell and mechanical system reduces emissions compared to less efficient and lower-emitting housing projects. It is also an investment in low and sustainable cost of living for Vermont's affordable housing owners and renters, since we include the cost of heat, cooling, and hot water in tenants' rent. Many private developers choose to take advantage of the split incentive when it comes to energy: investing less in a building's envelope or systems impacts their renters' pockets, not their own, as they generally do not pay for residents' heating, cooling, and hot water.

This measure would increase the current scope and scale of the incentive for affordable housing developers to exceed the RBES by creating a more realistic per-unit incentive. In addition to a per-unit incentive, installations of Zero Energy Ready Homes (ZERH) in place of a U.S. Department of Housing and Urban Development (HUD)-certified single wide mobile home unit will also be incentivized. Further, this measure has a strong equity component. This incentive would only serve homeowners up to 120% Area median income (AMI), and renters up to 100% AMI. The vast majority of homes in the current affordable

housing portfolio serve Vermonters under 60% AMI, meaning that those most in need will receive the greatest benefit.

ii. Demonstration of the Funding Need

The current level of investment by affordable housing funders in energy efficiency efforts far outpaces private counterparts. However, the available energy incentives have been inadequate to date: less than $4,000/unit, and sometimes as little as $2,700/unit. Affordable housing partners in Vermont estimate that a more appropriate incentive level is $25,000 per unit, or $27,000 per ZERH, which demonstrates that the current incentive level is grossly insufficient. Under Vermont's current energy code, we are on a path to near net zero by 2030 for new construction. However, the 2024 code does not require electrification. By incentivizing developers to exceed the RBES and therefore choosing to build high performance buildings using cold climate heat pumps in lieu of oil or gas furnaces, we reduce the use of fossil fuels and reduce to cost of living for affordable housing renters.

iii. Transformative impact

Vermont is facing the twin crises of climate change and a severe housing shortage that has resulted in the second-highest rate of homelessness in the nation. Residential buildings account for one-fifth of Vermont's greenhouse gas emissions and reducing the carbon footprint of our residential buildings is a critical component of the state's Climate Action Plan. But with each newly constructed residential building, we make choices in the context of the climate crisis and the housing crisis to achieve equitable results. Affordable housing is at the intersection of the climate and housing crisis.

B. Impact of GHG Reductions

The emission reductions from this measure were estimated using historical data from the Vermont Energy Investment Corporation and the Vermont Housing and Conservation Board.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 2,356 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 14,138 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure include: 1) 200 affordable housing units that exceed the RBES in Vermont, and 2) added capacity for existing affordable housing programs to focus on construction that incentivizes climate change mitigation activities.

The expected outcomes of this measure include:

- the GHG emissions reduction detailed above, as compared to the same units built without over compliance with the RBES;
- lower energy demand and therefore lower energy expenditures for low-income households and renters in Vermont;
- reduced energy bills for LIDACs in Vermont;
- and better indoor air quality in the covered housing units.

ii. Authorities and Implementation

This measure will be implemented by the Department of Housing and Community Development (DHCD), in partnership with affordable housing partners in Vermont such as Vermont Housing and Conservation Board and the Vermont Housing Finance Agency. DHCD has the authority to implement this measure pursuant to 3 V.S.A. §2453(3).

D. LIDACs

i. Community benefits

This measure will have sustainable benefits to LIDACs by increasing the number of affordable housing units that have low energy costs, therefore reducing the energy burden of LIDACs across Vermont. Lower energy costs tied to GHG reductions from housing will also yield air quality benefits because of reduced fossil fuel consumption from buildings, as well as better indoor air quality within these units.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in Section 10 of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for the PCAP, ANR received multiple comments on the critical intersection of affordable housing, energy costs, and climate change. Commenters mainly stressed the need for new housing development to be as climate friendly as possible, citing the RBES as not stringent enough to require the most affordable, lowest emitting technologies.

Natural and Working Lands Measure Details

9. Enhanced Carbon Sequestration on Farms

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to expand existing State programs that support agricultural practices that sequester carbon. These programs are administered by the Vermont Agency of Agriculture, Food, and Markets (AAFM). Funded practices would include: 1) agroforestry and silvopasture practices that integrate woody vegetation into agricultural land, 2) grazing practices that increase vegetative cover and forage, 3) edge-of-field practices that increase herbaceous and woody vegetation, and 4) agronomic practices that reduce tillage and increase vegetative cover. The current programs, with details on how new practices would be supported by this measure, include:

Capital Equipment Assistance Program (CEAP): Provides financial assistance for new or used innovative equipment that lessens a farm's greenhouse gas emissions, while reducing costs to farmers when they apply manure to their fields. With additional funding, CEAP would add and prioritize climate mitigation criteria into projects to reduce emissions from agricultural equipment and its use.

Farm Agronomic Practices (FAP): Funds soil-based agronomic practices that improve soil quality, increase crop production, and reduce erosion and agricultural waste discharges. In this program, practices

achieving carbon sequestration would be prioritized and would include conversation of acres to rotational grazing practices, reduction in tillage, no tillage, cover crop, and crop to hay.

Pasture and Surface Water Fencing (PSWF) Program: Provides pasture management technical assistance and financial assistance to Vermont farmers to improve land use practices to sequester carbon. In this program, practices achieving carbon sequestration would include conversion of acres from crop to hay.

Grassed Waterway and Filter Strip (GWFS) Program: Provides technical and financial assistance to Vermont farmers for in-field agronomic best practices to achieve carbon sequestration, including conversion of acres to filter strip, and from crop to hay. All practices in this program achieve carbon sequestration.

Conservation Reserve Enhancement Program (CREP): Program designed to remove land from agricultural production and establish vegetative buffers along waterways, which protect water quality. In this program, practices achieving carbon sequestration would include conversion of acres to riparian buffer (streambanks and riverbanks that are vegetated or forested rather than farmed).

This measure will meet the goals of the CPRG program by achieving emission reductions through sequestration, positively impacting farmers in low-income communities by supporting work to improve their practices. CPRG funding would complement current state and federally funded programs administered by AAFM, enhancing the carbon benefits of existing programs. This measure will also increase capacity to allow AAFM to meet the increasing demand for these carbon-benefit programs in the agricultural sector, many of which are innovative ways to achieve land-use goals (such as protecting agricultural land from development) while sequestering carbon.

ii. Demonstration of the Funding Need

AAFM is currently implementing these programs with state funding, plus federal funding through ARPA. Additional funds will be available via the IRA through the Natural Resource Conservation Service. However, due to the increase in demand for climate-focused agricultural practice funding, and the lack of capacity within the State to administer funds for a carbon-focused outcome, additional funding is needed to yield significant carbon sequestration benefits.

iii. Transformative impact

Enhancement of the current suite of programs will catalyze the significant progress that must be made in the agricultural sector to reduce emissions. This is the third largest GHG-emitting sector in Vermont, with little to no mitigation progress made to date. This measure capitalizes on the existing framework of program implementation in state government, as well as the thoughtful and detailed work of the Vermont Climate Council's recommendations for action in the agricultural sector.

B. Impact of GHG Reductions

These reductions were estimated using data provided by the Vermont Agency of Agriculture, Food and Markets. The COMET-Planner tool (available from the USDA NRCS and Colorado State University) was used to model GHG reductions attributable to the annual acreage enrolled in each Agricultural Program Description that corresponded with a quantifiable NRCS Climate-Smart Agriculture and Forestry (CSAF) mitigation activity.

i. **Magnitude of GHG reductions from 2025 – 2030 -** 580,000 $MTCO_2e$
ii. **Magnitude of GHG reductions from 2025 – 2050 -** 3,890,000 $MTCO_2e$

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure are 1) acres converted, or 2) practices that sequester carbon. The project types and expected number of acres are included in Table 9, below.

Table 9: Outputs expected from Agricultural Sequestration Measure

Agricultural Program Description	**Estimated Outputs (Acres per Year)**
Implement agroforestry and silvopasture practices that integrate woody vegetation in agricultural production.	18
Implement grazing practices that increase vegetative cover and forage quality, e.g. rotational grazing. (FAP & PSWF)	1811
Implement edge-of-field practices that increase herbaceous and woody vegetation, e.g. riparian forest buffer. (CREP & GWFS)	22
Implement agronomic practices that reduce tillage and increase vegetative cover, e.g., no-till, cover crop; pay for performance programs. (FAP)	
Reduced tillage	228
No tillage	309
Cover crop	4559
Crop to Hay	87
Expand Capital Equipment Assistance Program (CEAP) program to extend beyond water quality and incorporate climate change criteria.	
Reduced tillage	470
No tillage	639
Cover crop	1566
Crop to hay	116
Implement agronomic practices that reduce tillage and increase vegetative cover, e.g., no-till, cover crop; pay for performance programs. (FAP)	
Reduced tillage	4483
No tillage	6537
Cover crop	9628
Crop to hay	11777
Nutrient management	28070
TOTAL ANNUAL ACRES	70320

In addition to the impact outcomes detailed above, the expected outcomes of this measure are:

- increased staff capacity to implement GHG reduction measures;
- enhanced levels of engagement with the agricultural community through outreach to farmers and the organizations that support them;

- improved water quality to achieve clean water goals and mitigate climate change related threats to water quality; and
- increased reliance to climate change impacts like drought and flooding impacting agricultural lands in Vermont.

ii. Authorities and Implementation

AAFM will implement this measure within the framework of their existing programs, but with additional staff capacity specifically to support the enhancements, as detailed above. AAFM has the authority to implement this measure pursuant to 6 V.S.A. § 1(a)(9).

D. LIDACs

i. Community benefits

Increasing sequestration of carbon on farms through the programs in this measure will increase resilience to climate change because this measure results in both GHG reduction benefits and climate adaptation benefits. This measure will also benefit communities by enhancing engagement and increasing public awareness of projects and results in the farming community. The measure supports a viable farm economy in Vermont, which provides local jobs and locally sourced food—some of which goes to 3SquaresVT recipients, food shelf patrons, and other food insecurity and hunger relief programs. Finally, this measure will create new open green space and protect or enhance existing open green space.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement on the PCAP, we received feedback that agricultural practices that sequester carbon should focus on productive riparian buffers and increased biodiversity, as well as appropriate technical and engineering support for farmers implementing these practices. Some commenters also asked for a focus on tree health, and using species in planting projects that are the most resilient. One commenter supported the idea of animal farmers switching from grain-based to grass- or grazing-based systems, and renovating pastures to enhance growth of carbon storing vegetation.

10. Wetland Restoration and Acquisition

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to expand a regional wetland restoration and acquisition program statewide. The Vermont Fish and Wildlife Department (VFWD) has a long, successful history of conserving, managing, and restoring wetland habitat in Vermont. In fact, the first state-owned Wildlife Management Area (WMA) established in the eastern United States was Sandbar WMA, established as a refuge for migratory waterfowl in Milton, Vermont in 1920. Nearly 100 years later, VFWD protects more than 30,000 acres of some of the largest, most significant wetland systems in Vermont and is the largest

owner of wetland habitat in the state. In 1986 VFWD established the Vermont Duck Stamp Program to enhance the Department's wetland conservation efforts. The Vermont Duck Stamp program has been responsible for some of our state's greatest wetland conservation success stories, raising $4.5 million for the conservation of nearly 12,000 acres spanning 100 unique conservation projects. Over the past 10 years VFWD, in conjunction with partners such as the federal Natural Resources Conservation Service (NRCS) and US Fish & Wildlife Service (USFWS), has restored more than 50 acres of wetlands on WMAs. In addition, hundreds of acres of wetlands restored through NRCS via the Wetland Reserve Program, with the critical support of USFWS and Partners in Fish and Wildlife, have been added to WMAs to ensure long-term, effective land stewardship. VFWD owns 103 WMAs constituting 145,000 acres of outstanding wildlife habitat; the majority of those areas have wetland habitat.

Since 2018 the VFWD has received funding from the US EPA, via the Lake Champlain Basin Program, for wetland acquisition and restoration in the Lake Champlain Basin. To date, VFWD has received $5.5M in funding and has acquired 1,585 acres. 1,200 of those acres acquired are restorable to wetlands. The funding for this restoration effort requires that 40% of the total acreage acquired be restorable to wetlands via a change in land use. The program is currently slated to have 70% of the acres acquired to date restorable to wetlands, far exceeding the requirements. Wetland restoration and restoration planning are underway, post-acquisition, on these properties with partner organizations and external contractors.

The VFWD is uniquely situated as an entity that has the capacity to plan and execute these projects and to be the ultimate landowner after acquisition and restoration. The effectiveness of the acquisition and restoration program and the unique role that VFWD plays in wetland conservation statewide make it a logical agency for additional grant funding to expand these efforts. To date, funding has been dedicated to the Lake Champlain Basin because of clean water co-benefits that support State goals to improve water quality in Lake Champlain. Nevertheless, wetland restoration opportunities exist statewide and represent a significant unmet opportunity. Due to VFWD's long-standing commitment to conserving, restoring, and stewarding wetland habitat throughout Vermont, robust systems, relationships, and administrative structures already exist to expand this work.

Projects will focus on state acquisition of marginal farmland in strategic areas where the farms are being retired or will implement wetland restoration in collaboration with our partners. VFWD staff currently complete between 7-10 land acquisition projects a year. By expanding funding, VFWD can complete an additional 3-5 projects annually. VFWD anticipates that a minimum of 40% of those projects' land area will include changes in land management practices (e.g. corn production to floodplain forest) to support additional sequestration and storage.

This measure will meet the goals of the CPRG program by 1) supporting farmers who are a disadvantaged community in Vermont 2) achieving community benefits by supporting climate resilience through improving flood storage, and 3) increasing carbon sequestration and storage while supporting landscape-scale conservation.

ii. Demonstration of the Funding Need

While this work is currently funded by the US Environmental Protection Agency through the Lake Champlain Basin Program, the funding may only be applied to projects in the Lake Champlain watershed. Projects in the Connecticut River and Hudson River watersheds are not eligible for this funding. There is

no funding for this work statewide despite many opportunities to engage in wetland conservation and restoration projects outside of the Lake Champlain Basin.

iii. Transformative impact

This measure will increase wetland restoration and conservation in Vermont while also supporting farmers to transition marginal farmland to natural land, which in return will make their remaining land more economically productive and viable. The transition from marginal agriculture to wetlands will provide additional carbon sinks. Wetlands offer ecosystem services (e.g. water filtration, storm and floodwater attenuation, biodiversity) that help both human and natural communities in the face of a changing climate. Wetlands provide endless opportunities for popular recreational activities, such as hiking, boating, hunting, fishing, trapping, nature study, birdwatching, enhanced habitat connectivity, and scientific study.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using the COMET Planner tool with data and assumptions provided by the Vermont Fish and Wildlife Department.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 1,680 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 10,085 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be 4-6 conservation projects with a minimum of 40% of the acreage acquired restored to wetlands. The measure will be supported by a new limited-service position in the VFWD that will develop projects and oversee the wetland restoration planning to completion. The expected outcomes of this measure include increased sequestration, as outlined above, increased staff capacity to implement GHG reduction measures, and the creation of a state position to further develop and deploy wetland acquisition and restoration projects statewide.

ii. Authorities and Implementation

This measure will be implemented by the VFWD. The measure is authorized and implemented by VFWD pursuant to 10 V.S.A. §§4047-4050.

D. LIDACs

i. Community benefits

Facilitating wetland restoration and acquisition on marginal farmland benefits LIDAC communities by improving access to services and amenities, creating new green space and enhanced community beautification, and increasing resilience to climate change by making land use changes that increase resilience to flooding, species loss, and habitat loss.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond

implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for this PCAP, ANR received comments recognizing the need for additional funding and support be directed at disadvantaged communities with an emphasis on farmers, understanding that farmers have both a roll to play in cutting climate pollution but also support climate resilience.

11. Forest Management to Enhance Sequestration

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to expand staff capacity at Vermont Fish and Wildlife Department (VFWD) and Vermont Department of Forests, Parks and Recreation (VFPR) to ensure the deployment of increased funding made through the Inflation Reduction Act (IRA) to the Natural Resources Conservation Service (NRCS) to support climate practices on private land. The IRA provides an additional $19.5 billion over five years to support NRCS's conservation programs that yield climate change mitigation benefits. Implementation began in 2023. These investments mean that more producers will have access to conservation assistance and include:

- $8.45 billion for the Environmental Quality Incentives Program
- $4.95 billion for the Regional Conservation Partnership Program
- $3.25 billion for the Conservation Stewardship Program
- $1.4 billion for the Agricultural Conservation Easement Program
- $1 billion for Conservation Technical Assistance
- $300 million to measure, evaluate, quantify carbon sequestration and greenhouse gas emission reductions from conservation investments (see fact sheet)

For fiscal year 2024, which began Oct. 1, 2023, the Inflation Reduction Act provides:

- $1.65 billion for the Environmental Quality Incentives Program
- $754 million for the Regional Conservation Partnership Program
- $472 million for the Conservation Stewardship Program
- $189 million for the Agricultural Conservation Easement Program

These additional funds will help farmers and forestland owners implement expanded conservation practices that reduce greenhouse gas emissions and increase storage of carbon in their soil and trees. The conservation funding is in addition to otherwise available program funds, and participation is voluntary, incentive-based and targeted to support climate-smart mitigation activities and other conservation activities that facilitate them.

NRCS is increasing Climate-Smart Agricultural and Forestry Mitigation Activities eligible for Inflation Reduction Act funding for fiscal year 2024 through EQIP and CSP. These in-demand activities are

expected to deliver reductions in greenhouse gas emissions or increases in carbon sequestration as well as significant other benefits to natural resources like soil health, water quality, pollinator and wildlife habitat and air quality. In response to feedback received from conservation partners, producers and NRCS staff across the country, NRCS considered and evaluated activities based on scientific literature demonstrating expected climate change mitigation benefits. When applied through this framework, these activities are expected to deliver reductions in greenhouse gas emissions or increases in carbon sequestration. NRCS will continue to evaluate additional practices as science progresses and will evaluate and identify quantification methodologies during the fiscal year. Find the FY24 list of Climate-Smart Agricultural and Forestry Mitigation Activities here.

Even prior to this substantial increase in funding, Vermont NRCS was limited by technical assistance providers to meet with landowners on the ground. As such, NRCS has partnered with VFWD to expand its capacity for nearly twenty years. During that time, NRCS also executed a MOU with VFPR to add capacity too but that is no longer in place. This measure will seek to add an additional staff capacity to both Departments to support developing projects on the ground and navigating the NRCS application process on behalf of the landowner. VFWD and VFPR are best suited to do this work because of their relationships with forestland owners and farmers, as well as expertise as biologists and foresters.

This measure will meet the goals of the CPRG program by supporting forestland owners and farmers who are both disadvantaged communities in Vermont, achieving community benefits by supporting climate resilience through improving flood storage, and increasing carbon sequestration and storage while supporting a working forest economy which keeps forests as forests. Vermont's forests are largely under private ownership. Working with private landowners strengthens Vermont's rural economy and is critical to protecting biodiversity. Vermont's forested landscape also plays a regional and arguably global role in meeting net-zero targets, with the state roughly 74% forested. While Vermont remains one of the most forested states in the country, the loss of forested habitat is of concern; Vermont saw a loss of 3.27 kha of natural forest in 2022, equivalent to 1.35 MT of CO_2 emissions sequestered.

ii. Demonstration of the Funding Need

NRCS has continued to receive as increase in funding to implement projects, but without an increase in technical assistance funding to support the deployment of a significant increase in projects. These funds will complement project funding by providing the necessary capacity for technical assistance to develop projects.

iii. Transformative impact

This measure supports the necessary economic drivers to support private landowners to maintain and enhance their forestland to sequester carbon. Vermont's forests are being converted and fragmented by rural sprawl. According to the Forest Service, 14,207 acres of forest land are converted to non-forest every year. This means there is an average net loss of approximately 11,000 acres of forests a year, since roughly 3,000 acres of non-forest revert back to forest on an annual basis. Reversing this trend requires programs that successfully work with private landowners. Finally, by ensuring Vermont is able to fully deploy NRCS funds, Vermont will be well-positioned to receive funds in the long-term.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using the COMET Planner tool with data provided by the Vermont Fish and Wildlife Department.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 4,620 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 27,720 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be the development of a significant increase in acres enrolled in projects on private lands that support climate-smart practices. The measure will be supported by three new limited-service positions in VFWD (one) and VFPR (two). These positions will develop projects and oversee the NRCS process to apply for funding. The expected outcomes of this measure include increased sequestration, as outlined above, and a decline in the loss of forest overall in Vermont.

ii. Authorities and Implementation

This measure will be implemented by the VFWD. The measure is authorized and implemented by VFWD pursuant to 10 V.S.A. §§4047-4050.

D. LIDACs

i. Community benefits

Facilitating better forest management for carbon benefits LIDAC communities by improving access to services and amenities, the creation of new green space and enhanced community beautification, and increased resilience to climate change by making land use changes that make Vermont's landscape more resilient to flooding and species and habitat loss.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for this PCAP, ANR received comments recognizing broad support for climate solutions that support natural and working lands. The public went further to speak to the need for additional funding and support be directed at disadvantaged communities with an emphasis on farmers, understanding that farmers have both a roll to play in cutting climate pollution but also support climate resilience.

12. Land Acquisition and Restoration

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to further advance land conservation goals in the state to support the state's "30 by 30 goal" and increase carbon sequestration through land conservation. Vermont's Act 59 of 2023 establishes state goals of conserving 30% of the land of Vermont by 2030, and 50% by 2050. It

requires the Vermont Housing and Conservation Board (VHCB), in consultation with the Secretary of ANR to develop an inventory of the existing conserved lands in Vermont and a plan on how to reach the goals. The act recognizes the critical state of biodiversity loss and the need for immediate action to combat climate change. The act emphasizes the importance of protecting natural habitats and biodiversity for future generations. These goals are aligned with global conservation efforts and build on past efforts, such as the Vermont Fish and Wildlife and Agency of Natural Resource's Vermont Conservation Design framework.

Conservation is defined as an area with permanent protection from conversion, and the act defines three categories of conservation:

1. **Ecological Reserve Area**: An area protected permanently from conversion, managed to maintain a natural state. This includes allowing natural ecological processes and disturbance events to proceed with minimal interference.

2. **Biodiversity Conservation Area**: An area with permanent protection from conversion for most of its part, managed primarily to sustain species or habitats. These areas may require active interventions for specific species needs or habitat maintenance/restoration.

3. **Natural Resource Management Area**: An area mostly protected from conversion but subject to long-term, sustainable land management practices.

There are two milestones in this work, both led by VHCB in consultation with ANR. The first is the Conservation Inventory Report and the second is the Conservation Plan. Both the conservation inventory and conservation plan will be developed in consultation with range of stakeholders, including private owners of forestlands and agricultural lands, land trusts, conservation organizations, environmental organizations, working lands enterprises, outdoor recreation groups and businesses, watershed groups, municipalities, regional planning commissions, conservation commissions, and relevant State and federal agencies. The plan will be updated biennially to track progress.

Preliminary work has shown that Vermont will need significant additional resources to increase the pace and scale of conservation to meet these goals. This measure will complement land acquisition funding at VHCB to emphasize projects that enhance sequestration and storage through a change in land management. Working with a statewide network of partners, VHCB funds the conservation of agricultural land, natural areas, forestland, recreational land, and the preservation and restoration of historic properties. These investments strengthen Vermont's rural economy, protect wildlife habitat, provide public access to forestland, trails and water, and restore our historic community buildings, creating jobs and bringing visitors to Vermont.

Through grant funding to conservation partners, VHCB will select competitive acquisition projects that include a restorative land management change on at least 40% of the parcel. The restoration area will be articulated in a permanent conservation easement to ensure the additionality in perpetuity on the parcel. Projects will largely occur on farm conservation projects being developed by the Vermont Land Trust but in unique circumstances, state and non-profit partners focused on upland conservation may be able direct funding to projects that restore upland natural communities on industrial forestland or retired pasture.

ii. Demonstration of the Funding Need

While land acquisition is funded through various sources in Vermont, including state funds, federal funds, and philanthropic giving, there is a significant gap in capacity to meet the 30X30 goal which requires us to more than double the pace of conservation between now and 2030. Meeting these goals will in turn increase Vermont's capacity to enhance carbon sequestration from land-use change. Preliminary results from the inventory the VHCB is developing show that Vermont is roughly 23-27% conserved under the definitions of Act 59. Not all those lands will necessarily end up counting as "supporting and enhancing biodiversity." Assuming total acres are 6.125 million or 30% of Vermont's land area, the target for 30X30 is between 180,000 to 350,000 of new land conserved. Land in Vermont costs $2-5,000/acre, therefore the conservation of 300,000 acres will require significant new resources in Vermont.

iii. Transformative impact

Land conservation investments enhance carbon sequestration, strengthen Vermont's rural economy, protect wildlife habitat, provide public access to forestland, trails and water, and restore our historic community buildings, creating jobs and bringing visitors to Vermont. Vermont's forested landscape plays a regional and arguably global role in meeting net-zero targets, with the state roughly 74% forested. While Vermont remains one of the most forested states in the country, Vermont lost 3.27 kha of natural forest in 2022, equivalent to 1.35 MT of CO_2 emissions.

A closer look reveals that our forests are being converted and fragmented by rural sprawl. According to the Forest Service, 14,207 acres of forest land are converted on average to non-forest every year. This means there is an average net loss of approximately 11,000 acres of forests a year since roughly 3,000 acres of non-forest revert back to forest on an annual basis. Land acquisition is a key strategy to reverse forest loss.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using the COMET Planner tool with data provided by the Vermont Fish and Wildlife Department, the Department of Forests, Parks, and Recreation, and the Vermont Housing and Conservation Board.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 26,766 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 158,491 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be the development of 14-16 projects with a minimum of 40% of the acreage acquired including a change in land management that has quantifiable sequestration benefits. The expected outcomes of this measure include increased sequestration, as outlined above.

ii. Authorities and Implementation

This measure will be implemented by the VHCB. The measure is authorized and implemented by VHCB pursuant to 10 V.S.A. §312.

D. LIDACs

i. Community benefits

Facilitating land acquisition for conservation benefits LIDAC communities by improving access to services and amenities, the creation of new green space and enhanced community beautification, and increased resilience to climate change by making land use changes that make Vermont's landscape more resilient to flooding and species and habitat loss.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for this PCAP, ANR received comments recognizing broad support for land conservation in state and natural and working land solutions. The public went further to speak to the need for additional funding and support be directed at disadvantaged communities with an emphasis on farmers, understanding that farmers have both a roll to play in cutting climate pollution but also support climate resilience.

Non-energy Emissions Measure Details

13. Food Waste Reduction in Institutions

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to reduce the amount of food wasted and improve food scrap diversion programs at schools, hospitals, nursing homes, other institutions, and businesses in Vermont. The EPA estimates that wasted food generates nearly 60% of methane emissions from landfills. Managing food scraps in other ways, such as animal feed, composting, or anaerobic digestion reduces overall emissions from wasted food. The biggest impacts on emission reductions, however, are from preventing wasted food in the first place because a large portion of food's environmental impacts take place during growing, processing, manufacturing, and transporting. While food waste can occur in many sectors, food service contributes 18% of greenhouse gas emissions associated with wasted food in the U.S., second to residential (64%) and above manufacturing (11%), retail (6%), and farms (1%). ANR has several past and ongoing initiatives aiming at decreasing residential food waste including media campaigns, including the www.scrapfoodwaste.org website, food waste reduction workshops, and an annual food waste reduction challenge. However, effective behavior change requires more intensive interactions than is typically feasible at the broad residential sector scale and quantifying the impacts of residential-sector food waste reduction projects is challenging. The food service sector, however, is a great opportunity for targeted waste reduction projects; individual food service providers generate more food waste than individual residents and relatively simple changes in food service, such as reducing plate size, training staff, and putting up buffet signs encouraging coming up for seconds (as opposed to overloading plates) can lead to significant reductions in food waste.

This measure would involve working with participating institutions to: 1) conduct a food waste audit to determine how much food is currently being diverted and trashed, 2) conduct an evaluation of the wasted food (using food waste monitoring technology) and food scrap diversion program to ask: What is being wasted? Why is it being wasted? How much is being wasted? What happens to food scraps?, 3) develop and implement strategies for wasting less food and improving food scrap diversion, and 4) conducting a post-project audit to quantify progress.

Resources to measure food waste and waste reduction include existing technical tools, such as Lean Path, Phood, and Winnow.

This measure will meet the goals of the CPRG program by realizing significant emissions reductions across the entire food system. The program will also help all types of institutions, including those that support underserved communities, reduce costs and streamline services to improve efficiency of operations. ANR also sees this as an opportunity to demonstrate innovative technologies so that other jurisdictions can implement similar programs in conjunction with other state programs and requirements related to waste reduction and composting.

ii. Demonstration of the Funding Need

This measure will require funding for a program administrator to oversee each project within a participating institution, the purchase of the food waste monitoring technology, and implementation of recommendations to reduce waste, such as smaller size reusable plates, a milk dispenser to replace milk cartons, signage, etc.

iii. Transformative Impact

ANR's Waste Management and Prevention Division has explored other sources of funding for this measure and has not identified any applicable state or federal funding source to support this work. This project, however, will be leveraged with the existing robust outreach and education programs that ANR administers to compliment Vermont's Universal Recycling Law, which was phased in from 2014 through 2020 to ban all food scraps from the trash.

EPA's 2021 Report on food waste and its link to GHG emissions and climate change finds that fruits, vegetables, dairy and eggs are the most frequently wasted foods. This results in a waste of resources, including agricultural land, water, pesticides, fertilizers, and energy that cause greenhouse gas emissions, consumptions of degradation of freshwater resources, loss of biodiversity and ecosystem services, and degradation of soil and air quality. Each year, in Vermont we estimate that approximately 80,500 tons of food waste is landfilled each year. If it were composted, it would reduce greenhouse gas emissions by around 44,00 MMTCO2e, which is equivalent to removing the emissions from more than 9,300 passenger vehicles. This measure aims to reduce the use of resources associated with food loss and waste, therefore resulting in significant emissions reductions. This measure also aims to put in place permanent changes at the participating institutions, therefore demonstrating the use of technologies and analytical tools to create positive, lasting change, and the infrastructure and resources needed to facilitate the creation of new systems.

B. Impact of GHG Reductions

i. Magnitude of GHG reductions from 2025 – 2030 – 1032 $MTCO_2e$
ii. Magnitude of GHG reductions from 2025 – 2050 – 7,914 $MTCO_2e$

GHG reductions were estimated using the WARM model and data and assumptions about the proposed food waste reduction project as provided by the Vermont DEC Waste Management and Prevention Division.

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Outputs and Outcomes of the measure

The primary output of this measure will be a program to facilitate the analysis and implementation of food waste reduction measures at institutions in Vermont. Related outputs will be the number of institutions that participate in the program, and the number of tons of food waste reduced as a result of participation in the program.

The expected outcome of this measure will be a reduction in greenhouse gas emissions caused by the decomposition of food waste in landfills and other waste management systems, as outlined above. Other outcomes include cost savings for institutions that implement food waste reduction strategies, and enhanced community engagement through the practices of waste reduction more broadly. Other environmental benefits associated with reduced use of resources related to the food system will also yield positive outcomes.

ii. Authorities and Implementation

ANR's Department of Environmental Conservation, Waste Management and Prevention Division (WMPD), will administer this program. WMPD has vast experience in implementing Vermont's Universal Recycling Law, which includes a food scrap ban, and has the existing knowledge and expertise to ensure this measure's expected outputs and outcomes are achieved. WMPD will solicit an entity to administer this program via a competitive procurement process. The measure is authorized to be implemented by ANR pursuant to 10 V.S.A §554(15).

D. LIDACs

i. Community benefits

Reducing food loss and waste can help close the gap between the food that is available today and the amount of food needed for population growth expected by 2050, and therefore can address hunger. Pursuing food waste and loss solutions at the institutional level, which can be easier to address than at the consumer level, will have positive aspects for institutions that serve the broader community, therefore creating efficiencies and reducing costs to better serve the communities where institutions are housed.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

Members of the public expressed support for programs that reduce food waste. Specifically, commenters were interested in more funding for education and accessibility to waste disposal and food waste reduction, and more support for institutions that was to participate in food waste reduction. The

students are motivated to participate in these activities, but adequate funding, staffing and resources are needed to meet the demand.

14. High-GWP Refrigerant Replacement and Recovery

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure addresses emission from high global warming potential refrigerant in two ways: increasing the rate of recovery of refrigerants from systems and appliances at the end of their life, and replacement of refrigeration equipment with technology that utilizes non "f-gas" or natural refrigerants.

The removal and decommissioning of equipment containing refrigerant(s) requires proper refrigerant recovery equipment, techniques, and infrastructure to ensure potent greenhouse gases are not leaked or unintentionally released into the atmosphere. The decommissioning of larger equipment (e.g. commercial refrigerant "rack" systems) is assumed to be properly managed due to the large quantity of refrigerant and the economics of recovery. However, due to the market gaps illustrated below, proper recovery practices when working with small to mid-sized equipment (such as ductless heat pumps and condensing units) can be overlooked or challenging, resulting in significant GHG emissions. An effort aimed at supporting refrigerant recovery from small to mid-sized equipment would not only reduce emissions by improving opportunities for proper disposal but could also further reduce emissions by increasing the potential for recycling refrigerants for use in other purposes, which reduces the need to manufacture new high-GWP refrigerants.

The current market gaps for refrigerant recovery in small to mid-sized HVAC/Refrigeration systems would be addressed in the following ways:

- Provide contractor training and education materials to address lack of contractor training and education;
- Continue to explore Extended Producer Responsibility to support end of life refrigerant recovery efforts;
- Support supply chain development and contractor training to address lack of contractor access to best-in-class tools for completing refrigerant recovery;
- Leverage partnerships, supply chain relationships, and potentially incentives to support the development of infrastructure in Vermont to address the lack of access to refrigerant recovery infrastructure (refrigerant containers, drop-off facilities, etc.); and
- Offer incentives to ameliorate the lack of economic motivation for proper refrigerant recovery from smaller equipment.

Of particular concern are the growing number of heat pumps containing 410A refrigerant (GWP 2022), with more than 10,000 of these units being installed each year in Vermont. As this equipment reaches end of life, access to proper decommissioning protocols, infrastructure, and equipment is going to become increasingly important to ensure such activities assist, and not hinder, the state's ability to achieve its greenhouse gas reduction requirements. This program would support and enhance recovery

of refrigerants in compliance with EPA requirements, such as Section 608 of the Clean Air Act, and the Responsible Appliance Disposal (RAD) program.

When refrigeration equipment that contains high GWP refrigerants requires replacement, there is a significant market decarbonization opportunity to replace the equipment with technology that utilizes non- "F Gas", or "natural" refrigerants, rather than replace the equipment with the market's current conventional HFC/HFO options. Non- "F Gas", or "natural" refrigerants have ultra-low GWP values and also do not contain PFAS chemicals when manufactured or dispersed into the atmosphere. The cost of Non- "F Gas", or "natural" refrigerant equipment has reduced in recent years, and the supply chain is ready for increased delivery of such systems in Vermont. Notwithstanding these cost reductions, these products have a cost premium compared to conventional high-GWP equipment. As such, with appropriate incentives this program can support replacement of high-GWP refrigeration equipment with ultra-low GWP systems, and significantly transform Vermont's refrigeration market by preventing emissions throughout the entirety of refrigeration equipment life.

A natural refrigerant incentive program for commercial refrigeration would include (but not limited to):

- CO_2 Ammonia Racks
- CO_2 Condensing Units
- Propane Self-Contained Equipment
- Propane Packaged Coolers for Walk-ins
- Natural Refrigerant Heat pumps

In addition to incentives, this program would also provide supply-side support to contractors through training and other support efforts to help contractors sell Non- "F Gas" or "natural" refrigerant systems. The program would also leverage Vermont Efficiency Utility's existing relationship network with Vermont's largest refrigerant users, mostly grocery stores, to boost customer awareness and uptake of incentives. This program would also work in coordination with the Refrigerant Recovery, described above, program to ensure the replaced high-GWP refrigerant receives proper refrigerant recovery.

This measure, and the two programs contemplated within, will achieve the goals of the CPRG program by achieving significant and cost-effective GHG emissions, potentially avoid the use of hazardous substances that can cause significant health impacts especially to disadvantaged communities, compliments existing EPA programs related to refrigerant recovery, and facilitates implementation of innovative policies that can be expanded in scope and scale, and set examples for other jurisdictions. Additionally, the recovery program would address the contradiction of heat pump technology serving as a climate mitigation solution while also containing a high GWP refrigerant that could be emitted at the end of the heat pump's useful life.

ii. Demonstration of the Funding Need

Funding for these types of measures is largely unavailable when you consider the current suite of climate-focused funding at the state and federal levels. Given the lack of other incentives or rebates available to encourage the behavior contemplated in these programs, a state-administered program to

provide robust financial incentive will be critical to realize the benefits described, and to avoid end-of-life emissions from closed systems.

iii. Transformative impact

This measure has the potential to give individuals and solid waste entities the tools they need to successfully capture refrigerants from appliances at the end of their life, which will substantially reduce emissions of high GWP refrigerants. The tools and infrastructure put in place by this program have the potential to have sustained impact in emissions reductions. Because the costs to establish and operate these recovery programs outweigh the financial benefit, the state must establish and ensure an effective mechanism to ensure avoided emissions. Additionally, this measure has the potential to have sustained impacts in avoiding the use of toxic f-gas refrigerants in appliances and systems, meeting multiple goals of mitigating climate change and toxic emissions that harm human health and the environment.

B. Impact of GHG Reductions

The emissions reductions for the measure were estimated using historical data and assumptions provided by the Vermont Energy Investment Corporation's current refrigerant management activities and programs.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 4,373 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 17,820 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be the creation of a program to support and facilitate effective recovery of refrigerants from appliances at the end of their useful life, and the incentivized opportunity for entities with large refrigeration systems to install new equipment that uses natural refrigerants. Outputs will also include the number of units that undergo successful refrigerant recovery, and the number of entities that replace systems with those that use natural refrigerants.

Outcomes will include the avoided emissions of GHGs, as outlined above, and the avoided use of systems that use refrigerants that contain high GWP refrigerants and toxic compounds that can harm human health and the environment. Additional outcomes include the creation of high-quality jobs associated with recovery of refrigerants, and increased staff capacity to implement GHG reduction measures.

ii. Authorities and Implementation

ANR's Climate Action Office will implement this measure and will solicit administration of the program from an entity via a competitive procurement process. ANR has authority to implement this measure pursuant to 10 V.S.A. §554(15).

D. LIDACs

i. Community benefits

Funding for the replacement component of this measure will be prioritized to be most impactful for local markets in LIDACs, and business serving low-access areas (a.k.a. food deserts). Projects that will increase

access to efficiency, low carbon refrigeration while increasing the resiliency of Vermont's cold chain will be prioritized.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement on the PCAP, ANR received a comment about the importance of prioritizing measures that use natural refrigerants as substitutes for high GWP refrigerants in new and existing equipment due to concerns over toxicity and climate impacts. Aside from this specific comment, we heard no further public comment for or against this measure. This measure was included during public outreach as part of ANR's suite of mitigation strategies.

Multi-Sector Mitigation Measure Details

15. Reduction of Emissions from Processes at Solid Waste Management Entities (SWMEs) and Wastewater Treatment Facilities (WWTFs) in Vermont

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to incentivize changes to the handling, processing and storage of waste at wastewater treatment facilities (WWTFs), solid waste management entities (SWMEs) and landfills in Vermont by making improvements to processes that yield GHG emission reductions. This measure includes the creation of a grant funding program that would be open to eligible WWTFs, SWMEs, and private waste-handling businesses in Vermont for the completion of the following types of projects that would have demonstrated emissions reduction benefits associated with WWTF and SWME operations and materials management:

- Reduce methane from landfills or wastewater treatment facilities,
- Reduce or divert waste including food and yard waste, recyclables, etc. through improved production practices, improved collection services, and increased reuse or recycling rates,
- Reduce GHG emissions associated with movement of sludge, plastics production, use, and waste management, such as durable service ware that reduces single-use plastics,
- Expand composting and bio-digestion infrastructure to reduce GHG emissions and increase beneficial use of organic waste, and
- Reduce construction and demolition waste through building reuse, deconstruction, and material diversion and reuse.

Some examples of projects that could be implemented include: the acquisition of a slow-speed, high torque shredder in order to significantly reduce the volumes, mass, and frequency of outbound loads of tires requiring transport from Vermont to Maine; the distribution of small residential cone solar digesters

to divert meat, fish, grease, and cooking oil waste from the landfill; replacement of recycling drop off facilities to be more energy efficient, allow for better access and safety, and better management of recycling to minimize processing; replacement of fossil fuel powered compost screeners with electric powered compost screeners; replacement of diesel backhoe or loaders used in transfer station with electric powered equipment to collect, move and process waste materials to reduce emissions and exposure to employees; and switching from sludge dewatering techniques to sludge drying and recycling to reduce emissions.

This measure meets the goals of the CPRG program by achieving emissions reductions at WWTFs and SWMEs through innovative and replicable process improvements. The projects carried out through this measure will also likely benefit local communities that are co-located with these types of facilities through improvements to local air quality, and access to safer and user-friendly facilities. These process improvements are also likely to complement other state and federal funding sources that are aimed at reducing emissions from mobile sources or buildings and may also be applied to SWMEs.

ii. Demonstration of the Funding Need

While some state and federal funding exists to assist entities like WWTFs and SWMEs to reduce emissions through replacement of on-road vehicles, make building retrofits to reduce or eliminate fossil fuel use, or install solar to offset use of electricity from the grid, there is limited to no funding sources available for unique process improvements that will reduce emissions related to overall facility and business operation.

iii. Transformative impact

This measure is likely to have significant impact to the way WWTFs and SWMEs process and manage solid waste, reducing emissions both from the use of energy in their processes, and diversion of waste from landfills. These changes will be sustainable, long-term transformations to operations that will allow emission reduction benefits to be carried through the lifetime of the facility and its key equipment and function.

B. Impact of GHG Reductions

The emissions reductions from this measure were estimated using various tools, such as the Deisel Emissions Qualifier, and data and assumptions provided by DEC's Waste Management and Prevention Division and SWMEs,

i. **Magnitude of GHG reductions from 2025 – 2030 –** 288 MT CO_2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 1251 MT CO_2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

i. Expected Outputs and Outcomes

The expected outputs of this measure will be the number of projects implemented to reduce emissions from processes and materials management at WWTFs and SWMEs. There may be specific outputs from each unique project, but they will be project specific and are not yet known. For example, an output of acquisition of a new shredder would be the reduction in the number of truck trips to a tire recycling facility.

The outcomes of this measure will the reduction of GHG emissions likely occur from implementation of the projects at WWTFs and SWMEs, as described above, and the associated reduction of criteria and hazardous air pollutants that may occur from reductions in emissions from energy usage at SWMEs. Further outcomes will be the benefits to the communities neighboring these facilities, which will likely be local air quality improvements, and better and more user-friendly access to facilities to encourage recycling and food waste diversion.

ii. Authorities and Implementation

ANR will implement this measure through a grant program administered by the Waste Management and Prevention Division within the Department of Environmental Conservation. Project proposals for grant funding will be solicited via a competitive bid process. ANR has the authority to implement this measure pursuant to 10 V.S.A. §554(15).

D. LIDACs

i. Community benefits

Community benefits to LIDACs are expected to include improved public health resulting from reductions in co-pollutants (ozone, PM2.5 and hazardous air pollutants) such as reductions in new asthma cases and reductions in hospital admissions and emergency department visits, decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources, improved conditions for employees of SWMEs by reducing exposure to harm diesel emissions, and better and safer access to materials management facilities.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for the PCAP, members of the public commented generally on the need to incentivize and encourage food waste reduction, both at the individual and at the facility level. Some commenters said that there is a need for better access to recycling and composting facilities, where systems within those facilities can be improved to make waste diversion activities safer and easier for members of the public.

16. Municipal Climate Mitigation Action Program

A. Measure Summary and Approach

i. Description of the measure

The goal of this measure is to support Vermont municipalities in advancing and implementing climate mitigation measures that meet their local goals and priorities related to climate change. Projects will be implemented as part of an expansion of the framework of at least two existing programs being administered by the State of Vermont. The first program is the Municipal Energy Resilience Program (MERP), which is administered by the Department of Buildings and General Services (BGS). Act 172 (2022) gave MERP $45 million to support dependable and sustainable connections to critical municipal

services for all Vermonters. Municipally owned buildings in cities, towns, incorporated villages, fire districts, and all other governmental incorporated units (except school districts) are eligible. MERP targets communities in need of energy resilience investments, often having excessive energy burden (the portion of income spent on heating, electricity, and transportation). MERP provides the following funding opportunities: Up to $4,000 Community Capacity Building Mini Grants; free building Energy Resilience Assessments; and up to $500,000 Implementation Grants for weatherization, thermal efficiency, and supplementing/replacing fossil fuel heating systems with more efficient renewable or electric versions. BGS has reported to ANR that they expect this program to be significantly oversubscribed, therefore leaving an opportunity for additional resources to further support projects that will reduce GHG emissions but won't be able to receive funding from the current program at its current level of funding. This measure would increase the resources available to BGS to implement the MERP program, and therefore increase the amount of GHG benefits that municipalities in Vermont can realize from participating in this program.

The second program is the Municipal Technical Assistance Program (MTAP), which is part of the State's ongoing efforts to make the most of state and federal funding and expand funding to communities who need additional assistance. The Agency of Administration in coordination with local Regional Planning Commissions is granting funds to municipalities throughout the state for Municipal Technical Assistance. These funds are intended to assist those communities with a high need for state and federal grants but lower capacity for accessing and applying for those sources. The Agency of Administration developed the Vermont Community Index (VCI) to evaluate the needs of communities across the state, with any municipalities showing greater need prioritized for funding. Towns meeting the criteria based on the VCI are pre-approved for participation in a list published by the Agency of Administration. If you do not see your community on the pre-approved list, please have a representative of your community complete the Municipal Assistance Request below for the Agency to collect and evaluate your assistance request.

In October of 2023 the Agency of Administration expanded Municipal Technical Assistance to municipalities above the 50th percentile in the VCI needs based index, and select communities in the 25-50th percentile range who were determined by the state to be significantly impacted by the flooding in July of 2023. This measure would utilize the existing structure and function of the MTAP program to connect ANR with municipalities and regional planning commissions to identify GHG mitigation project priorities of municipalities that otherwise remain unfunded because of a lack of state of federal funds. ANR would administer a grant program, in partnership with the Regional Planning Commissions, to provide these additional resources to facilitate municipalities in meeting their GHG reduction goals.

This measure will meet the goals of the CPRG program by using the framework of existing state programs to further achieve significant GHG mitigation activities where funding is not otherwise available. Because both of these programs prioritize support and participation for municipalities that have limited capacity to implement mitigation activities, and also have a high energy burden, this measure will have the most positive impacts for LIDACs within municipalities that are prioritized through the existing programs. The ability to achieve reductions effectively and efficiently is the most impactful feature of this measure, because it connects additional resources to existing programs that are currently operating to achieve goals identical to the CPRG program. Finally, this measure represents programs that can serve as models for other states that want to support municipal action in achieving statewide GHG reduction goals.

ii. Demonstration of the Funding Need

This measure includes the expansion of two programs for which participation from eligible municipalities is currently oversubscribed, representing a unique opportunity and need to achieve GHG emission reductions across local units of government in furtherance of the state's climate goals.

Funding that is currently supporting these programs is originally derived from State ARPA funds. However, as previously explained, these funds are insufficient to realize the full opportunity that exists within municipalities to mitigate GHG emissions.

MTAP, specifically, will support municipalities with a full assessment of the types of state and federal funding available that could complement, or support in part, mitigation activities. Those funding sources will be stacked when and if available with CPRG funding.

iii. Transformative impact

This measure will capitalize on the momentum created by these two existing programs to implement additional mitigation projects that will have a lasting impact on emissions reductions within Vermont. Even more critical, the focus on communities that have a higher energy burden and limited capacity will ensure that these mitigation activities can be accessed by all municipalities in Vermont, not just the ones that have robust staff capacity and resources.

B. Impact of GHG Reductions

The emissions reductions for this measure were estimated using municipal data provided by the Department of Buildings and General Services and outputs from LEAP modeling used for the Vermont Thermal Programs Study.

i. **Magnitude of GHG reductions from 2025 – 2030 –** 6,429 MT CO2e
ii. **Magnitude of GHG reductions from 2025 – 2050 –** 38,579 MT CO2e

C. Environmental Benefits – Outputs, Outcomes, and Administration

The expected outputs of this measure will be the number of municipalities that can implement GHG mitigation activities with the additional resources potentially available through the CPRG Program. Additional outputs will be project specific but will likely be related to specific mitigation activities tied to municipal infrastructure, like fuel-switching to electrification, weatherization, reduction in vehicle miles traveled, and vehicle electrification.

The outcomes of this measure will be primarily the GHG reductions expected, as outlined above, as well as reduction in CAP and HAPs associated with fuel switching and electrification activities. Additionally, a lower energy demand for municipalities will impact the tax burden for residents of municipalities, resulting in broad savings opportunities for communities. Municipal capacity is likely to increase due to expansion of the existing MTAP program, especially in communities that have a higher energy burden and limited capacity to access and implement funding from state and federal sources.

i. Authorities and Implementation

This measure will be implemented by BGS for the MERP program expansion, and by ANR in partnership with the Regional Planning Commissions for expansion of the MTAP program and other programs to

assist municipalities with high-impact mitigation projects. Authority to implement these programs currently exists in 29 V.S.A. § 152(a)(33) for BGS, and 10 V.S.A. §554(15) for ANR.

D. LIDACs

i. Community benefits

Community benefits to LIDACs are expected to include decreased energy costs and improved energy security from energy efficiency improvements and more resilient energy sources, increased resilience to climate change from GHG reduction measure that have both GHG benefits and climate adaptation benefits, the creation of capacity in municipalities where there is not enough staff or resources to compete for state or funding opportunities, and the reduction of CAPs and HAPs from fossil fuel combustion associated with municipal buildings heating and cooling.

ii. Community Engagement

A detailed description of ANR's community engagement plan related to climate change and the outcomes of public engagement related to the PCAP is included in the "Public Engagement and Outreach" Section of this PCAP. As described in that plan, engagement will continue beyond implementation of this PCAP, and will help to inform post-implementation mitigation and assessment of outputs.

During public engagement for the PCAP, ANR received the highest volume of comments related to the limited capacity of municipalities to effectively implement climate mitigation measures. ANR also heard that creating new and different programs would only be more burdensome, and that existing programs should be refined and expanded to allow to communities to be able to engage with the same administrators and stakeholders, and not engage in redundant process. ANR also heard from towns and cities in Vermont that need additional resources to specifically plan for climate mitigation, adaptation, and resilience activities in their communities. This planning work will be considered as ANR implements its CPRG Planning Grant and begins work on the CCAP.

Supporting EPA's Strategic Climate Goals

All measures included in this PCAP support EPA's goal of Tackling the Climate Crisis by facilitating the reduction of or directly reducing emissions that cause climate change. Further, and as described in this PCAP, these measures also support this goal by generating co-benefits related to increasing the adaptive capacity of Vermont and Vermonters in the face of future climate impacts, reducing emissions of harmful co-pollutants, increasing public health benefits, and addressing environmental justice through improvements to environmental quality for disproportionately impacted communities and lower costs through more efficient and healthy heating and building infrastructure.

Cleaner transportation options, like light-duty and medium- and heavy-duty electric vehicle adoption measures support the EPA strategic plan by:

1. Reducing tailpipe emissions of internal combustion engine vehicles, including GHG, CAP, and HAP emissions; and
2. Enhancing access to clean transportation, including electric vehicles, by prioritizing incentives for disadvantaged communities and offering robust technical assistance and training to ensure a successful transition to electric transportation;

Heating, cooling, and building infrastructure measures support EPA's strategic plan by:

1. Reducing emissions from buildings by improving building insulation and systems and fuel switching to lower-emitting technology;
2. Reducing the energy burden to low-income Vermonters; and
3. Improving indoor air quality by improving building ventilation and reducing indoor combustion emissions.

Non-energy sector measures support EPA's strategic plan by:

1. Reducing GHG emissions by reducing waste and also diverting waste from the landfill; and
2. Mitigating fugitive GHG emissions of high GWP substances by ensuring responsible end-of-life capture for refrigerants and helping businesses switch to lower-GWP and less toxic refrigerant alternatives.

Natural and Working Lands conservation and management measures support EPA's strategic plan by:

1. Acquiring land to avoid conversion for developed uses and therefore ensure additional carbon sequestration through conservation; and
2. Increase uptake in enrollment of land management programs that yield additional carbon sequestration benefits.

Co-benefits of priority measures

The implementation of the greenhouse gas reduction measures included in this PCAP are anticipated to have a broad range of benefits. This section describes the anticipated co-pollutant reductions associated with implementation of the priority measures identified in this PCAP as well as air quality improvements, improved public health outcomes, economic benefits, increased climate resilience, and other environmental benefits.

Criteria and Hazardous Air Pollutant Reduction

Both criteria air pollutants (CAPs) and hazardous air pollutants (HAPs), or air toxics, can cause serious harm to both human health and the environment. There are many separate actions and measures focused specifically on reducing CAPs and HAPs, however, there is also a large degree of overlap between measures that reduce greenhouse gas emissions and those that reduce emissions of CAPs and HAPs. Incorporating the reduction of CAPs and HAPs into the measure prioritization process will provide additional public health and environmental benefits outside of helping to slow global warming. To understand where this overlap in measure outcomes exists it is necessary to understand both sources and emissions totals of CAPs and HAPs as well as greenhouse gases. The National Emissions Inventory (NEI) is a comprehensive and detailed source of information related to air emissions sources. EPA works with State, Local, and Tribal air agencies to estimate emissions from their jurisdictions and then supplements that with data from EPA to build and produce the NEI every three years. Emissions data for several of the major criteria pollutants (nitrogen oxides (NOx), particulate matter 2.5 (PM2.5), and volatile organic compounds (VOCs)) as well as two selected HAPs has been included by Vermont county in Table 10 below. These NEI categories are cross walked to the corresponding and applicable GHG Inventory sector, and includes the categories (at the EIS Sector level) that would be impacted to some degree by measures put forward in the PCAP. Brief descriptions by applicable sector are provided below.

Agriculture

The 2020 NEI documents that Vermont's agricultural crops and livestock are responsible for substantial emissions of the criteria air pollutant PM2.5. Tilling resulted in emissions of over 420 tons of PM2.5 statewide in 2020. Vermont's proposed GHG priority measures in the Agricultural sector include actions that reduce soil tillage, increase the overall acreage where no-till crop planting is utilized, expand the use of vegetative cover crops, implement agroforestry and silvopasture techniques, and improve nutrient management practices. These measures are likely to yield the co-benefit of reducing direct emissions of PM2.5 through decreased disturbance of agricultural soils during crop planting, as well as through improved soil moisture retention.

Transportation

The mobile source related sectors in the 2020 NEI are the largest contributing source of NOx in Vermont, and also produce considerable emissions of VOCs, which combine to form ground level ozone that is a hazard to both human health and the environment. Several of the priority measures in the transportation sector of this PCAP focus on electrification of both the light-duty, as well as medium and heavy-duty vehicles. Electrifying vehicles reduces both emissions of greenhouse gases as well as criteria air pollutants by reducing the amount of fossil fuels combusted overall by vehicles in the sector. By creating a point-of-sale incentive program for electric medium and heavy-duty vehicles and the associated charging infrastructure, as well as well as providing funding for the continuation and expansion of existing light-duty EV incentive programs, Vermont will continue to make progress towards

reducing greenhouse gas emissions and the emissions of criteria air pollutants in the transportation space by accelerating EV adoption rates. Programs and strategies that reduce vehicle miles traveled (VMT) also have an impact on emissions by reducing overall fossil fuel combustion as well as having the potential to lower emissions of PM2.5 from paved and unpaved road dust, which is the second largest source of PM2.5 in the state.

Waste Management

The majority of the waste related emissions in the nonpoint portion of the 2020 NEI is PM2.5 from open burning, but the totals do include emissions of VOCs from wastewater treatment plants from around Vermont. There are also a significant number of HAPs as well as methane emissions associated with the decomposition of waste in the two largest landfills in the state, only one of which is currently still in operation. Actions in the PCAP related to the waste sector do not specifically address emissions from wastewater, open burning, or HAP emissions from landfills, however, the measures that focus on reducing food waste in schools and making recycling facilities more efficient will help to reduce the total amount of waste entering the landfill and so will decrease the overall emissions generated.

Buildings and Thermal (Residential, Commercial, and Industrial)

CAP and HAP emissions from fuel combusted for residential space heating in this sector are substantial, resulting in emissions of 11,961 tons of PM2.5, 2,241 tons of NOx, and 11,591 tons of VOCs including 1,293 tons of the HAPs benzene and formaldehyde during 2020. Proposed PCAP actions such as the development and deployment of a centralized thermal efficiency clearinghouse and targeted energy coaching program, program expansion for low to moderate income weatherization and thermal efficiency will result in sizable CAP and HAP emissions reductions. Improving building envelope efficiency through weatherization directly reduces household energy demand, fuel consumption and associated combustion emissions. Additional enhancements to energy efficiency through, for example, installation of heat pumps will further reduce household fuel consumption and associated emissions while also resulting in improvements to indoor air quality.

Industrial Processes

Operations included in the 2020 NEI for industrial processes are mostly related to activities which will not be addressed by the measures in the PCAP. Selected industrial processes have been included in Table 10 below that would correspond to general categories included in the GHG Inventory. The actions in the PCAP that ties to the industrial processes sector is the program which will help to increase the rate of recovery of high global warming potential hydrofluorocarbon (HFC) containing refrigerants and the end of their life as well as a program for the replacement of existing refrigeration units currently utilizing HFCs with units that use non fluorinated (non “f-gas”) natural refrigerants. Both of these measures will help to decrease the emissions of a number of different fluorinated gases into the atmosphere.

Table 10: Subset of Select 2020 NEI Annual Emissions Totals by county Cross-walked to GHG Sectors

County/Sector	NOx (tons)	PM2.5 (tons)	VOCs (tons)	Formaldehyde (tons)	Benzene (tons)
Addison	**688.5**	**1,076.9**	**1,212.6**	**71.0**	**29.7**
Agriculture	0.0	154.7	89.4	0.0	0.0
Industrial Processes	0.0	4.6	0.5	0.0	0.0
Residential/Commercial/Industrial	255.4	815.4	756.0	63.1	20.8
Transportation/Mobile Sources	420.7	43.2	338.8	7.3	7.7

County/Sector	NOx (tons)	PM2.5 (tons)	VOCs (tons)	Formaldehyde (tons)	Benzene (tons)
Waste Management	12.5	58.9	28.0	0.5	1.2
Bennington	**561.4**	**922.5**	**1,143.5**	**70.1**	**29.8**
Agriculture	0.0	13.1	5.2	0.0	0.0
Industrial Processes	0.0	0.0	19.2	0.0	0.1
Residential/Commercial/Industrial	281.0	857.8	785.7	65.7	21.6
Transportation/Mobile Sources	274.2	22.2	321.6	4.0	7.2
Waste Management	6.2	29.4	11.8	0.4	1.0
Caledonia	**573.2**	**905.4**	**1,077.2**	**69.1**	**27.5**
Agriculture	0.0	42.4	23.9	0.0	0.0
Industrial Processes	0.0	0.9	19.3	0.0	0.1
Residential/Commercial/Industrial	202.0	805.9	752.8	63.1	20.8
Transportation/Mobile Sources	365.0	26.8	269.7	5.5	5.7
Waste Management	6.2	29.4	11.6	0.4	1.0
Chittenden	**2,907.4**	**1,904.7**	**2,351.9**	**129.7**	**61.0**
Agriculture	0.0	45.2	16.2	0.0	0.0
Industrial Processes	0.0	11.6	2.1	0.0	0.0
Residential/Commercial/Industrial	958.3	1,491.8	1,180.1	95.9	31.4
Transportation/Mobile Sources	1,917.1	206.0	1,071.6	33.1	27.9
Waste Management	32.0	150.1	81.9	0.8	1.7
Essex	**145.5**	**301.8**	**780.6**	**24.5**	**15.1**
Agriculture	0.0	6.7	5.1	0.0	0.0
Industrial Processes	0.0	0.9	0.1	0.0	0.0
Residential/Commercial/Industrial	39.2	262.5	251.1	21.2	7.0
Transportation/Mobile Sources	103.3	17.7	517.5	3.2	7.8
Waste Management	3.0	14.0	6.8	0.1	0.3
Franklin	**677.2**	**1,008.4**	**1,323.8**	**69.3**	**30.2**
Agriculture	0.0	112.3	101.2	0.0	0.0
Industrial Processes	0.0	8.4	113.5	0.0	0.3
Residential/Commercial/Industrial	244.8	803.4	741.8	61.9	20.4
Transportation/Mobile Sources	421.3	31.1	344.0	6.8	8.1
Waste Management	11.2	53.2	23.3	0.6	1.4
Grand Isle	**204.1**	**190.8**	**774.7**	**16.1**	**15.2**
Agriculture	0.0	20.4	8.4	0.0	0.0
Industrial Processes	0.0	0.0	0.1	0.0	0.0
Residential/Commercial/Industrial	33.5	146.0	138.4	11.6	3.8
Transportation/Mobile Sources	169.4	18.5	626.2	4.4	11.1
Waste Management	1.2	5.9	1.7	0.1	0.3
Lamoille	**409.8**	**934.7**	**1,067.3**	**69.8**	**27.7**
Agriculture	0.0	23.6	10.8	0.0	0.0
Industrial Processes	0.0	0.0	0.3	0.0	0.0
Residential/Commercial/Industrial	221.0	858.0	789.2	66.2	21.7
Transportation/Mobile Sources	181.0	16.1	251.2	3.1	5.0
Waste Management	7.8	37.0	15.8	0.5	1.0

County/Sector	NOx (tons)	PM2.5 (tons)	VOCs (tons)	Formaldehyde (tons)	Benzene (tons)
Orange	**475.1**	**1,113.3**	**1,281.0**	**85.2**	**33.6**
Agriculture	0.0	52.6	28.5	0.0	0.0
Industrial Processes	0.0	2.0	0.4	0.0	0.0
Residential/Commercial/Industrial	197.9	1,012.9	963.5	81.0	26.7
Transportation/Mobile Sources	271.3	17.6	279.2	3.7	5.7
Waste Management	5.9	28.2	9.4	0.5	1.2
Orleans	**612.9**	**1,003.1**	**1,293.6**	**75.2**	**29.8**
Agriculture	0.0	78.7	51.6	0.0	0.0
Industrial Processes	0.0	0.9	19.2	0.0	0.1
Residential/Commercial/Industrial	202.4	859.2	805.1	67.6	22.2
Transportation/Mobile Sources	404.1	34.1	300.5	7.2	6.5
Waste Management	6.3	30.3	117.2	0.4	1.0
Rutland	**1,168.2**	**1,606.4**	**1,896.3**	**112.4**	**46.7**
Agriculture	0.0	58.0	17.2	0.0	0.0
Industrial Processes	0.0	60.4	39.1	0.0	0.1
Residential/Commercial/Industrial	447.8	1,314.7	1,191.5	99.6	32.6
Transportation/Mobile Sources	701.9	86.3	500.1	12.1	12.4
Waste Management	18.4	86.9	148.5	0.7	1.6
Washington	**1,177.5**	**1,574.0**	**1,708.6**	**116.4**	**45.0**
Agriculture	0.0	23.6	13.2	0.0	0.0
Industrial Processes	0.0	23.8	19.6	0.0	0.1
Residential/Commercial/Industrial	463.4	1,379.1	1,253.8	104.7	34.4
Transportation/Mobile Sources	696.5	64.9	379.6	11.2	9.3
Waste Management	17.5	82.5	42.3	0.6	1.3
Windham	**874.2**	**1,137.0**	**1,346.2**	**85.2**	**35.4**
Agriculture	0.0	20.0	10.8	0.0	0.0
Industrial Processes	0.0	0.9	0.6	0.0	0.0
Residential/Commercial/Industrial	346.8	1,025.1	926.8	77.4	25.4
Transportation/Mobile Sources	516.0	37.3	383.3	7.3	8.8
Waste Management	11.3	53.8	24.6	0.6	1.3
Windsor	**1,023.6**	**1,490.2**	**1,705.1**	**111.6**	**45.5**
Agriculture	0.0	39.7	12.3	0.0	0.0
Industrial Processes	0.0	17.7	19.7	0.0	0.1
Residential/Commercial/Industrial	421.2	1,337.2	1,236.3	103.3	34.0
Transportation/Mobile Sources	590.5	39.2	413.9	7.5	9.7
Waste Management	11.8	56.4	22.9	0.8	1.8
Grand Total	**11,498.5**	**15,169.2**	**18,962.3**	**1,105.6**	**472.2**

Resilience and Adaptation

Many of the measures in this PCAP have strong co-benefits of increased resilience and adaptation to the conditions caused by climate change. A discussion of these co-benefits is organized by sector, below.

Natural and Working Lands

This PCAP prioritizes measures that restore and permanently conserve land to enhance a parcel's ability to store and sequester carbon, as well as support private landowners. These measures specifically contemplate avoided land conversion, wetland and upland restoration, and enhanced management practices to improve a forest's ability to sequester carbon. While Vermont's natural and working lands are a key component of Vermont's climate mitigation strategy, these lands also serve the function of safeguarding ecosystems, promoting biodiversity, and mitigating the impact of extreme weather events on agriculture, forestry, and water resources. Flooding is Vermont's most costly natural disaster, and measures such as wetland and floodplain restoration will not only store and sequester carbon, but significantly reduce the economic impact of flooding on Vermont's communities. Estimates of the value of restored floodplains and wetlands in Middlebury, VT, indicate damage reduction of 84-95% for Tropical Storm Irene in 2011, and an annual value of flood mitigation services to Middlebury, VT that could be as high as $450,000. Solutions such as these seek to buffer the state's infrastructure and built environment from the most intense impacts of climate change and significantly lower the cost of future natural disasters on Vermont's communities.

Buildings and Thermal

Measures that mitigate emissions from buildings by improving building envelopes and switching fossil fueled appliances to electric solutions will have a significant impact on Vermont's ability to reduce GHG emissions economy wide. There is also an opportunity for this important work to consider how a building and its systems can be more resilient to recent and severe weather events, like the devastating flooding events that occurred throughout Vermont in 2023. LIDACs in floodplains are often at higher risk of suffering impacts from these events. Improved building envelopes and electric appliances can also aid in the increased resilience of individuals to other climate change impacts such as extreme heat and poor air quality due to wildfire smoke. More efficient building heating and cooling systems result in lower costs for residents, and ultimately an increased capacity, especially for LIDACs, to recover from climate change stressors. Measures in this sector will support incentives for these communities and perform mitigation work to be more resilient to climate disasters.

Mobile home communities provide an important source of affordable housing for Vermonters. Tropical Storm Irene highlighted the disproportionate vulnerability of many of Vermont's mobile home communities, with mobile homes accounting for over 15% of impacted households despite representing only 7% of the state's total housing stock. LIDACs, which include many who live in mobile home communities, are at a higher risk of suffering from impacts such as flooding. Measures that support improved building system resilience will have direct benefit for Vermont's LIDACs by improving overall building system resilience to flooding and other severe weather events.

Public Health

The more greenhouse gases emitted into the atmosphere, the more we can expect the planet to warm, resulting in more severe extreme weather and health impacts. Many, if not all, of the measures included in this PCAP will also improve public health. Often, these actions provide immediate health, environmental, economic, or other benefits today while also reducing potential impacts of climate change in the future. Many of these actions are considered "win-win" strategies because they will provide multiple benefits to society even if future climate change has less impact than is currently expected. Measures that reduce greenhouse gas emissions will also bring about substantial

improvements in human nutrition and human movement, two of the most important determinants of health. Vehicle electrification and increased use of transit will reduce vehicle emissions and therefore improve air quality; the development of compact, mixed-use city, town, and village centers with safe and complete pedestrian and bicycling facilities will increase physical activity, improve access to jobs, businesses, and other destinations, reduce vehicle emissions due to less travel, and improve air quality; increased energy efficiency of buildings will increase indoor comfort with lower heating and cooling costs, and improve air quality; and planting trees and developing green infrastructure will improve water quality, reduce the risk of flooding, improve community aesthetics, reduce air conditioning costs and reduce emissions due to less air conditioning.

Low Income and Disadvantaged Community Analysis

The implementation of the measures included in this PCAP are anticipated to provide significant benefits to low-income and disadvantaged communities (LIDACs) in Vermont. This section identifies each LIDAC within Vermont covered by this PCAP, how ANR meaningfully engaged with LIDACs in the development of this PCAP, and how ANR will continue to engage with these communities into the future. For a discussion of estimated benefits or disbenefits related to the implementation of each priority measure, please refer to the detailed measure descriptions discussed above.

Background

Ensuring a Just Transition

In conjunction with developing the VT CAP, the Just Transitions Subcommittee of the Vermont Climate Council supported the work by ensuring that the strategies and actions will benefit and support all residents of the State of Vermont fairly and equitably. The term “Just Transitions” encompasses both public policy and business action that address the impacts of the transition away from greenhouse gas emissions for jobs and livelihoods (the transition "out") to low or zero greenhouse gas emission jobs and livelihoods of a sustainable society (the transition "in"). The Just Transitions Subcommittee designed six key principles to guide the development of the VT CAP. These include:

1. Ensuring Inclusive, Transparent, and Innovative Engagement in the development of the plan and associated policies and program.
2. Creating Accountable and Restorative recommendations that recognize inequality and seek to resolve them using clearly identified strategies.
3. Moving at The Speed of Trust where candor and honesty are recognized as essential for public trust and preparing Vermonters for transition to a sustainable climate future.
4. Incorporating Solidarity to create inclusionary spaces for all traditions and cultures, particularly for Indigenous communities, recognizing them as integral to a healthy and vibrant Vermont.
5. Prioritizing The Most Impacted First through recommendations that address the needs of impacted and frontline communities first, providing the greatest benefits of transitions to these communities.
6. Developing Supports for Workers, Families, and Communities that consider and plan for potential impacts on workers, families and their communities based on the implementation of Vermont’s Climate Action Plan

The Guiding Principles also include a process for assessing “equity and justice” which includes an explicit reflection and analysis of:

- Impacted and Frontline Communities;
- Analyzing Burdens and Benefits;
- Ensuring Equitable and Just Engagement;
- Funding and Data; and
- Implementation and Outcomes.

Moreover, a scoring rubric was developed to accompany a narrative response for each of the Assessment Questions. Each recommendation put forward in the VT CAP was reviewed using this criterion. The criterion include:

- Frontline/Impacted
- Communities; Analyzing Burdens and Benefits;
- Ensuring Equitable & Just Engagement;
- Funding & Data;
- Implementation & Questions;
- Which Groups Derive Direct Benefits.

This rubric was designed to be used in the recommendation prioritization process and supported identifying strategies and actions that require additional equity and justice considerations before being advanced to implementation.

Vermont's Environmental Justice Law and Policy

Also known as Act 154 of 2022, the Vermont Environmental Justice (EJ) Law is the state's first law specifically meant to address environmental health disparities and improve the health and well-being of all Vermont residents. The Environmental Justice Law establishes Vermont's Environmental Justice State Policy.

The purpose of the Environmental Justice Law is to ensure all Vermonters regardless of race, cultural background, or income have equitable access to environmental benefits such as clean air and water, healthy food, and public transportation. The Environmental Justice Law also protects communities from disproportionate environmental burdens such as polluted air and water, climate change impacts, and limited access to green spaces. The Environmental Justice Law requires State agencies to meaningfully engage Vermonters in the environmental decision-making processes.

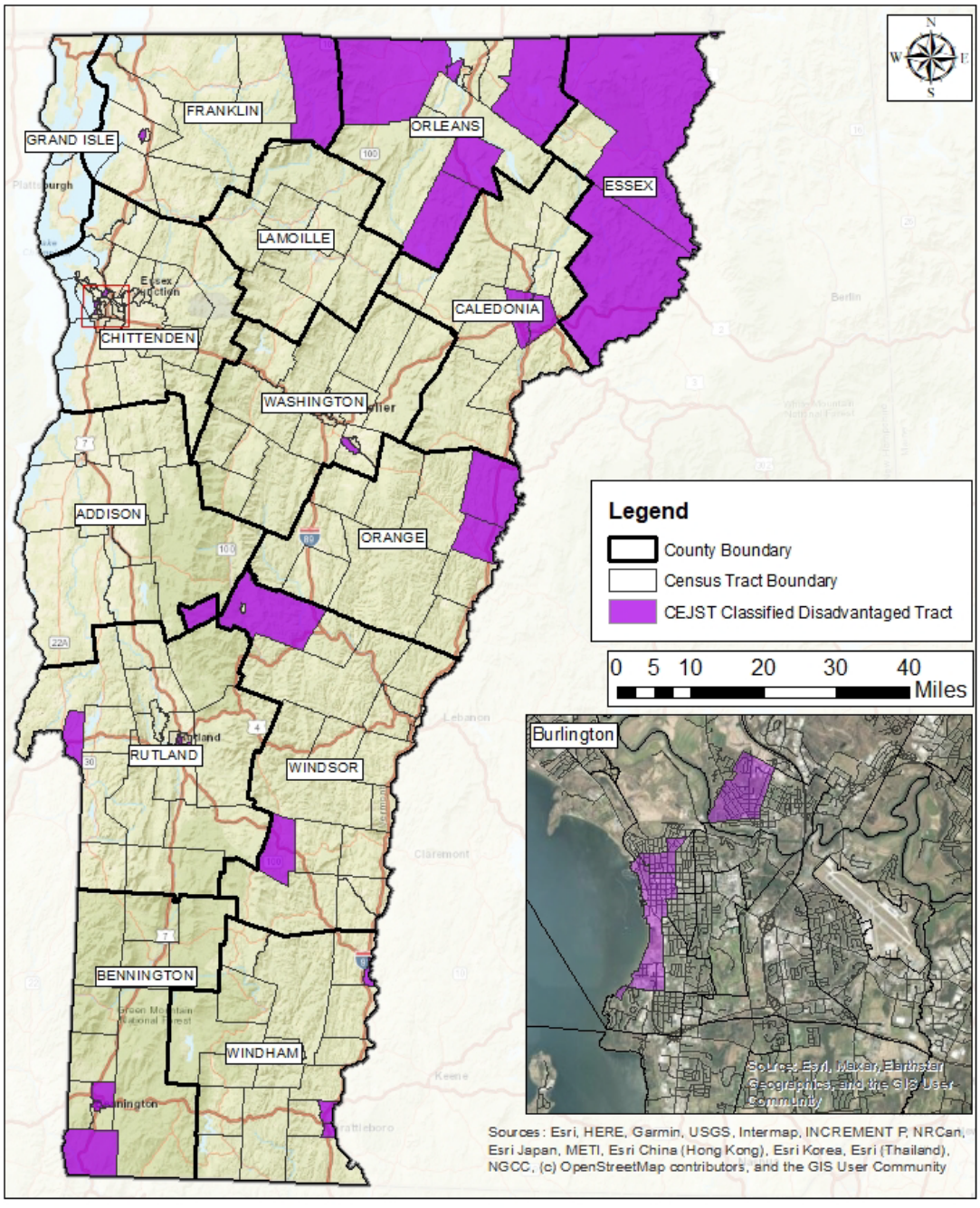
The Environmental Justice Law creates an Environmental Justice Advisory Council and an Interagency Environmental Justice Committee. The Advisory Council is composed of a range of community representatives, and they provide independent advice to State agencies and the General Assembly on matters related to environmental justice. The Interagency Committee is composed of representatives from ten State agencies, and they coordinate State agency implementation of the Environmental Justice Law. Over the coming years, the Advisory Council and Interagency Committee will work together to implement the Environmental Justice Law and ensure that State agencies embed environmental justice throughout the development, implementation, and enforcement of environmental laws, regulations, and policies.

Identification of LIDACs in Vermont

For the purposes of the CPRG Program, EPA has defined LIDACs as any community that is identified as disadvantaged by the Climate and Economic Justice Screening Tool (CEJST). This tool uses datasets, indicators of burden, in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. The tool uses this information to identify communities that are overburdened and underserved so they can be prioritized in development of measures to be implemented pursuant to the CPRG Program.

The communities identified in CEJST are particularly vulnerable to the impacts and risks associated with climate change. Vermonters are living with these impacts now, including drought, wildfire smoke exposure, flooding events, and extreme heat. Over 15% of Vermont's census tracts, 28 out of 184 are considered disadvantaged as shown in Figure 1. See Table 11 below for a list of LIDAC census tracts in Vermont, organized by county and population.

Figure 1: Vermont Disadvantaged Census Tracks in CEJST



Vermont - Disadvantage Census Tracts

Note: Census track information and was downloaded from the Climate and Economic Justice Screening Tool (CEJST) on 2/2/2024. Identification of a census tract as disadvanted was based on CEJST determination.

Sources: 1) VCGI, county boundaries, Trans_roads
2) CEJST census tract data
3) ESRI World Street Map basemap

Date: 2/2/2024

This map is for illustrative purposes only. The accuracy of the data layers shown on this map are limited by the accuracy of the source materials. No warranty as to the accuracy or the usefulness of the data is expressed or implied.

Figure 1

Table 11: Disadvantaged Census Tracts and Population in Vermont by County

County	Number of Disadvantaged Census Tracts	Total Population in Disadvantaged Census Tracts
Addison	0	0
Bennington	3	10,192
Caledonia	2	7,224
Chittenden	3	8,859
Essex	2	5,015
Franklin	2	6,841
Grand Isle	0	0
Lamoille	0	0
Orange	2	4,954
Orleans	5	14,265
Rutland	3	10,829
Washington	1	4,179
Windham	3	10,708
Windsor	2	4,741
Total	**28**	**87,807**

* D*isadvantaged census tracts identified using CEJST tool.*

While ANR is using the CEJST tool for the purpose of identifying LIDACs for impacts analysis in relation to the PCAP, it is important to note how Vermont's Environmental Justic Law defines these communities differently. Vermont's Environmental Justice Law defines the term "Environmental Justice Focus Population" (3 V.S.A. §6002(4)) as: "Any census block group in which: 1) the annual median household income is not more than 80 percent of the State median household income; 2) Person of Color and Indigenous Peoples comprise at least six percent or more of the populations; or 3) at least one percent or more of households have limited English proficiency." Further information on how Vermont has identified and visualized EJFP across Vermont is included in Appendix D. Consideration of EJFPs in Vermont will also be considered as the measures in this PCAP and advanced further to more detailed design and implementation.

Impact of Priority Measures on LIDACs

For a complete discussion of each measure's impact on LIDACs, see the "Measures for Prioritization in the CPRG Program" Section above, where each measure specifically identifies the impacts to LIDACs relative to the goals and expected outcomes of each measure.

Engagement with LIDACs in Vermont

One of the first deliverables of the Environmental Justice law is to establish core principles of community engagement. The Interagency Committee is the lead implementer for developing the core principles and is currently implementing a strategy to develop the core principles with ANR, the Advisory Committee, and public stakeholders. As detailed above in the "Public Engagement and Outreach" Section above,

ANR's Climate Action Office's overall 2023-24 Community Engagement Plan also includes goals and strategies for engagement with LIDACs.

The Engagement Plan strives to achieve the following goals:

- **Provide information and knowledge** that helps people prepare for climate impacts, take action, and access programs that can benefit them.
- **Lift up the voices and viewpoints of communities** into the implementation of climate-related initiatives and the ongoing work of the Vermont Climate Council, so that a diverse group of Vermonters can influence these efforts.
- **Build relationships and communication channels** that will help Vermonters work collaboratively on future climate action.

Plan to assess and quantify more thorough quantitative analysis of benefits

Equitable distribution of environmental benefits is a central pillar of environmental justice and the Vermont EJ Law. The second deliverable of the VT EJ Law is focused on equitable distribution of environmental benefits, which mean "the assets and services that enhance the capability of communities and individuals to function and flourish in society. Examples of environmental benefits include access to a healthy environment and clean natural resources, including air, water, land, green spaces, constructed playgrounds, and other outdoor recreational facilities and venues; affordable clean renewable energy sources; public transportation; fulfilling and dignified green jobs; healthy homes and buildings; health care; nutritious food; Indigenous food and cultural resources; environmental enforcement; and training and funding disbursed or administered by governmental agencies."

The Agency of Natural Resources must develop guidance on how the ten State agencies covered under the VT EJ Law (the "covered agencies") determine which investments provide environmental benefits to EJ focus populations. The guidance document will be created in consultation with the EJ Advisory Council and Interagency EJ Committee and will inform covered agencies baseline environmental benefit spending reports and annual benefit spending reports, due annually starting January 15, 2026. ANR anticipates updating this guidance over time. These reports will quantify the potential benefits to LIDAC communities resulting from the implementation of measures in the PCAP.

Authority to Implement Priority Measures

ANR has reviewed existing statutory and regulatory authority to implement each priority measure in this PCAP. Citations from the relevant authority are organized by implementing agency in Table 12 below. As none of the measures contemplated in this PCAP requires new regulatory authority or expands the scope of jurisdiction of ANR or another agency of state government, no new authority will be required to implement the included measures. Generally, ANR and the lead agency for each measure has authority to accept federal grant funds and use those funds to support the programs and policies of each respective agency. There are no state laws or regulations in effect that prohibit or restrict the implementation of the measures in this PCAP. ANR plans to act as the fiscal agent for any funding awarded via the CPRG program, including implementation awards, and will execute sub-award agreements with partner agencies and other implementing entities listed below as required.

Table 12: Relevant Authority to implement PCAP Measures

Agency	Relevant Authority	Description of authority
ANR	10 V.S.A. 554(15)	Power to accept, receive, and administer federal grants for the purposes of controlling emissions of air contaminants.
	10 V.S.A. § 6603(6)	Accept, receive, and administer federal funds for the purpose of waste management. This includes the ability to convey such grants or other funds to municipalities or other instruments of State or local government.
	10 V.S.A. §§4047-4050	Accept and receive monies into various funds and accounts created for and managed by ANR's Dept. of Fish and Wildlife
	3 V.S.A. §2807	Accept and receive grant monies into the Lands and Facilities Trust Fund
BGS	29 V.S.A. § 152(a)(33)	Accept grants of funds, equipment, and services from any source, including federal appropriations, for the installation, operation, implementation, or maintenance of energy conservation measures or improvements at State buildings.
VTrans	19 V.S.A. § 7(f)(2); 5 V.S.A. §206(b)	Cooperate with the appropriate federal agencies and receive federal funds in support of programs within the Agency.
DHCD (ACCD)	3 V.S.A. §2453(3)	Cooperate with the appropriate federal agencies and administer federal funds in

		support of programs within the department.
AAFM	6 V.S.A. § 1(a)(9)	Apply for and accept grants of money or other gifts on behalf of the Agency of Agriculture, Food and Markets.
VHCB	10 V.S.A. §312	Deposits into the Vermont Housing and Conservation Board Trust fund monies received from any source, public or private.

Climate Workforce Planning in Vermont

The priority measures included in this PCAP will result in the creation of high-quality jobs for Vermonters. This section details Vermont's strategies and commitments to ensure job quality, and a diverse, highly skilled workforce for implementation of the priority measures.

Workforce Partnerships

Beyond the specific measures put forward in this PCAP that enhance workforce opportunities through education and training, the Climate Action Office continues to consider its role in supporting workforce development. As a member of the US Climate Alliance, Vermont is working with the 24-member Governor's Alliance to advance state leadership on workforce development. Strategic partnerships with other states, especially our neighboring northeast states, will be critical in driving the change we need to meet the demand.

In addition, the CAO has been working with the Serve, Learn, and Earn Program in Vermont to advance a partnership to support climate jobs in the sectors that overlap with their programming. Serve Learn Earn is a collaboration of Vermont Youth Conservation Corps, Vermont Works for Women, Audubon Vermont, and ReSOURCE. Their vision is for every Vermont resident to have a viable pathway to employment and an affordable education. Their free programs provide paid service and learning opportunities across the state. The Vermont Legislature recognized the importance of this work – and this collaboration – with an appropriation in 2021, administered by the Vermont Department of Forests, Parks, and Recreation. This funding supports each organization's direct service training programs, increasing opportunities for Vermonters to obtain good-paying jobs while also meeting the needs of Vermont businesses and communities. These programs have a strong focus on the climate workforce and economy.

Strength and Opportunities for Workforce Improvement

Through Vermont's CPRG Planning Grant, the CAO will advance workforce improvement through analyses being developed for the Comprehensive Climate Action Plan. The expertise of existing programs and partnerships will inform the development of these improvement strategies.

Messaging Opportunities

ANR's partnership with the Serve, Learn, and Earn Program focuses specifically on messaging. The CAO has capacity through our Community Engagement and Communications Coordinator to partner with this Program to support new climate initiatives at participating organizations. A great example is the work of Vermont Works for Women (VWFW). VWFW promotes economic justice by advancing gender equity and supporting women and youth at every stage of their career journeys. Since 1987, VWFW has supported women and girls to recognize their potential and explore, pursue, and excel in work that leads to economic well-being. They provide career exploration programs and events, training in the skilled trades, career coaching and mentorship, and gender equity workshops. In doing so, Vermont women, girls, and gender-expansive individuals feel empowered to make career decisions that best meet their needs and goals.

These jobs are foundational to building a climate workforce. The CAO will align workforce outreach and messaging with the measures in this PCAP.

Workforce Funding Needs

Beyond the work described here, the CAO will continue to connect with state leaders on climate to consider workforce funding needs beyond what federal grants from agencies such as the Department of Energy. For example, Vermont's Office of Economic Opportunity is considering workforce needs related to the thermal sector fuel switching and weatherization, with a focus on building capacity at technical high schools and state colleges. The Vermont legislature also recently received a report on the current capacity of technical career and training programs at high schools and state colleges, which highlights work needed to connect these programs to create a constructive and efficient network of training opportunities to meet the new climate-oriented workforce needs of the state.

Job Opportunities expected from PCAP Measures

Each measure included in this PCAP is expected to impact the need for a more robust climate workforce. The programs and policies of the state will all be brought to bear in meeting this need, and ensuring that high quality employment opportunities are created as a result of the expanding climate economy. These opportunities are discussed generally, by sector, below.

Transportation

ANR expects job opportunities related to retraining and trade transition in the electric vehicles and truck space, as well as opportunities in the technical education space for students interested in pursuing an auto mechanical career. ANR and VTrans will continue to coordinate with the Learn, Serve, Earn Program and other Department of Labor programs to facilitate advancement of the programs to support job creation and training related to electric vehicle mechanical training.

Buildings and Thermal (RCI)

ANR expects measures in the buildings and thermal space to yield the creation of high-quality Energy Navigator positions at the entity selected to administer the program described in this measure.

ANR also expects these measures to create even greater demand for thermal efficiency contractors, plumbers, electricians, and Heating, Ventilation, and Cooling technicians, and therefore existing workforce development programs will need to further support this need. Current programs include incentives for contractors to deploy thermal efficiency projects in LIDACs, helping to focus the demand for this work where it will have the most impact in supporting contractors in completing projects.

Natural and Working Lands

ANR expects that additional workforce will be needed to assist farmers in converting land and modifying practices consistent with these programs. Additionally, tree nursery and planting resources will likely be an increased need as programs that promote increased vegetation and land conservation rise in demand.

Land acquisition and conversation measures are expected to yield the creation of additional workforce opportunities in transitioning marginal farmland to wetlands and making the remaining farmland more economically viable, keeping land forested and supporting the forest economy workforce, and supporting public land acquisition which grows the outdoor recreation economy in Vermont.

Non-energy sector emissions

While measures related to reduction in food waste are likely to have little impact on job creation, it may improve how certain jobs or human resources are used in relation to the function of the food system.

High quality jobs are likely to be created to increase the capacity for refrigerant recovery at waste management entities. The refrigerant recovery measure will include funding to train the workforce that will be required to realize the avoided emissions associated with the refrigerant recovery program.

Multi-sector emissions

While a limited number of jobs are likely to be created through the implementation of measures to reduce emissions from solid waste management entities, these programs are expected to improve the condition of recycling facilities, making them safer and healthier places to work.

Leveraging Funding Sources

Many of the priority measures included in this PCAP expand upon or complement existing programs. ANR has explored federal and non-federal funding sources to determine whether these sources could fund each priority measure and whether such funding is sufficient to fully implement the measure. This section generally describes the other funding sources available that will be leveraged to successfully and more effectively implement the measure described in this plan. Each measure description discussed above includes a more detailed description of how a funding source listed here will be leveraged to achieve the outcomes of each measure. A list of other sources of funding to be leveraged, organized by source and sector, is included below.

State or Federal Source	Title of funding source	Sector impacted
State	Acts relating to the Transportation Program and miscellaneous changes to laws related to transportation: Act 62 (2023), Act 184 (2022), Act 55 (2021), and Act 59 (2019.	Transportation
State	Municipal Energy Resilience Act: Act 172 (2022).	Buildings and Thermal
State	Home Weatherization Assistance Program	Buildings and Thermal
State	Electric Vehicle Supply Equipment (EVSE) Grant Program: Act 62 (2023).	Transportation
State	Volkswagen Environmental Mitigation Trust	Transportation
State	Migratory Waterfowl Fund	Natural and Working Lands
State	Habitat Stamp Fund	Natural and Working Lands
State	Vermont Housing and Conservation Board Trust Fund	Buildings and Thermal, Natural and Working Lands
Federal	Inflation Reduction Act	Buildings and Thermal, Transportation, Natural and Working Lands
Federal	American Rescue Plan Act	Buildings and Thermal, Transportation, Natural and Working Lands
Federal	Infrastructure, Investment, and Jobs Act (e.g. Carbon Reduction Strategy and Program, and the	Buildings and Thermal, Transportation

	National Electric Vehicle Infrastructure Program)	
Federal	Diesel Emission Reduction Act	Transportation
Federal	US EPA Lake Champlain Basin Program	Natural and Working Lands

Regional and Local Climate Mitigation Opportunities

Vermont's Act 174 of 2016 established a new set of municipal and regional energy planning standards, which if met allow those plans to carry greater weight - substantial deference - in the siting process for energy generation. While meeting these standards is voluntary, many regions and municipalities in Vermont have used this as an opportunity to think strategically about ways their communities can take a coordinated and meaningful approach to mitigating GHG emissions. Some regions and municipalities have even adopted stand-alone Climate Plans to help inform and set priorities for local and regional development and land-use decision-making that could impact the climate. These plans are informed by climate data and modeling supplied by the Vermont Public Service Department and applied to municipal planning with the assistance of their Regional Planning Commission.

There are eleven Regional Planning Commissions (RPCs) in Vermont. RPCs are Political Subdivisions of the State of Vermont created by their member municipalities pursuant to 24 VSA §4341. RPCs provide technical assistance to municipalities, and since Vermont does not have county governments, Vermont's Regional Planning Commissions act as a link between municipal affairs and state government. RPCs work in fields that directly and indirectly affect the public at large: land use, transportation, housing, economic development, environmental quality, and more.

Throughout the development of this PCAP, ANR has engaged directly with RPCs through the Vermont Association of Planning and Development Agencies (VAPDA) to solicit feedback from their Energy and Climate Committee. Through this engagement, and further strengthened by a CPRG Planning Grant sub-award to the Northwest Vermont RPC, an inventory of regional and local climate and energy planning provisions has been compiled and is incorporated by reference into this PCAP in Appendix E. Many of the measures included in this PCAP will directly and indirectly support the work of Vermont's regions and municipalities in furthering their climate mitigation priorities by funding critical gaps in resources needed to implement GHG reducing activities. Specifically, the measure described above that expands upon the existing Municipal Energy Resilience and Municipal Technical Assistance Programs will inject necessary resources into severely oversubscribed programs. In the cases of these pre-existing programs, much of the groundwork has been completed to plan for and facilitate these infrastructure and building upgrades, but more implementation funding is needed. This is reflected in the regional and local plan provisions incorporated herein. However, even additional resources are needed to plan for and implement climate mitigation work at this level. ANR will continue to partner with RPCs as it works to develop the CPRG's Comprehensive Climate Action Plan (CCAP) to facilitate this important work.

Conclusion and Next Steps

This PCAP is the first deliverable under the CPRG planning grant awarded to ANR. ANR and its partners will continue planning, engagement, and action to reduce emissions; invest in sustainable infrastructure, technologies, and practices; build our economy; and enhance the quality of life for all Vermonters. Later in 2024, ANR will submit an application to EPA for grant funding from the CPRG Program to implement the measures included in this PCAP. In 2025, ANR will publish a CCAP alongside the required update to Vermont's Climate Action Plan due in July of 2025, that establishes equitable and sustainable economic development strategies that reduce emissions across all sectors. The CCAP will include near- and long-term emissions projections, a suite of emission reduction measures, a robust analysis of measure benefits, plans to leverage federal funding, and a workforce planning analysis. In 2027, ANR will publish a status report that details implementation progress for measures included in the PCAP and CCAP, any relevant updates to PCAP and CCAP analyses, and next steps and future budget and staffing needs to continue implementation of CCAP measures.

VERMONT

Agency of Natural Resources

Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2020

April 2023

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Note to Readers

The format for the Greenhouse Gas Emissions Inventory and Forecast report has been updated in this release to make the document more accessible for public consumption, as well as to incorporate certain sensitivity analyses and other recommendations of the Vermont Climate Council (VCC) and Subcommittees, in line with the Global Warming Solutions Act. This report estimates greenhouse gas (GHG) emissions levels by sector, and includes important considerations related to emission estimates. Any significant methodology changes made since the previous inventory report are also discussed in this document. A separate methodology document - *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* - is available and discusses the specific sector by sector methodologies and datasets utilized in greater depth. The *Methodologies* document will be updated with each inventory release as necessary when improvements to methods or datasets occur.

For additional information and resources on climate action in Vermont from adaptation and resilience to mitigation pathways and strategies, please visit our website: https://climatechange.vermont.gov/.

Executive Summary

The concentration of greenhouse gases (GHG) in the earth's atmosphere continue to increase due to anthropogenic emissions from different sectors and processes. Greenhouse gases absorb solar radiation and trap heat energy in the atmosphere which warms the planet. Global warming is already having impacts here in the Northeastern U.S. and around the globe[1], including impacts to communities and natural ecosystems, many of which are already marginalized or disproportionately impacted. Understanding Vermont's contribution to this global problem and the sources and sectors which are responsible for these emissions is a critical first step in reducing emissions that contribute to global warming. The goal of this inventory is to provide an understanding of emissions sources in Vermont in a way that enables the tracking of emissions levels through time and to help inform decisions on future mitigation strategies and pathways that is consistent with other jurisdictions.

The Vermont Greenhouse Gas Emissions Inventory and Forecast reports are required pursuant to Vermont statute 10 V.S.A. § 582[2]. The Inventory quantifies historic 1990 and 2005 baseline GHG levels and tracks changes in emissions through time to determine progress toward the state's GHG reduction requirements in 10 V.S.A. § 578[3], which were updated with the passage of the Global Warming Solutions Act (GWSA)), (Act 153) in 2020.[4] The emissions reduction requirements of the GWSA are 26% below 2005 levels by 2025, 40% below 1990 levels by 2030, and 80% below 1990 levels by 2050.

The methodology and data used to inform this inventory can be understood in detail in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* companion document. This report provides emissions estimates, as well as general information and emissions trends for each sector. Updates to calculation methodologies and data that have been used to generate emissions estimates in the inventory are briefly described in the sections below and are discussed in greater detail in the Methodology document.

The official emissions totals in this inventory report are measured on a gross basis, meaning they do not account for any sequestration of CO_2 from the atmosphere. Supplemental information estimating sequestration totals from the Land-use, Land Use Change, and Forestry (LULUCF) sector are also included in this report, as well as estimates of biogenic CO_2 emissions from wood combustion in several sectors. For further discussion on the accounting of biogenic CO_2 and the LULUCF sector please refer to the Methodology document.

This inventory includes official estimates for three years (2018, 2019, and 2020) to provide as up-to-date data as possible. Overall emissions declined from 2017 through 2020 as shown in Figure 1, with variability within each sector. Estimates from 2020 are likely an outlier due to the

[1] U.S. Global Change Research Program – Fourth National Climate Assessment: Chapter 18: Northeast https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf
[2] Vermont Statute 10 V.S.A. § 582: https://legislature.vermont.gov/statutes/section/10/023/00582
[3] Vermont Statute 10 V.S.A. § 578: https://legislature.vermont.gov/statutes/section/10/023/00578
[4] Vermont Legislature - Global Warming Solutions Act (Act 153): https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT153/ACT153%20As%20Enacted.pdf

impacts of the COVID-19 pandemic, which had a substantial impact on the transportation/mobile sources sector, reducing emissions by approximately 15% from 2019 to 2020. Electricity sector emissions from the previous report have been adjusted upward for the years 2016 through 2019 due to a calculation error in the previous report which is explained in Sector 2.1.5. Total emissions in 2020 were 7.99 million metric tons of CO_2 equivalent ($MMTCO_2e$). Transportation/mobile sources sector totals are expected to rebound to some degree based on the rebound in both VMT and Fuel sales in 2021, but the extent of that rebound is unclear.

This report also provides 5 and 10 year emissions projections for 2025 and 2030. The 5 and 10 year emissions estimates projections are 8.55 $MMTCO_2e$ for 2025 and 7.32 $MMTCO_2e$ in 2030 and were calculated using the business as usual percent changes by sector from GHG mitigation pathway modeling values completed for the Vermont Climate Action Plan. Estimating future emissions levels depends on a multitude of factors that are difficult to predict and has been further complicated by the impact on the economy and social behaviors stemming from the COVID-19 pandemic.

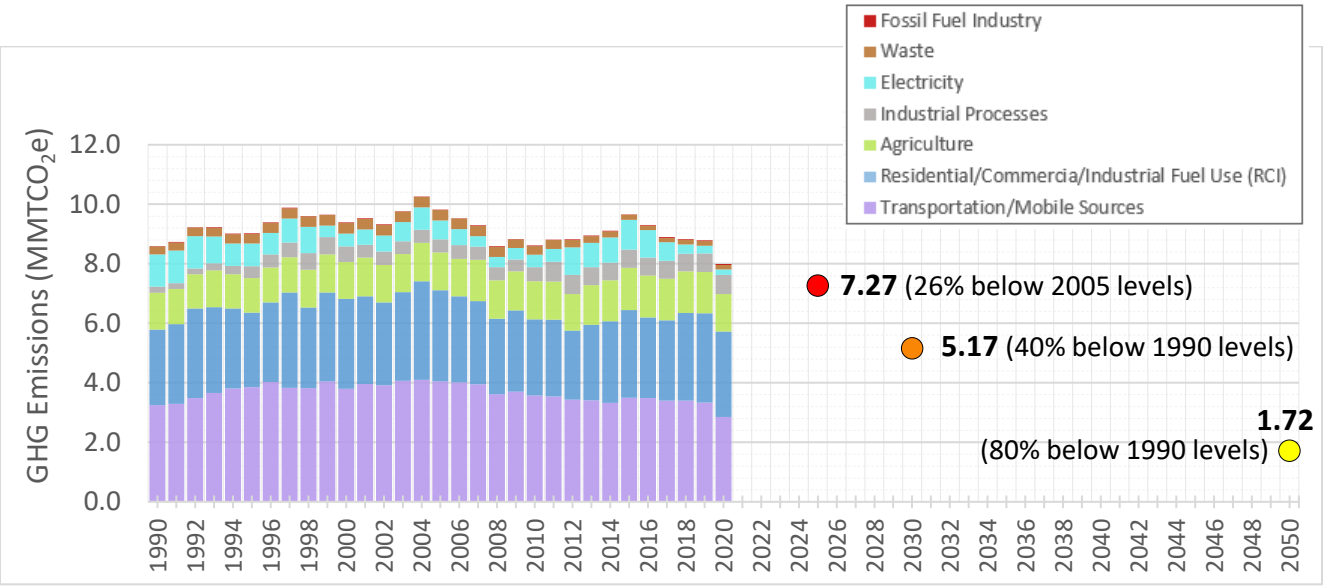

Figure 1: Vermont statewide greenhouse gas emissions levels and mandated reduction targets as defined in 10 V.S.A. § 578.

1. Introduction

The *Vermont Greenhouse Gas Emissions Inventory and Forecast* (Inventory) provides estimates of the amount of human caused (anthropogenic) greenhouse gas emissions produced within the state of Vermont in units of million metric tons of carbon dioxide (CO_2) equivalent ($MMTCO_2e$). The 100-year Global warming potential (GWP) values are used from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) per IPCC inventory guidelines, but additional estimates using the AR5 GWP values are included for select years as Appendix B of this report. Estimates of emissions using the AR4 20-year GWP values are available the select years in the companion Methodology document. The Inventory estimates and tracks the levels of greenhouse gas emissions for the state as accurately and consistently as possible through time and are generated using methods and datasets discussed in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* companion document. This report includes estimates for the years 1990 – 2020 and supersedes estimates included in previous reports. Including the most current data is important to help understand our progress towards required emissions reductions levels. Data is currently available to span three years (2018, 2019, and 2020) and so this iteration of the Inventory covers the years 1990 – 2020.

1.1 Vermont and the U.S. GHG Comparisons

In comparing the sectoral contributions from Vermont to the U.S. as a whole, there are some significant differences to note. Vermont has a higher percentage of emissions from transportation, thermal use in buildings (RCI), and agriculture than the country as a whole, which is likely due to the rural nature of the state and the disproportionate use of heating fuel during the winter months. It also has a much lower percentage of emissions from electricity generation (Figure 2 and Figure 3) due to the large amounts of low or no carbon electricity in the state's portfolio.

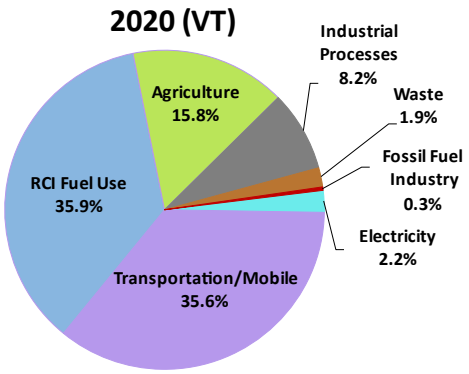

Figure 2: Vermont GHG percent contributions by sector.

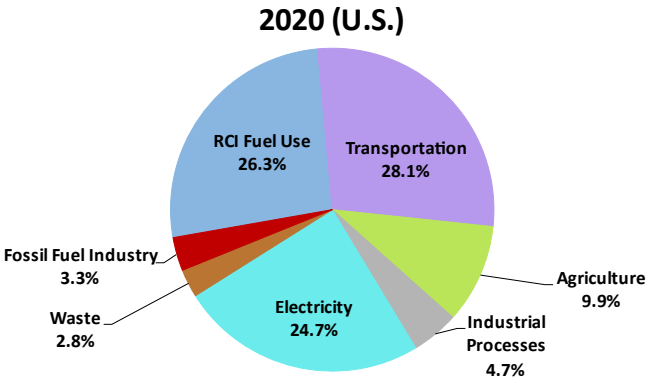

Figure 3: U.S. GHG percent contributions by sector. Data for the U.S. contributions by sector has been reallocated to match the Vermont sector categories in this report.

2 Vermont GHG Emissions by Sector

2.1 Overview

Tracking greenhouse gas emissions by sector helps us to understand each sector's share of emissions, and how those emissions levels are changing over time. This information is important for prioritizing and informing policy decision-making related to each sector and subsectors. The sectors in this report include transportation/mobile sources, residential/commercial/industrial (RCI) fuel use, agriculture, industrial processes, electricity consumption, waste, and the fossil fuel industry. The land-use, land use change, and forestry (LULUCF) sector is also included, but is not incorporated into the overall gross totals. Figure 4 below shows the estimates of GHG emissions by sector back to the 1990 baseline. Additional detail on each sector can be found in the subsections below with more information on the calculation methodologies and data sources located in the accompanying Methodology document.

Emissions of biogenic carbon dioxide, which are produced from the burning, breaking down, or processing of biologically-based material, are not included in the overall gross totals in the inventory based on IPCC inventory guidelines[5]. Those emissions are instead captured in the LULUCF sector through changes in land use and the amount of stored carbon on the landscape (carbon stocks and fluxes). Estimates of emissions of biogenic CO_2 have been included as additional information by sector where applicable and where the data exist. A detailed explanation of the accounting decisions and calculations for biogenic emissions in Vermont is included in the Methodology document.

[5] IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

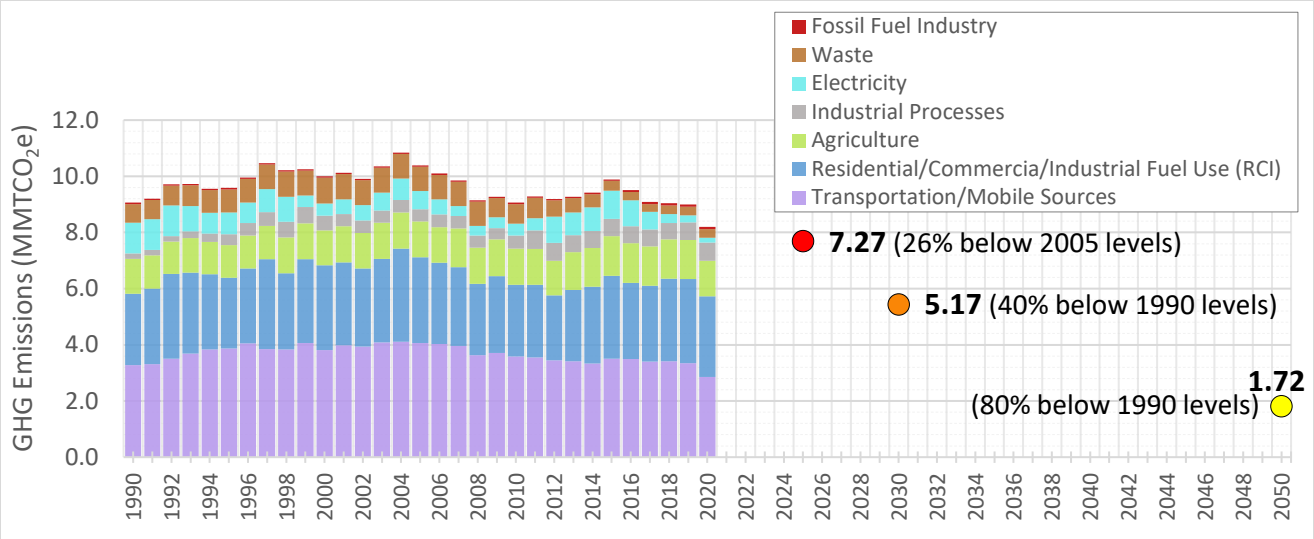

Figure 4: Total and sector-specific GHG emissions in Vermont, 1990-2020 with targets.

2.1.1 Transportation/Mobile Sources

The transportation and mobile sources sector estimates emissions of greenhouse gases related to the movement of people and goods through and around Vermont. The totals include emissions from the combustion of fuels used in cars and trucks on Vermont roads, the use of aviation gasoline and jet fuel for aircraft, and emissions from certain other non-road equipment like recreational vehicles, lawn equipment, boats, and rail (Table 1). The use of gasoline and diesel by vehicles on the roads of Vermont is the largest source of emissions in the sector (Table 2), with light duty gasoline vehicles being the largest source category within the onroad vehicle fleet (Table 3).

The transportation and mobile sources sector has consistently been the highest emitting sector in Vermont, but due to a significant decrease in 2020, emissions from the sector were lower than those from the residential, commercial and industrial fuel use sector. Reductions in transportation sector emissions in 2020 (Figure 5) were due to the COVID-19 pandemic and the resulting reductions in vehicle miles traveled (VMT) and sales of gasoline in the state. Statewide VMT (Figure 6) and sales of gasoline (Figure 7) both rebounded somewhat in 2021, but totals were still below pre-pandemic levels. Emissions levels in this sector depend on a number of complex factors including travel behaviors, fuel prices, vehicle consumer choices, vehicle fuel efficiency standards, and electrification policies and initiatives. These factors are difficult to predict and, in the case of travel behaviors, are likely to be permanently impacted by changes in behavior related to the COVID-19 pandemic.

Table 1: Mobile source contributions by fuel type.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Transportation/Mobile Sources (MMTCO2e)	**3.25**	**4.05**	**3.40**	**3.40**	**3.34**	**2.85**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	3.14	2.50	2.52	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.65	0.76	0.75	0.71	0.65
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.13	0.06	0.07	0.07	0.06
Other sources (CO_2, CH_4, N_2O)	0.15	0.13	0.07	0.06	0.06	0.05
Ethanol (biogenic CO_2)*	0.00	0.01	0.17	0.16	0.17	0.14
Biodiesel (biogenic CO_2)*	0.00	0.00	0.05	0.03	0.02	0.02

** biogenic totals not included in gross total estimates*

Table 2: Percent contribution to transportation emissions from onroad and nonroad sources (2017 NEI)[6].

Transportation Subsector *(NEI and Previous Nonroad methodology)*	Percent Contribution (2017)
Onroad Gasoline and Diesel	85%
Farm/Rail/Boats/Other Diesel and Gas (nonroad)	15%

Table 3: Percent contribution to transportation emissions by vehicle type (2017 NEI)[9].

Onroad Transportation Subsector *(2017 NEI)*	Percent Contribution (2017)
Light-duty Gasoline Vehicles	84%
Heavy-duty Diesel Vehicles	13%
Light-duty Diesel Vehicles	2%
Heavy-duty Gasoline Vehicles	1%

[6] 2017 National Emissions Inventory (NEI) Data: https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data#dataq

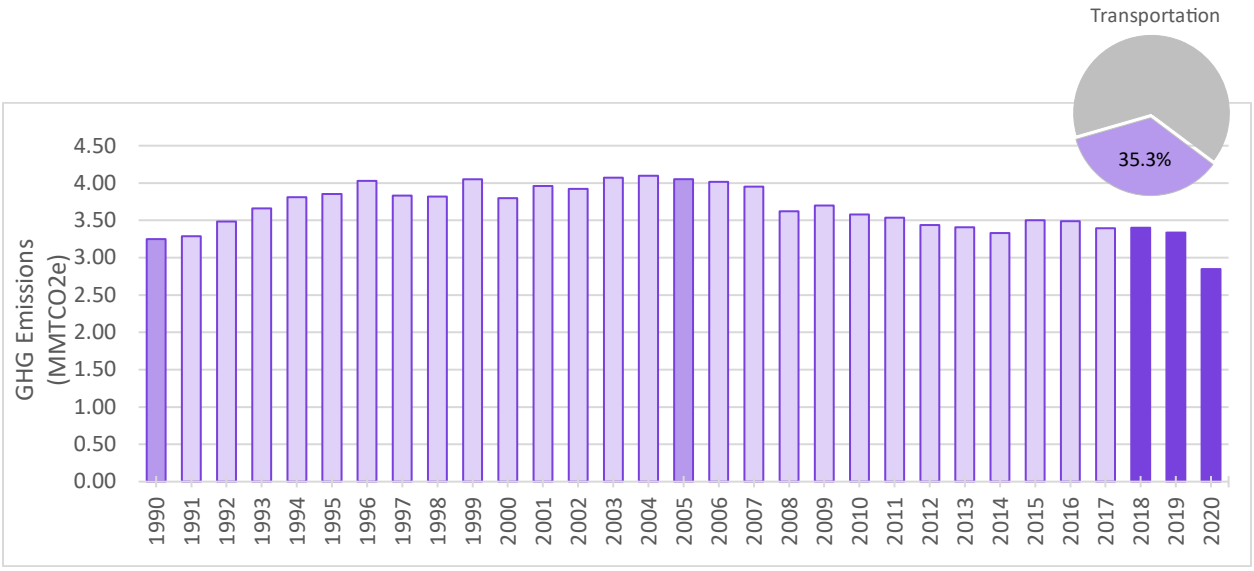

Figure 5: Vermont GHG emissions from transportation/mobile sources sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark purple.

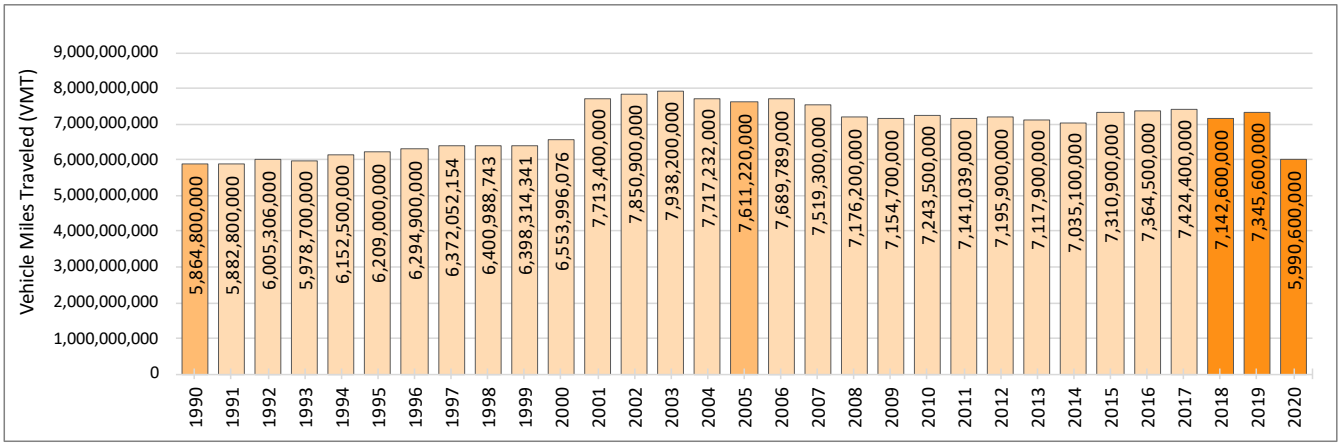

Figure 6: Vehicle miles traveled in Vermont by year (Source: VTrans). Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in darker orange.

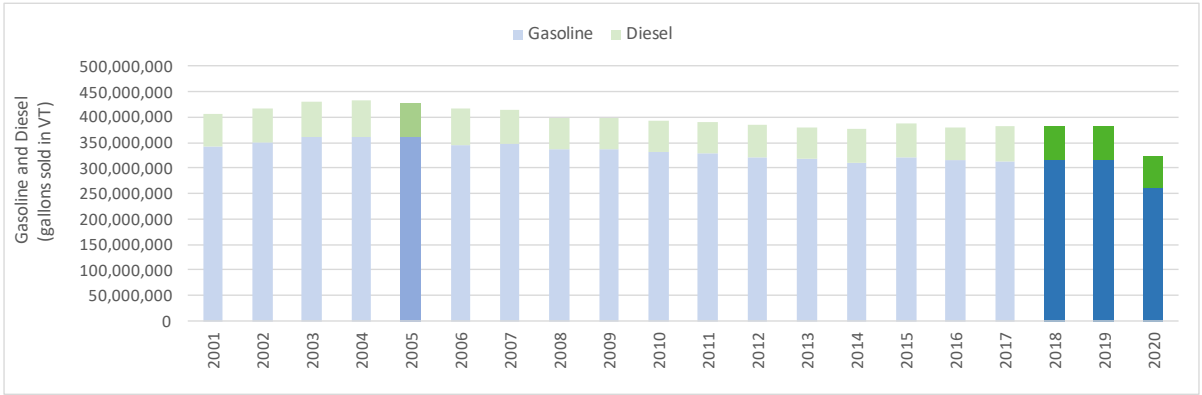

Figure 7: Gallons of gasoline and diesel sold in Vermont by year (Source: Joint Fiscal Office). Years from 2001-2020 are included with the 2005 baseline year highlighted and the updated 2018-2020 values shown in darker blue and green.

2.1.2 Residential/Commercial/Industrial (RCI) Fuel Use

The majority of greenhouse gas emissions from the Residential/Commercial and Industrial Fuel Use sector are related to the use of fossil fuels for space heating, water heating, and cooking, in residential, commercial, and industrial buildings. Emissions are mostly CO_2 from the use of fuel oil, propane, and natural gas but do include methane (CH_4) and nitrous oxide (N_2O) from burning fossil fuels and wood (Table 4). The industrial portion of the RCI sector also includes diesel fuel used in several non-road categories such as farm use, off-highway construction, and logging operations. Due to the decrease in emissions in the transportation sector in 2020, the RCI sector was the highest emitting sector in the state in 2020, barely surpassing the transportation sector total (Figure 2).

The residential subsector is responsible for the greatest share of emissions of the RCI sector at nearly 53% in 2020, followed by the commercial subsector at 30.8% and the industrial subsector at 16.7% (Table 5). The use of fuel oil in the residential subsector is the highest emitting source within the sector overall, followed by residential propane and the use of natural gas in the commercial subsector (Table 5). Overall emissions from the sector increased by 2% from 2018 to 2019 and then decreased by 4.4% between 2019 and 2020. The fluctuation of emissions levels (Figure 8) are caused mainly by winter heating season demand as well as fuel prices, but can also be impacted by weatherization initiatives, fuel switching, and increased efficiency of appliances. RCI sector emissions totals have been plotted with heating degree days in Figure 9, as an indicator of average winter temperatures, to illustrate the relationship between GHG emissions in the RCI sector and winter temperature fluctuations.

Table 4: GHG emissions from the RCI sector by subsector and fuel type.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Residential/ Commercial/ Industrial (RCI) Fuel Use	**2.54**	**3.06**	**2.70**	**2.94**	**3.00**	**2.87**
Residential - Oil, Propane, Natural Gas, and other	1.41	1.66	1.39	1.48	1.56	1.42
Residential - Wood (CH_4, N_2O)	0.06	0.07	0.09	0.09	0.09	0.08
Commercial - Oil, Propane, Natural Gas, and other	0.57	0.72	0.78	0.92	0.89	0.88
Commercial - Wood (CH_4, N_2O)	0.00	0.00	0.00	0.00	0.00	0.00
Industrial - Oil, Propane, Natural Gas and Other	0.47	0.60	0.44	0.44	0.45	0.48
Industrial - Wood (CH_4, N_2O)	0.00	0.00	0.00	0.00	0.00	0.00
Residential - Wood (biogenic CO_2)*	0.83	0.95	1.28	1.30	1.30	1.16
Commercial - Wood (biogenic CO_2)*	0.03	0.01	0.04	0.04	0.04	0.02
Industrial - Wood (biogenic CO_2)*	0.29	0.27	0.16	0.17	0.17	0.13
Renewable Natural Gas (RNG)*	0.000	0.000	0.000	0.000	0.001	0.002

** biogenic totals not included in gross total estimates*

As discussed previously, biogenic emissions are not included in the gross emissions totals in this inventory. The biogenic CO_2 values from the burning of wood (listed in Table 4) are included here for informational purposes only, and the methodology used for calculating these totals, as well as the IPCC guidance related to biogenic emissions, is discussed in the Methodology document.

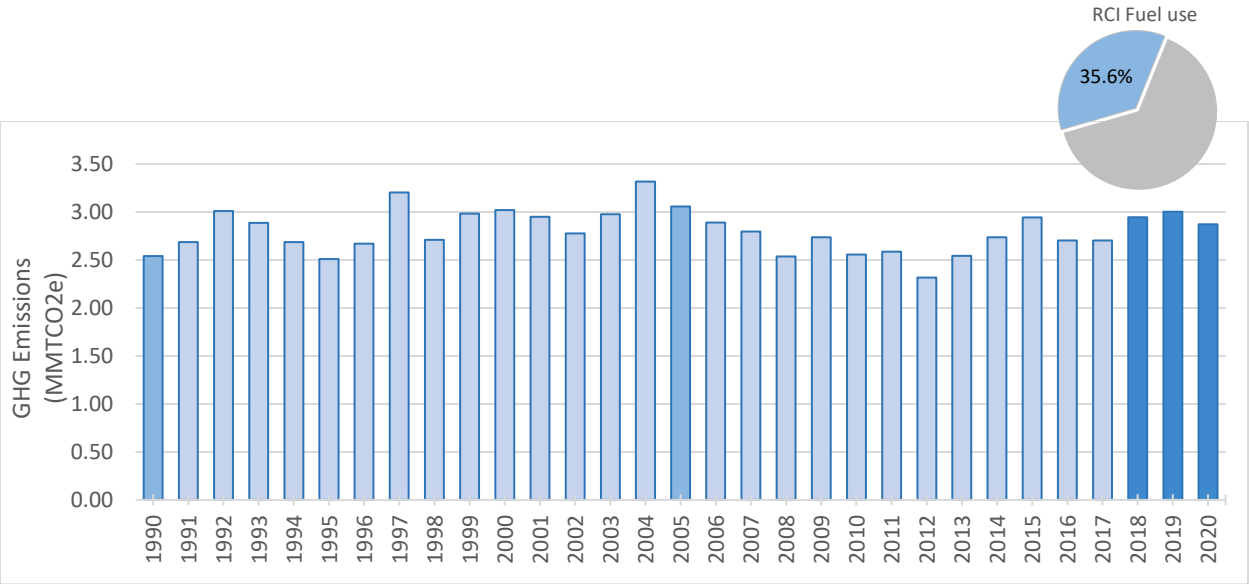

Figure 8: Vermont GHG emissions from the RCI sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark blue.

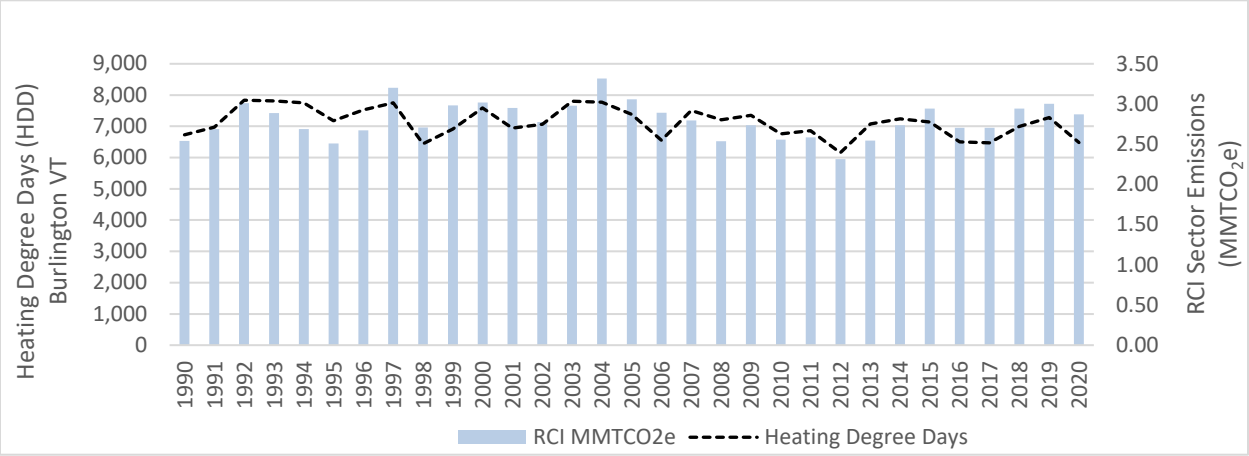

Figure 9: Vermont RCI sector emissions in $MMTCO_2e$ plotted with the heating degree days (the difference between 65 degrees and a day's average temperature if below 65 degrees) from 1990 – 2020.

Table 5: GHG emissions contributions by fuel type and subsector within the RCI sector (2020).

RCI Breakdown by Subsector and by Fuel (2020)	Subsector	Emissions ($MMTCO_2e$)	Percent of Subsector Total	Percent of Total by Subsector
Fuel Oil	Residential	0.80	53.2%	52.5%
Propane	Residential	0.38	25.4%	
Natural Gas	Residential	0.21	13.8%	
Wood ($CH_4 + N_2O$)	Residential	0.08	5.6%	
Other	Residential	0.03	2.0%	
Total	**Residential**	**1.51**	**100%**	
Fuel Oil	Commercial	0.23	25.4%	30.8%
Propane	Commercial	0.22	24.9%	
Natural Gas	Commercial	0.38	43.2%	
Wood ($CH_4 + N_2O$)	Commercial	0.00	0.2%	
Other	Commercial	0.06	6.3%	
Total	**Commercial**	**0.89**	**100%**	
Fuel Oil	Industrial	0.30	62.0%	16.7%
Propane	Industrial	0.01	2.2%	
Natural Gas	Industrial	0.12	24.3%	
Wood ($CH_4 + N_2O$)	Industrial	0.00	0.4%	
Other	Industrial	0.05	11.1%	
Total	**Industrial**	**0.48**	**100%**	
Grand Total	**All**	**2.87**		**100.0%**

2.1.3 Agriculture

The agriculture sector includes estimates of the emissions of CH_4 and N_2O from agricultural practices and activities in Vermont. These include emissions related to the digestive processes of animals, manure management, fertilizer application, and processes related to agricultural soils. Carbon dioxide emissions from this sector are almost entirely biogenic, and so are not included in the sector totals, with the exception of liming and urea fertilization (Table 6). Total emissions from the sector have remained relatively constant in the last several years (Figure 10), declining by about 1% from 2018 to 2019 and with a slightly larger decline of around 9% in 2020. This trend is likely due to decreases in emissions from fertilizer, and a slightly lower number of dairy cows.

Agricultural emissions totals in the Inventory do not account for any sequestration (removal of CO_2 from the atmosphere) by vegetation, storage in agricultural soils, or any emissions benefits from agricultural management practices such as no till or cover cropping. Many Vermont farmers are already working to reduce emissions from their farms by adopting agricultural conservation practices to reduce tillage and fertilizer use and these practices have benefits for both GHG emissions and water quality. As recommended by the Vermont Climate Council, ANR is currently working with the Agency of Agriculture Food and Markets (AAFM) through a

consultant process to investigate the availability of tools and datasets that will allow for more accurate accounting and a more holistic picture of greenhouse gas emissions and sinks associated with the agricultural sector in Vermont. Additional information related to data and emissions from the agricultural sector in the state can be found in the Vermont Carbon Budget report[7] that was completed as a part of the GWSA and Climate Action Plan process.

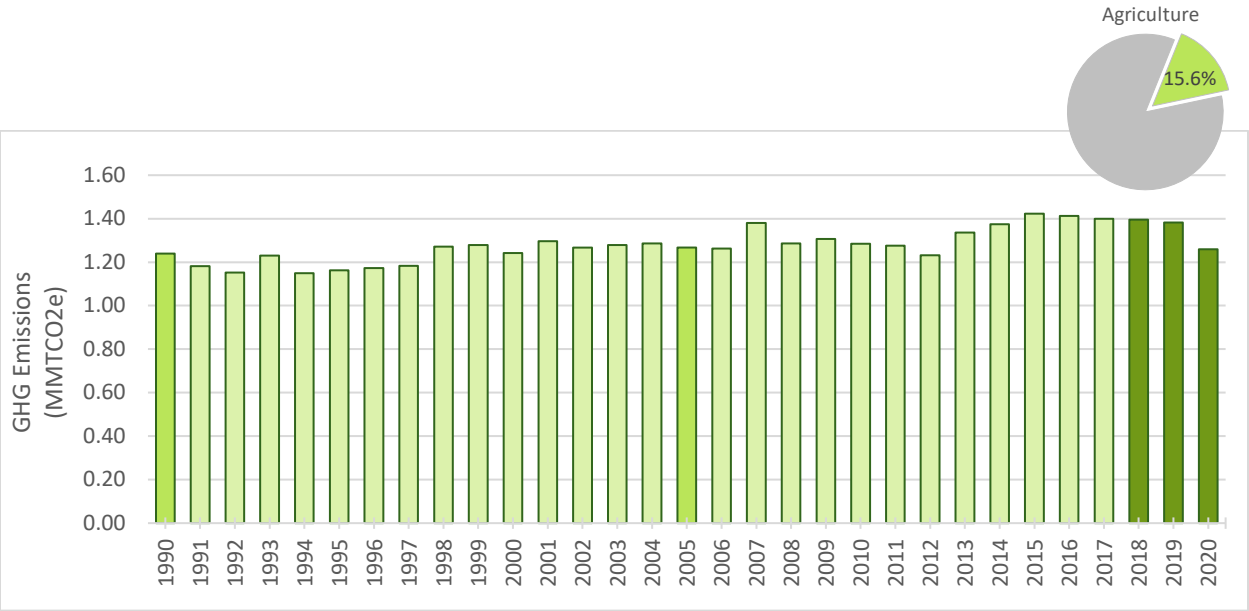

Figure 10: Vermont GHG emissions from the agriculture sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark green.

Table 6: GHG emissions contributions of subsectors within the agriculture sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Agriculture	**1.24**	**1.27**	**1.40**	**1.40**	**1.38**	**1.26**
Enteric Fermentation (CH_4, N_2O)	*0.70*	*0.63*	*0.64*	*0.64*	*0.63*	*0.61*
Manure Management (CH_4, N_2O)	*0.18*	*0.33*	*0.35*	*0.36*	*0.35*	*0.33*
Agricultural Soils (CH_4, N_2O)	*0.36*	*0.30*	*0.35*	*0.36*	*0.37*	*0.29*
Liming and Urea Fertilization (CO_2)	*0.00*	*0.00*	*0.05*	*0.04*	*0.04*	*0.03*

[7] Vermont Carbon Budget Report: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Carbon%20Budget%20for%20Vermont%20Sept%202021.pdf

2.1.4 Industrial Processes

The Industrial Processes (IP) sector includes GHG emissions related to industrial manufacturing processes occurring in Vermont, as well as the use of high GWP gases in a number of applications. Many of the high emitting manufacturing categories generally covered in the IP sector of GHG inventories, such as the production of chemicals and materials like lime, ammonia, nitric acid, cement, iron, and steel, are not occurring in Vermont. The state does not have many large manufacturing facilities, which is evidenced by the fact that there are less than a dozen facilities in the state that report to EPA's Greenhouse Gas Reporting Program[8], which has a reporting threshold of 25,000 metric ton CO_2e. There are emissions of sulfur hexafluoride (SF_6) associated with the electric transmission system in Vermont, which have the potential to increase with additional electrification initiatives, however, emissions of high GWP fluorinated gases from ozone depleting substances (ODS) substitutes, and the manufacturing of semiconductors dominate emissions from the sector making up around 94% of the total (Table 7). Emissions estimates from the IP sector have remained fairly flat from 2018 to 2020, with a small increase in emissions from semiconductor manufacturing (Figure 11).

Ozone depleting substances substitutes are gases that are being used to replace gases that deplete the ozone layer. A number of these gases, mainly hydrofluorocarbons (HFCs), are very potent planet warming gases with high GWPs and their use and leakage into the atmosphere is a driver of global warming. These gases are used in refrigeration equipment, air conditioning equipment, aerosol propellants, and foams. The phase out and replacement of these substances with lower GWP alternatives is underway in Vermont through the passage of Act 65 (2019)[9] and Act 121 (2022)[10], which prohibits the use of high-GWP HFCs in certain end uses.

The manufacturing of semiconductors is a complex process that requires the use of very high GWP gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). These gases are used in the plasma etching and chemical vapor deposition process, as well as in heat transfer fluids. Emissions can be mitigated by adding destruction devices to combust some of the high GWP gases before they are released to the atmosphere, and by finding alternatives for the gases used in the processes themselves.

[8] EPA Greenhouse Gas Reporting Program: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp
[9] Vermont Act 65: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT065/ACT065%20As%20Enacted.pdf
[10] Vermont Act 121: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT065/ACT065%20As%20Enacted.pdf

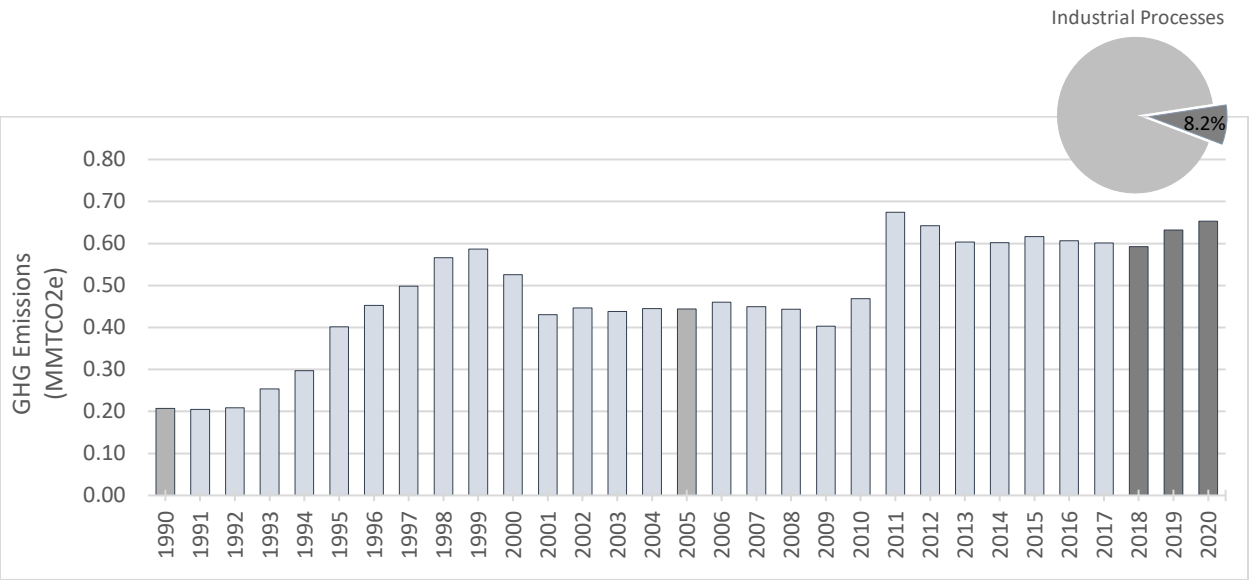

Figure 11: Vermont GHG emissions from the industrial processes sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark grey.

Table 7: GHG emissions contributions of subsectors with the industrial process sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Industrial Processes	**0.21**	**0.44**	**0.60**	**0.59**	**0.63**	**0.65**
ODS Substitutes (HFCs, PFCs, NF_3 SF_6)	0.00	0.18	0.34	0.34	0.36	0.37
Electric Utilities (SF_6)	0.04	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs, NF_3 SF_6)	0.16	0.21	0.23	0.22	0.23	0.24
Limestone & Dolomite Use (CO_2)	0.00	0.03	0.02	0.02	0.03	0.03
Soda Ash Use (CO_2)	0.01	0.01	0.00	0.00	0.00	0.00
Urea Consumption (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00

2.1.5 Electricity Consumption

The electricity sector includes emissions associated with all electricity used by Vermonters and is the only sector in the inventory where emissions that occur outside of the boundaries of the state are accounted for. This is because in Vermont we consume more than three times as much electricity as we generate in state[11] and also makes sense from the perspective of the interconnected nature of the New England electric grid. Emissions estimates are still only for emissions that occur at the point of generation and do not include estimates of any emissions that occur "upstream" of the sources themselves. Sources of electricity that are considered renewable have been assumed to have zero emissions within this accounting framework. Additional

[11] Energy Information Administration (EIA) – State Profile and Energy Estimates: https://www.eia.gov/state/?sid=VT

information on the methodologies for estimating emissions in the electric sector can be found in the Methodology document.

Electricity sector emissions reported previously from 2016 through 2019 have been updated in this report. Totals for those years were estimated artificially lower because the data utilized for the calculations was based on customer retail sales instead of total generation and load, and so did not include emissions from the electricity that was lost during transmission to customers. The correction of this error and the associated update increases the electricity sector totals for those years, as can be seen in Table 8 below.

Table 8: Difference in electricity sector totals from 2016 – 2019 from previous report.

Sector	Emissions in $MMTCO_2e$					
	2015	2016	2017	2018	2019	2020
Electricity Sector Previous Report (1990 - 2017)	1.00	0.81	0.49	0.18	0.13	NA
Electricity Sector Updated Values (including line losses)	1.00	0.92	0.62	0.31	0.25	0.18
Difference Resulting from Update	**0.00**	**0.11**	**0.13**	**0.13**	**0.13**	**0.00**

Even with the updates to the emissions totals to include line losses, the electricity sector remains one of the lowest emitting sectors in the state (Appendix A) and accounted for 2.2% of statewide emissions in 2020 with the majority of emissions associated with the residual system mix portion of the portfolio (Table 9). Low emissions totals from the sector are due mainly to our reliance on electricity from hydroelectric and nuclear generation. Declines in emissions in this sector (Figure 12) are attributed to distribution utilities meeting and exceeding Renewable Energy Standard (RES)[12] requirements for their electricity portfolios. In the last several years between 57% and 69% of the electricity in Vermont has been from hydroelectric generation with electricity and renewable energy certificates (RECs) from Hydro-Québec (HQ) being well over half of that total.

[12] Vermont Public Utility Commission – Renewable Energy Standard: https://puc.vermont.gov/electric/renewable-energy-standard

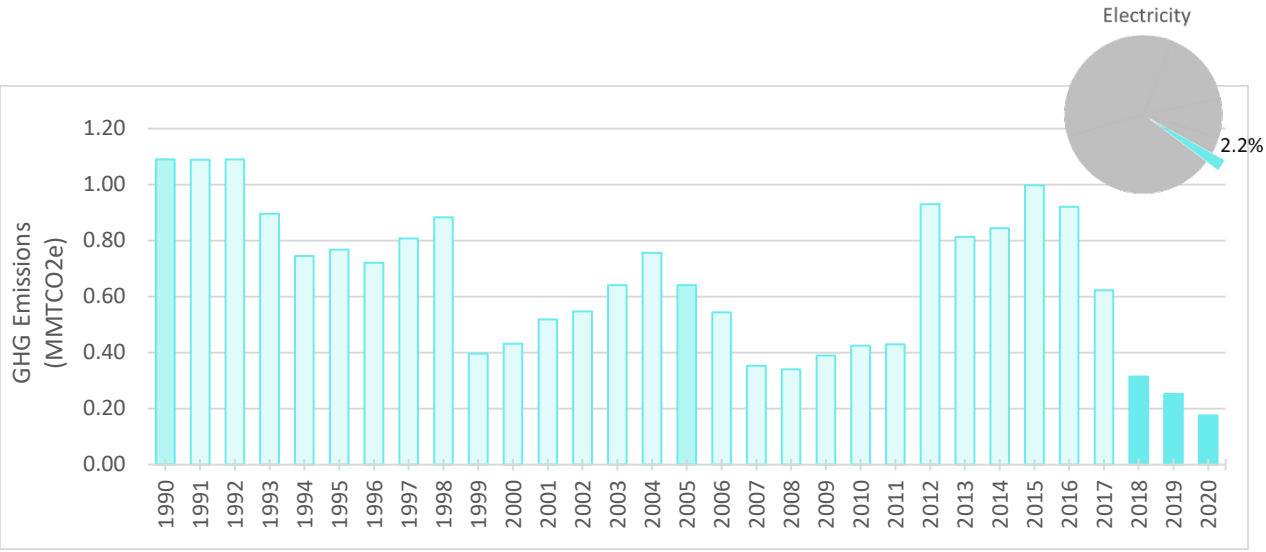

Figure 12: Vermont GHG emissions from the electricity sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in bright blue.

Table 9: GHG emissions contributions by fuel and system mix in the electric sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Electricity Consumption	**1.09**	**0.64**	**0.62**	**0.31**	**0.25**	**0.18**
Coal	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.01	0.00	0.00	0.00
Oil	0.01	0.01	0.00	0.00	0.00	0.00
Wood (CH_4, N_2O)	0.00	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.62	0.60	0.30	0.24	0.16

* Biogenic CO_2 emissions are not included in totals[13]

2.1.6 Waste

Emissions of greenhouse gases associated with the waste sector include CH_4 and N_2O from both solid waste and wastewater. This includes emissions related to wastewater treatment systems, landfills, and composting. Carbon dioxide emissions from the waste sector are considered biogenic and are not included in the sector totals. Total emissions from both the solid waste and wastewater sectors remained flat from 2018 through 2020 (Figure 13), and the waste sector remains one of the smallest emitting sectors at 1.9% of the statewide total. Emissions estimates

[13] Biogenic emissions from wood combustion for the generation of electricity are not included in the Inventory totals. This includes emissions from the two main wood biomass electric generation facilities in the state, McNeil and Ryegate. Biogenic CO_2 emissions from these two facilities are significant, totaling approximately 0.86 $MMTCO_2e$ in 2020, but are not accounted for in the Inventory both because the emissions are biogenic and because the RECs produced by these two facilities are sold almost exclusively outside of Vermont. Additional information related to the accounting of biogenic CO_2 can be found in the Methodology document.

for the sector were updated in this inventory report using supplemental information from EPA for industrial wastewater and composting that had not been available until recently. The addition of these two subcategories has increased the totals from the sector since the previous report (Table 10). Vermont's Universal Recycling law (Act 148)[14] has helped to lower emissions in the solid waste sector by banning recyclable materials, leaf and yard debris, and food scraps from landfills which reduces the amount of landfill gas produced.

Table 10: GHG emissions contributions within the waste sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Waste	**0.27**	**0.35**	**0.15**	**0.16**	**0.16**	**0.16**
Solid Waste (CH_4, N_2O)	0.21	0.28	0.07	0.08	0.08	0.08
Composting (CH_4, N_2O)	0.00	0.01	0.01	0.01	0.01	0.01
Wastewater (CH_4, N_2O)	0.05	0.07	0.06	0.06	0.06	0.07

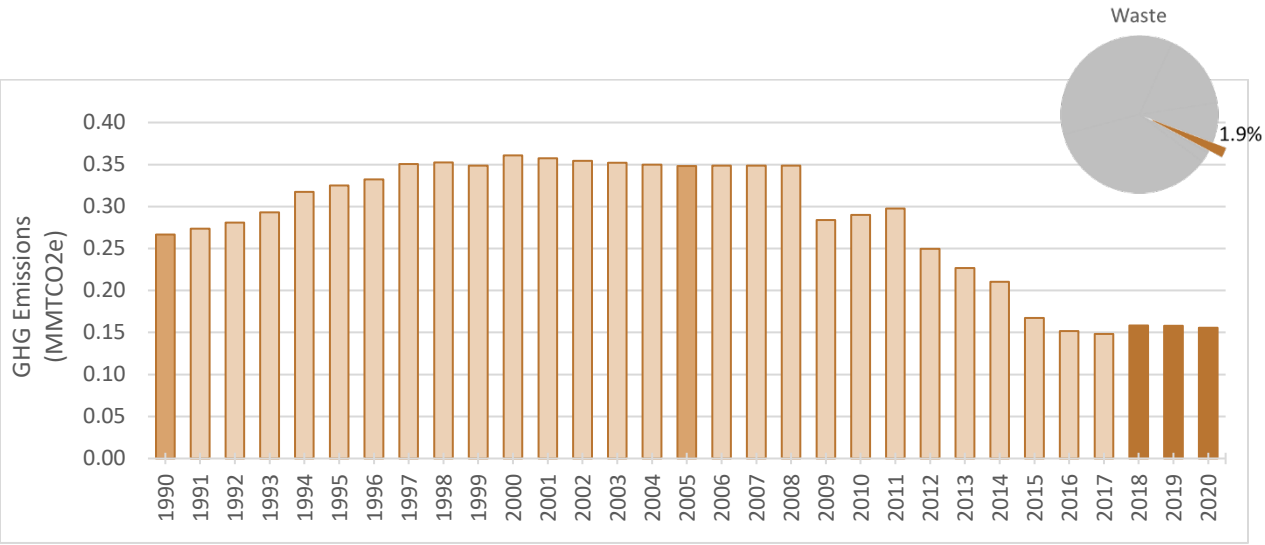

Figure 13: Vermont GHG emissions from the waste sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark brown.

2.1.7 Fossil Fuel Industry

Emissions of greenhouse gases from the fossil fuel industry account for CH_4 emissions from natural gas leaks or fugitive emissions from the transmission and distribution pipelines and related services in Vermont. All of the emissions related to the combustion of fossil fuels is captured within other sectors in this inventory. Total emissions from the sector account for only

[14] Vermont Department of Environmental Conservation – Universal Recycling Law: https://dec.vermont.gov/waste-management/solid/universal-recycling

0.3% of the statewide total. Emissions in this sector increase as new natural gas services and lines are installed, but those increases are offset to some degree as older, and more leak prone pipe and service types are replaced with pipes and services made from updated and less leak prone materials (Figure 14). This offsetting effect has led to stable emissions levels in this sector in the last several years (Table 11) after the increase seen from the extension of Vermont Gas services to Addison County.

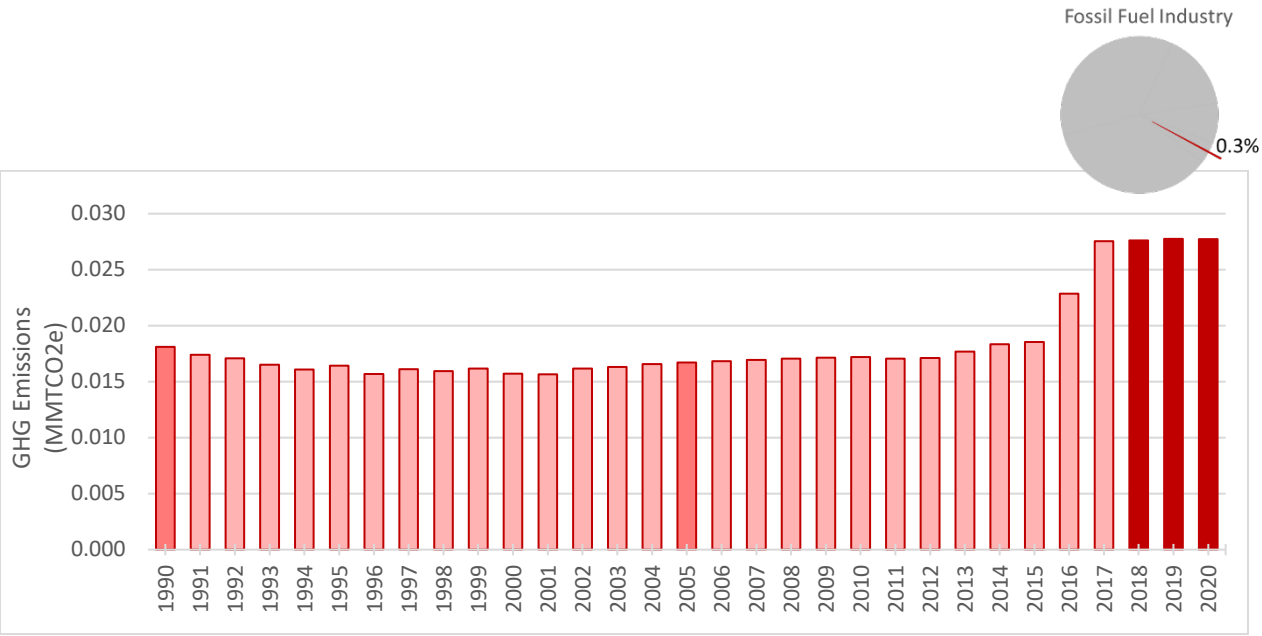

Figure 14: Vermont GHG emissions from the fossil fuel industry sector. Years from 1990-2020 are included with the 1990 and 2005 baseline years highlighted and the updated 2018-2020 values shown in dark red.

Table 11: GHG emissions contributions within the fossil fuel industry sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2017	2018	2019	2020
Fossil Fuel Industry	**0.018**	**0.017**	**0.028**	**0.028**	**0.028**	**0.028**
Natural Gas Distribution (CH_4)	0.007	0.003	0.004	0.004	0.004	0.004
Natural Gas Transmission (CH_4)	0.011	0.014	0.023	0.023	0.023	0.023

3 Additional Emissions Inventory Components

Discussion of estimates of emissions and sinks from sectors or portions of sectors that are not included in the official gross inventory totals published in the Inventory are provided below. For additional explanation of why certain emissions and sinks are not accounted for in the total gross emissions for Vermont, please refer to the *Methodologies* document.

3.1 Land Use, Land-Use Change, and Forestry (LULUCF)

Greenhouse gas emissions and sequestration resulting from changing or maintaining certain land uses as well as the cycling and storage of carbon in the forests of Vermont is a critical component to understanding a more holistic picture of GHG emissions in the state. Forests and other vegetation sequester CO_2 from the atmosphere and convert it into stored biological material through the process of photosynthesis, essentially removing or negating GHG emissions released into the atmosphere. Some of that sequestered carbon can also be transferred into soils for potentially longer-term storage in forests, agricultural lands, and other land types. Changes to land use can impact the carbon stored on that land either causing it to be emitted as CO_2 or potentially increasing sequestration, depending upon the change. Managing natural working lands (NWL) and conserving forests and other natural ecosystems is crucial to increase resilience to climate change, and to allow these systems to both retain and potentially store more carbon.

Accurately estimating the emissions and/or sequestration (sink) based on annual changes in the landscape and forests to determine an overall net emission or sink is challenging. Data are not readily available or high enough resolution to estimate these changes at the state level every year, and carbon cycling through these systems and ecosystems is complex and not always well understood. In the previous inventory report only sequestration by forests was included as supplemental information because estimates were available from the Forest Inventory and Analysis (FIA)[15] program. This inventory report includes newly released estimates[16] from the EPA of state-level emissions and sinks from land use conversions for land use types besides forests. This supplemental information was created by the EPA by downscaling estimates calculated for the National Inventory Report[17]. Estimates of the changes in carbon on the landscape (fluxes) and carbon emitted and sequestered by forests are shown in Table 12. The LULUCF sector in Vermont is a large emissions sink overall, meaning that it sequesters far more CO_2 than is emitted within the sector, but the annual sequestration has been declining steadily since 1990 as can be seen in the green bars in Figure 15 below. Sequestration in the state is dominated by forests as seen in Table 12, and the declining sequestration over time mirrors the loss of forested land in the state[18]. Additional information related to the LULUCF sector estimates can be found in the Methodology document.

[15] Forest Inventory and Analysis (FIA) Program: https://www.fia.fs.usda.gov/
[16] EPA State GHG Emissions and Removals: https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals
[17] EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020
[18] Vermont Forest Parks and Recreation – Vermont Forest Carbon Inventory: https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Climate_Change/Files/VermontForestCarbonInventory_Mar2021.pdf

Table 12: Emissions and sinks for select years from the LULUCF sector in Vermont.

Land-Use, Land use change, and Forestry (LULUCF)	Emissions/Sequestration in $MMTCO_2e$								
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**	**2020**
Forest Carbon Flux (Forest Land Remaining Forest Land)	(9.17)	(8.61)	(8.09)	(7.51)	(7.16)	(6.73)	(6.48)	(6.41)	(6.35)
Aboveground Biomass	*(4.12)*	*(4.11)*	*(4.12)*	*(4.14)*	*(4.17)*	*(4.02)*	*(3.95)*	*(3.92)*	*(3.88)*
Belowground Biomass	*(0.79)*	*(0.79)*	*(0.79)*	*(0.79)*	*(0.80)*	*(0.77)*	*(0.76)*	*(0.75)*	*(0.74)*
Deadwood	*(1.36)*	*(1.32)*	*(1.27)*	*(1.19)*	*(1.06)*	*(0.96)*	*(0.90)*	*(0.88)*	*(0.87)*
Litter	*(0.17)*	*(0.15)*	*(0.13)*	*(0.12)*	*(0.11)*	*(0.11)*	*(0.10)*	*(0.10)*	*(0.10)*
Soil (Mineral)	*(1.23)*	*(1.02)*	*(0.84)*	*(0.66)*	*(0.46)*	*(0.26)*	*(0.21)*	*(0.20)*	*(0.20)*
Soil (Organic)	-	-	-	-	-	-	-	-	-
Drained Organic Soil	-	-	-	-	-	-	-	-	-
Total wood products and landfills	*(1.50)*	*(1.22)*	*(0.94)*	*(0.61)*	*(0.56)*	*(0.61)*	*(0.56)*	*(0.56)*	*(0.56)*
Land Converted to Forest Land	(0.27)	(0.27)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Cropland Remaining Cropland (Ag soil carbon flux)	(0.18)	(0.20)	(0.10)	(0.15)	(0.15)	(0.10)	(0.09)	(0.09)	(0.11)
Land Converted to Cropland	0.38	0.42	0.42	0.42	0.44	0.48	0.48	0.48	0.48
Grassland Remaining Grassland	(0.04)	(0.05)	(0.04)	(0.01)	(0.01)	0.04	0.01	0.02	0.00
Land Converted to Grassland	(0.03)	(0.05)	(0.04)	(0.03)	0.00	(0.03)	(0.02)	(0.02)	(0.02)
Wetlands Remaining Wetlands	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Land Converted to Wetlands	0.00	0.00	0.00	0.00	0.00	-	-	-	-
Settlements Remaining Settlements	(0.37)	(0.36)	(0.37)	(0.38)	(0.40)	(0.41)	(0.40)	(0.40)	(0.40)
Land Converted to Settlements	0.55	0.60	0.65	0.68	0.71	0.73	0.74	0.74	0.74
LULUCF Net CO_2 Flux (w/ harvested wood products)	**(9.14)**	**(8.52)**	**(7.83)**	**(7.24)**	**(6.84)**	**(6.27)**	**(6.02)**	**(5.94)**	**(5.92)**

** Note that parentheses indicate net sequestration.*

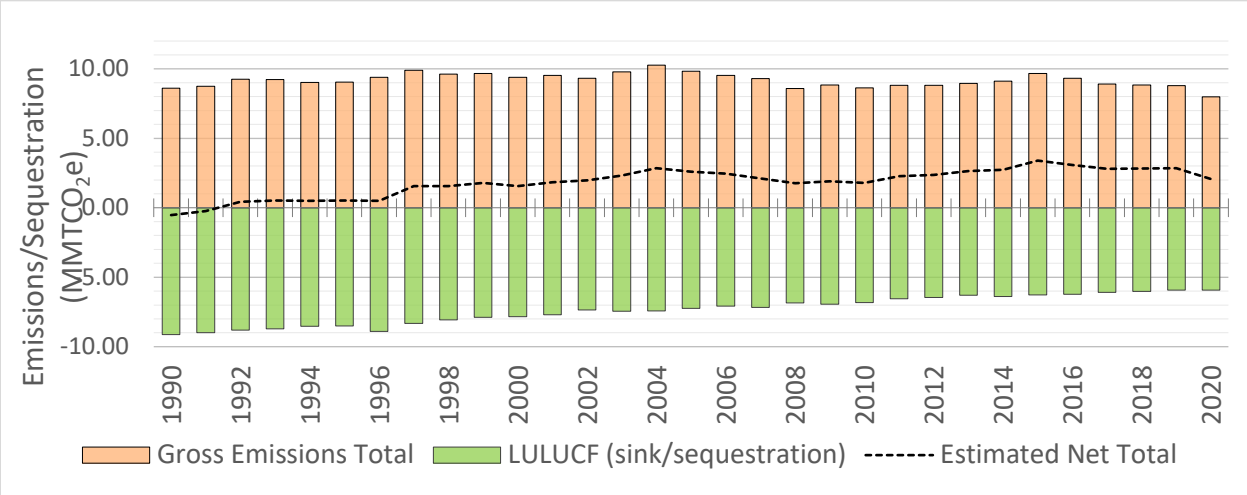

Figure 15: Estimated gross emissions, total sequestration, and net GHG levels in Vermont from 1990-2020.

3.2 Biogenic CO_2

Emissions of biogenic CO_2 are directly tied to the LULUCF sector. Wood use for energy is the largest source of human-caused biogenic CO_2 emissions in Vermont, but those emissions are not included in the inventory totals because the carbon (and releases of CO_2) from that wood is captured in the changes in carbon on the landscape and in the forests of Vermont as per IPCC guidelines. Estimating the carbon and CO_2 fluxes from changes in land use and from forests is not an exact science, nor are there currently accurate data on the amount of wood cut, imported, or combusted annually in Vermont to compare the LULUCF flux estimates to. Biogenic CO_2 estimates have been included in several of the inventory sectors in this report as supplemental information and to help provide a sense of scale of these emissions and transfer of carbon from the landscape. Additional work is ongoing with other states in the region to coordinate methodologies to estimate emissions and sinks in the LULUCF sector and related to forests and forest carbon.

3.3 GWP_{bio}

GWPbio is a factor that is used to account for a portion of biogenic CO_2 emissions at the point of combustion, specifically for the combustion of wood, while also giving partial emissions credit for the renewability of the resource. One of the main influences of GWP_{bio} factors are the rotation periods for the harvested biofuels. Essentially, the longer the rotation period for the vegetation that was cut and combusted to regrow, the higher the associated GWP_{bio} multiplier. These factors are meant to be applied to lifecycle emissions estimates but given the importance of emissions from wood combustion in Vermont and the acknowledgement that the pulse of CO_2 emitted when biomass is combusted leads to additional global warming before the CO_2 can be re-sequestered, providing an alternative accounting framework seems appropriate. A GWP_{bio} factor of 0.32 was taken from the Biogenic Carbon Footprint Calculator[19] for cool temperate climate and used to estimate the values shown in Table 13 below.

Table 13: GWP_{bio} Emissions estimates for the RCI sector.

RCI Sector - GWPbio	MMTCO$_2$e					
	1990	2005	2017	2018	2019	2020
Residential - Wood (biogenic CO2 - GWP_{bio})	0.27	0.30	0.41	0.42	0.42	0.37
Commercial - Wood (biogenic CO2 - GWP_{bio})	0.01	0.00	0.01	0.01	0.01	0.01
Industrial - Wood (biogenic CO2 - GWP_{bio})	0.09	0.09	0.05	0.06	0.05	0.04

[19] Biogenic Carbon Footprint Calculator – World Wildlife Federation: https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx

4 Emissions Forecasts

4.1 Projected GHG Emissions Levels for 2025 and 2030

As is seen in this inventory report, emissions of greenhouse gases come from a variety of different sectors and processes, and are influenced by many factors including the economy, markets, state and federal policies and regulations, personal and consumer choices, and unforeseen events such as the COVID-19 pandemic. Estimating what greenhouse gas emissions totals will be in a future year requires making many assumptions. Recent modeling completed through 2050 to inform the Vermont Climate Action Plan (CAP)[20] and the Comprehensive Energy Plan (CEP)[21] is used here to project emissions estimates in the Inventory. This is a change from the projection methodologies used in previous inventory reports because this Vermont specific CAP and CEP modeling was not available for those Inventory iterations. Greenhouse gas estimates and modeling performed as a part of the CAP/CEP process included business as usual (BAU) baseline estimates, which are estimates of emissions levels assuming similar trends continue into the future without any new policies to reduce emissions. The CAP/CEP modeling and assumptions differed from those used in this inventory report, so percent changes in the modeled BAU totals were used to project the emissions in this report for each sector as seen in Table 13 below.

The decline in emissions estimates for 2020 in this report are a very real example of the impact that social and economic events can have on GHG emissions, and why they are difficult to accurately predict. It is unclear to what extent, if any, the reductions seen in 2020 will maintain and become permanent behavioral changes, and this will likely have a real impact on future emissions levels in Vermont and globally. The data and tools needed to complete emissions estimates for 2021 are not yet available. However, based on fuel sales and VMT data for 2021 (Figure 16 and Figure 17) emissions in the transportation sector are expected to rebound somewhat.

[20] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan
[21] Vermont Comprehensive Energy Plan: https://publicservice.vermont.gov/about-us/plans-and-reports/department-state-plans/2022-plan

Table 14: GHG emissions projections using percent changes from CAP modeling[22].

Sector	2018 Inventory ($MMTCO_2e$)	Pathways BAU Percent Change (2018 - 2025)	Pathways BAU Percent Change (2018 - 2030)	2025 Projection ($MMTCO_2e$)	2030 Projection ($MMTCO_2e$)
Electricity	0.31	21.9%	-3.8%	0.38	0.30
Transportation/Mobile	3.40	-6.6%	-36.8%	3.18	2.15
Residential/Commercial/Industrial Fuel Use (RCI)	2.94	-4.9%	-10.1%	2.80	2.65
Agriculture	1.40	0.6%	1.3%	1.40	1.41
Industrial Processes	0.59	1.8%	4.1%	0.60	0.62
Waste	0.16	0.2%	0.5%	0.16	0.16
Fossil Fuel Industry	0.03	1.0%	1.6%	0.03	0.03
Total	**8.83**			**8.55**	**7.32**

Note: Percent changes in the transportation sector estimates are from the mitigation scenario modeling that uses higher electric vehicle adoption rates. The Advanced Clean Cars II regulation had not been adopted when the original BAU projections were made and so was not incorporated. Percent changes in the agricultural sector were used from 2020 – 2025 because of an artificial drop in emissions from that sector in the BAU modeling that was skewing the projections.

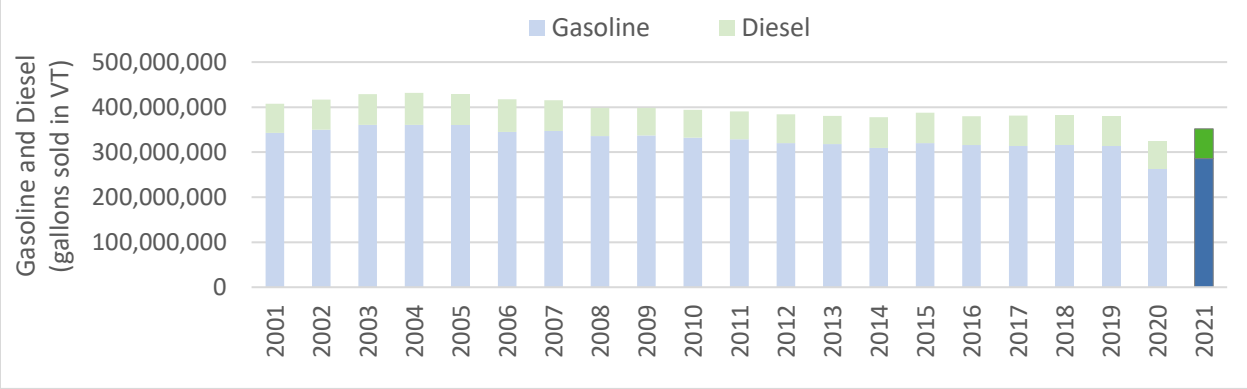

Figure 16: Gallons of gasoline and diesel sold in Vermont by year (Source: Joint Fiscal Office).

[22] Projections in Table 14 are based on an extrapolation of 2018 GHG inventory estimates. Because the BAU modeling was completed before the 2020 emissions estimates had been completed for this GHG Emissions Inventory report and before data related to the impacts of the COVID-19 pandemic were available, GHG emissions in 2020 in the transportation sector estimates in the BAU are larger than in reality. Since the projections in this table were based on 2018 GHG Inventory report values, which did not reflect decreases in transportation sector emissions related to the COVID-19 pandemic, and those emissions reductions were also not captured in the BAU modeling, the estimates in the table are artificially inflated. The amount to which they are inflated depends in large part on the extent emissions in the transportation sector rebound to pre-COVID levels in the coming years, however, the projections in the next iteration of the GHG Emissions Inventory and Forecast report are expected to be lower.

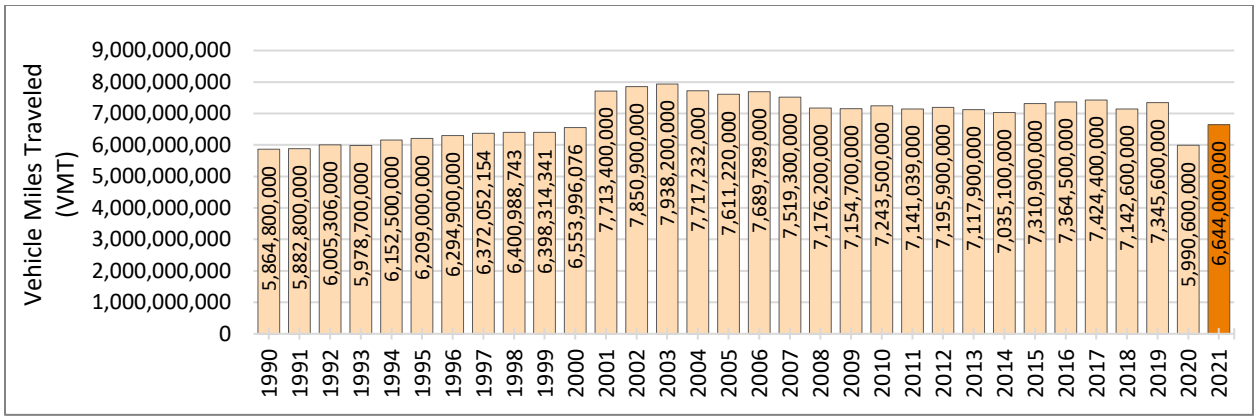

Figure 17: Vehicle miles traveled in Vermont by year (Source: VTrans)

5 Conclusion

The 1990-2020 Vermont Greenhouse Gas Emissions Inventory and Forecast report provides both current and historical estimates of GHG emissions in Vermont. Historical emissions totals serve as baseline values to track progress towards Vermont's mandated emissions levels and provide insights into which sectors to prioritize for mitigation policies. The three new years of data released in this report (2018-2020), show very slight declines in overall emissions. Emissions levels dropped again in 2020 but this was due mainly to decreases in the transportation sector related to impacts from the COVID-19 pandemic, which are expected to at least partially rebound based on 2021 fuel sales and VMT data.

This inventory report is one way to understand GHG emissions associated with Vermont and the actions of Vermonters. The approaches taken by the Agency of Natural Resources for this annual in-boundary inventory attempt to maintain consistency with other states in the region, as well as IPCC guidelines, and are based on data availability and the most current understanding of the various methods and tools to estimate GHG emissions. There are several analyses currently underway that will help to provide additional information and insights in the future on specific sectors and using alternative frameworks and assumptions. These analyses will inform policies and decisions related to GHG emissions and activities in the state, including a lifecycle emissions analysis to better understand the "upstream" and "downstream" emissions from energy use in Vermont, a consumption-based inventory that combines lifecycle emissions with consumption estimates for the state, an analysis to incorporate local data and more accurately quantify emissions and sequestration on a net basis from agricultural practices, and a project to improve estimates and tracking of forest carbon on a regional level. When these analyses and reports are completed they will provide additional information to supplement and expand upon estimates provided in this report.

Appendix A – Vermont Historic Greenhouse Gas Emissions by Sector [23]

Sector	Million Metric Tons CO_2 Equivalent: $MMTCO_2e$																						
	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity Supply & Demand (consumption based)	**1.09**	**0.77**	**0.43**	**0.52**	**0.55**	**0.64**	**0.76**	**0.64**	**0.54**	**0.35**	**0.34**	**0.39**	**0.43**	**0.43**	**0.93**	**0.81**	**0.84**	**1.00**	**0.92**	**0.62**	**0.31**	**0.25**	**0.18**
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00
Oil	0.01	0.01	0.06	0.03	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.47	0.51	0.59	0.71	0.62	0.51	0.31	0.29	0.34	0.36	0.37	0.90	0.78	0.81	0.96	0.90	0.60	0.30	0.24	0.16
Residential / Commercial / Industrial (RCI) Fuel Use	**2.54**	**2.51**	**3.02**	**2.95**	**2.78**	**2.98**	**3.32**	**3.06**	**2.89**	**2.79**	**2.54**	**2.74**	**2.56**	**2.58**	**2.32**	**2.54**	**2.74**	**2.94**	**2.70**	**2.70**	**2.94**	**3.00**	**2.87**
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.31	0.37	0.50	0.42	0.44	0.45	0.47	0.45	0.43	0.48	0.46	0.46	0.45	0.46	0.43	0.51	0.57	0.64	0.65	0.65	0.75	0.76	0.71
Oil, Propane & Other Petroleum	2.14	2.05	2.45	2.46	2.27	2.46	2.78	2.53	2.38	2.24	2.00	2.20	2.02	2.04	1.80	1.94	2.07	2.20	1.96	1.96	2.10	2.15	2.08
Wood (CH_4 & N_2O)	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.09
Wood combustion (biogenic CO_2 - not included in gross totals)	1.15	1.24	1.11	1.10	1.06	1.04	1.10	1.23	1.26	1.22	1.21	1.23	1.28	1.32	1.32	1.37	1.43	1.43	1.44	1.47	1.52	1.51	1.32
Transportation	**3.25**	**3.85**	**3.80**	**3.96**	**3.92**	**4.07**	**4.10**	**4.05**	**4.02**	**3.95**	**3.62**	**3.70**	**3.58**	**3.54**	**3.44**	**3.41**	**3.33**	**3.50**	**3.49**	**3.40**	**3.40**	**3.34**	**2.85**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	2.77	3.03	3.00	3.07	3.21	3.17	3.14	3.02	3.02	2.77	2.73	2.68	2.64	2.56	2.53	2.46	2.55	2.52	2.50	2.52	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.85	0.54	0.73	0.66	0.67	0.65	0.65	0.70	0.68	0.63	0.66	0.73	0.72	0.71	0.72	0.71	0.79	0.81	0.76	0.75	0.71	0.65
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.06	0.03	0.03	0.13	0.13	0.16	0.14	0.11	0.21	0.07	0.08	0.08	0.07	0.08	0.08	0.09	0.06	0.07	0.07	0.06
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
All Mobile (CH_4, N_2O)	0.13	0.15	0.14	0.15	0.14	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
Ethanol + Biodiesel (biogenic CO2 - not included in gross totals)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.13	0.18	0.17	0.17	0.18	0.20	0.19	0.19	0.22	0.22	0.19	0.19	0.17
Fossil Fuel Industry	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**
Natural Gas Distribution	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas Transmission	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Industrial Processes	**0.21**	**0.40**	**0.53**	**0.43**	**0.45**	**0.44**	**0.45**	**0.44**	**0.46**	**0.45**	**0.44**	**0.40**	**0.47**	**0.67**	**0.64**	**0.60**	**0.60**	**0.62**	**0.61**	**0.60**	**0.59**	**0.63**	**0.65**
ODS Substitutes	0.00	0.05	0.13	0.15	0.15	0.16	0.17	0.18	0.20	0.21	0.22	0.23	0.25	0.26	0.28	0.29	0.31	0.32	0.33	0.34	0.34	0.36	0.37
Electric Utilities (SF_6)	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.16	0.28	0.34	0.24	0.25	0.24	0.22	0.21	0.23	0.21	0.20	0.14	0.18	0.37	0.33	0.27	0.25	0.26	0.24	0.23	0.22	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.02	0.02	0.03	0.03
Soda Ash Use	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**0.27**	**0.33**	**0.36**	**0.36**	**0.35**	**0.35**	**0.35**	**0.35**	**0.35**	**0.35**	**0.35**	**0.28**	**0.29**	**0.30**	**0.25**	**0.23**	**0.21**	**0.17**	**0.15**	**0.15**	**0.16**	**0.16**	**0.16**
Solid Waste	0.21	0.27	0.30	0.29	0.29	0.28	0.28	0.28	0.28	0.27	0.27	0.21	0.21	0.23	0.18	0.15	0.14	0.10	0.08	0.07	0.08	0.08	0.08
Composting	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Wastewater	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Agriculture	**1.24**	**1.16**	**1.24**	**1.30**	**1.27**	**1.28**	**1.29**	**1.27**	**1.26**	**1.38**	**1.29**	**1.31**	**1.28**	**1.28**	**1.23**	**1.34**	**1.37**	**1.42**	**1.41**	**1.40**	**1.40**	**1.38**	**1.26**
Enteric Fermentation	0.70	0.67	0.69	0.68	0.67	0.66	0.65	0.63	0.63	0.64	0.64	0.64	0.62	0.63	0.62	0.64	0.64	0.63	0.64	0.64	0.64	0.63	0.61
Manure Management	0.18	0.19	0.26	0.29	0.30	0.32	0.31	0.33	0.32	0.33	0.34	0.33	0.33	0.33	0.32	0.32	0.32	0.34	0.36	0.35	0.36	0.35	0.33
Agricultural Soils	0.36	0.31	0.28	0.32	0.29	0.29	0.32	0.30	0.30	0.31	0.30	0.33	0.33	0.31	0.28	0.37	0.39	0.40	0.37	0.35	0.36	0.37	0.29
Liming and Urea Fertilization	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.01	0.00	0.00	0.01	0.03	0.05	0.05	0.05	0.04	0.04	0.03
TOTAL GROSS EMISSIONS	**8.61**	**9.03**	**9.39**	**9.53**	**9.33**	**9.77**	**10.27**	**9.83**	**9.54**	**9.30**	**8.59**	**8.84**	**8.62**	**8.82**	**8.82**	**8.95**	**9.12**	**9.66**	**9.31**	**8.90**	**8.83**	**8.79**	**7.99**
Land-use, Land Use Change, and Forestry (LULUCF)	**-9.14**	**-8.52**	**-7.83**	**-7.70**	**-7.36**	**-7.45**	**-7.43**	**-7.24**	**-7.09**	**-7.18**	**-6.84**	**-6.94**	**-6.84**	**-6.56**	**-6.46**	**-6.31**	**-6.39**	**-6.27**	**-6.22**	**-6.10**	**-6.02**	**-5.94**	**-5.92**
Estimated Net Emissions Total	**-0.53**	**0.52**	**1.56**	**1.83**	**1.97**	**2.32**	**2.84**	**2.59**	**2.45**	**2.12**	**1.76**	**1.90**	**1.78**	**2.26**	**2.36**	**2.64**	**2.73**	**3.39**	**3.09**	**2.80**	**2.82**	**2.86**	**2.07**

[23] Totals may not sum exactly due to independent rounding.

Appendix B: Gross Emissions Totals for select years using AR5 100-yr GWP values.

Sector	Emissions in $MMTCO_2e$								
	1990	1995	2000	2005	2010	2015	2018	2019	2020
Electricity Supply & Demand (consumption based)	**1.09**	**0.77**	**0.43**	**0.64**	**0.43**	**1.00**	**0.31**	**0.25**	**0.18**
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.00	0.01	0.02	0.00	0.00	0.00
Oil	0.01	0.01	0.06	0.01	0.04	0.01	0.00	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.62	0.36	0.96	0.30	0.24	0.16
Residential / Commercial / Industrial (RCI) Fuel Use	**2.55**	**2.51**	**3.03**	**3.06**	**2.56**	**2.95**	**2.95**	**3.01**	**2.88**
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.31	0.37	0.50	0.45	0.45	0.65	0.75	0.76	0.71
Oil, Propane & Other Petroleum	2.14	2.05	2.45	2.53	2.02	2.20	2.10	2.15	2.08
Wood (CH_4 & N_2O)	0.07	0.08	0.07	0.08	0.09	0.10	0.11	0.11	0.10
Transportation	**3.24**	**3.84**	**3.79**	**4.04**	**3.57**	**3.50**	**3.40**	**3.33**	**2.84**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	2.77	3.03	3.14	2.68	2.55	2.52	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.85	0.54	0.65	0.73	0.79	0.75	0.71	0.65
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.13	0.07	0.08	0.07	0.07	0.06
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.01
All Mobile (CH_4, N_2O)	0.12	0.13	0.12	0.11	0.07	0.05	0.04	0.04	0.03
Fossil Fuel Industry	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**
Natural Gas Distribution	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas Transmission	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03
Industrial Processes	**0.21**	**0.40**	**0.53**	**0.44**	**0.47**	**0.62**	**0.59**	**0.63**	**0.65**
ODS Substitutes*	0.00	0.05	0.13	0.18	0.25	0.32	0.34	0.36	0.37
Electric Utilities (SF_6)	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.16	0.28	0.34	0.21	0.18	0.26	0.22	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.03
Soda Ash Use	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**0.30**	**0.36**	**0.40**	**0.39**	**0.32**	**0.18**	**0.17**	**0.17**	**0.17**
Solid Waste	0.24	0.30	0.33	0.31	0.24	0.11	0.09	0.09	0.09
Composting	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Wastewater	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Agriculture	**1.28**	**1.21**	**1.30**	**1.33**	**1.34**	**1.48**	**1.46**	**1.44**	**1.32**
Enteric Fermentation	0.78	0.75	0.77	0.71	0.69	0.71	0.72	0.71	0.69
Manure Management	0.18	0.19	0.27	0.35	0.35	0.36	0.38	0.37	0.35
Agricultural Soils	0.32	0.27	0.25	0.27	0.29	0.36	0.32	0.33	0.25
Liming and Urea Fertilization	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.04	0.03
Grand Total (gross)	**8.68**	**9.12**	**9.49**	**9.92**	**8.71**	**9.74**	**8.92**	**8.87**	**8.08**

Note *: It was not possible to update the ODS Substitutes category with AR5 100-yr GWP values because of how the estimates in that subsector are calculated. Updating GWP values only impacts emissions of gases other than CO_2, so many emissions totals remain unchanged.

Appendix C: Vermont Key Category Analysis by Scale Assessment.

Sector	Scale 1990	Key Category in 1990	Scale 2005	Key Category in 2005	Scale 2020	Key Category in 2020
Electricity Supply & Demand (Consumption - based)						
Coal	0.00%	No	0.00%	No	0.00%	No
Natural Gas	0.54%	No	0.00%	No	0.00%	No
Oil, Propane, & Other Petroleum	0.16%	No	0.11%	No	0.00%	No
Wood (CH_4, N_2O)	0.03%	No	0.14%	No	0.15%	No
Residual System Mix	11.93%	Yes	6.27%	Yes	2.05%	Yes
Residential/ Commercial/ Industrial (RCI) Fuel Use						
Coal	0.26%	No	0.02%	No	0.00%	No
Natural Gas	3.65%	Yes	4.59%	Yes	8.86%	Yes
Oil, Propane, & Other Petroleum	24.82%	Yes	25.75%	Yes	25.98%	Yes
Wood (CH_4, N_2O)	0.77%	No	0.75%	No	1.10%	No
Transportation/Mobile						
Motor Gasoline (Onroad and Nonroad) (CO_2)	29.84%	Yes	31.91%	Yes	26.13%	Yes
Diesel (Onroad and Nonroad) (CO_2)	5.23%	Yes	6.61%	Yes	8.11%	Yes
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.03%	No	0.00%	No	0.00%	No
Jet Fuel & Aviation Gasoline (CO_2)	0.89%	No	1.36%	No	0.78%	No
Non-Energy Consumption - Lubricants (CO_2)	0.22%	No	0.13%	No	0.16%	No
All Mobile (CH_4, N_2O)	1.51%	No	1.21%	No	0.45%	No
Fossil Fuel Industry						
Natural Gas Distribution	0.08%	No	0.03%	No	0.05%	No
Natural Gas Transmission	0.13%	No	0.14%	No	0.29%	No
Industrial Processes						
ODS Substitutes	0.01%	No	1.84%	Yes	4.59%	Yes
Electric Utilities (SF_6)	0.47%	No	0.14%	No	0.08%	No
Semiconductor Manufacturing (HFC, PFC & SF_6)	1.86%	Yes	2.16%	Yes	3.06%	Yes
Limestone & Dolomite Use	0.00%	No	0.32%	No	0.36%	No
Soda Ash Use	0.07%	No	0.05%	No	0.05%	No
Urea Consumption	0.00%	No	0.00%	No	0.03%	No
Waste Management						
Solid Waste (CH_4, N_2O)	2.47%	Yes	2.81%	Yes	0.96%	No
Wastewater	0.62%	No	0.67%	No	0.82%	No
Agriculture						
Enteric Fermentation	8.09%	Yes	6.45%	Yes	7.68%	Yes
Manure Management	2.07%	Yes	3.37%	Yes	4.18%	Yes
Agricultural Soils	4.20%	Yes	3.04%	Yes	3.59%	Yes
Liming and Urea Fertilization	0.03%	No	0.04%	No	0.32%	No

Appendix D: Vermont Key Category Analysis by Trend Assessment

Sector	Subsector	Trend Assessment (1990-2020)	Contribution to the trend (1990 - 2020)	Cumulative total (1990-2020)
Electricity Supply & Demand	Residual System Mix	1.39	0.27	0.27
Residential/ Commercial/ Industrial (RCI) Fuel Use	Natural Gas	0.63	0.12	0.39
Industrial Processes	ODS Substitutes	0.59	0.11	0.50
Transportation/Mobile Sources	Diesel (Onroad and Nonroad) (CO_2)	0.32	0.06	0.56
Agriculture	Manure Management	0.12	0.02	0.59
Transportation/Mobile Sources	All Mobile (CH_4, N_2O)	0.15	0.03	0.62
Waste	Solid Waste (CH_4, N_2O)	0.22	0.04	0.66
Agriculture	Enteric Fermentation	0.25	0.05	0.70
Electricity Supply & Demand	Natural Gas	0.08	0.01	0.72
Industrial Processes	Semiconductor Manufacturing (HFCs, PFCs, SF_6, NF_3)	0.14	0.03	0.75
Residential/ Commercial/ Industrial (RCI) Fuel Use	Oil, Propane, & Other Petroleum	0.21	0.04	0.79
Transportation/Mobile Sources	Motor Gasoline (Onroad and Nonroad) (CO_2)	0.78	0.15	0.93
Industrial Processes	Electric Utilities (SF_6)	0.06	0.01	0.94
Residential/ Commercial/ Industrial (RCI) Fuel Use	Wood (CH_4, N_2O)	0.04	0.01	0.95
Transportation/Mobile Sources	Jet Fuel & Aviation Gasoline (CO_2)	0.02	0.00	0.96
Industrial Processes	Limestone & Dolomite Use	0.05	0.01	0.97
Agriculture	Agricultural Soils	0.04	0.01	0.97
Residential/ Commercial/ Industrial (RCI) Fuel Use	Coal	0.04	0.01	0.98
Electricity Supply & Demand	Oil	0.02	0.00	0.98
Fossil Fuel Industry	Natural Gas Transmission	0.02	0.00	0.99
Electricity Supply & Demand	Wood (CH_4, N_2O)	0.02	0.00	0.99
Waste	Wastewater	0.02	0.00	1.00
Transportation/Mobile Sources	Non-Energy Consumption - Lubricants (CO_2)	0.01	0.00	1.00
Transportation/Mobile Sources	Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	1.00
Fossil Fuel Industry	Natural Gas Distribution	0.00	0.00	1.00
Industrial Processes	Soda Ash Use	0.00	0.00	1.00
Industrial Processes	Urea Consumption	0.00	0.00	1.00
Electricity Supply & Demand	Coal	0.00	0.00	1.00

VERMONT

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Agency of Natural Resources

Vermont Greenhouse Gas Emissions Inventory and Forecast

Methodologies

April 2023

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Acronyms & Abbreviations

AAFM: Agency of Agriculture, Food and Markets

ACCII: Advanced Clean Cars II regulation

ACT: Advanced Clean Trucks regulation

AFOLU: Agriculture Forestry and Other Land Use

ANR: Agency of Natural Resources

AR4: Intergovernmental Panel on Climate Change Fourth Assessment Report

AR5: Intergovernmental Panel on Climate Change Fifth Assessment Report

BAU: Business As Usual

Btu: British thermal unit

CFCs: chlorofluorocarbons

CH_4: methane

CO_2: carbon dioxide

CO_2e: carbon dioxide equivalent

CO_2FFC: Carbon dioxide from Fossil Fuel Combustion SIT module

DEC: Vermont Department of Environmental Conservation

e-CFR: Electronic Code of Federal Regulations

EIA: Energy Information Administration

EPA: Environmental Protection Agency

EV: electric vehicle

F-gas: fluorinated gas

FHWA: Federal Highway Administration

FLIGHT: Facility Level Information on GreenHouse gases Tool

FPR: Vermont Department of Forests Parks and Recreation

GHG: greenhouse gas

GHGRP: GreenHouse Gas Reporting Program

GWP: global warming potential

HCFCs: hydrochlorofluorocarbons

HFC: hydrofluorocarbon

IP: industrial processes

IPCC: Intergovernmental Panel on Climate Change

ISO-NE: independent systems operator – New England

JFO: Joint Fiscal Office

kWh: kilowatt hour

LFG: landfill gas

LFGTE: landfill gas-to-energy

LEAP: Low Emissions Analysis Platform

LULUCF: land-use, land use change, and forestry

MWh: megawatt hour

N_2O: nitrous oxide

NEPOOL-GIS: New England Power Pool - Generation Information System

NF_3: nitrogen trifluoride

NWL: Natural and Working Lands

ODS: ozone depleting substances

PFC: perfluorocarbon

PHMSA: Pipeline and Hazardous Materials Safety Administration

PSD: Public Service Department

RCI: residential/commercial/industrial

REC: renewable energy certificate

SEDS: State Energy Data System

SF_6: sulfur hexafluoride

SIT: State Inventory Tool

UNFCCC: United Nations Framework Convention on Climate Change

USCA: United States Climate Alliance

USDA: United States Department of Agriculture

VMT: vehicle miles traveled

VTrans: Vermont Agency of Transportation

1 Introduction

The *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodology* report is a supporting document for the Greenhouse Gas (GHG) Emissions Inventory and Forecast report completed by the Vermont Agency of Natural Resources. The Methodology report provides details on the specific methodologies and datasets used to calculate the emissions totals in the inventory and will be updated as necessary when methodologies, datasets, or assumptions used in the inventory calculations change through time.

Foundational Information

Greenhouse gases are gases that warm the planet by trapping heat in the atmosphere. These gases allow shortwave solar radiation to reach the earth's surface but absorb the longer wave radiation that is reradiated from the surface and keep that heat energy trapped within the atmosphere rather than allowing it to escape back into space. The higher the concentrations of greenhouse gases in the atmosphere, the more heat energy is trapped and the warmer the planet becomes.

There are many gases that trap heat in the atmosphere. The most significant of these gases, and the ones included in the National Inventory Report produced by the Environmental Protection Agency (EPA), are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Some of these greenhouse gases do occur naturally in the atmosphere, such as CO_2, CH_4, and N_2O, but since the industrial revolution human activities have rapidly increased their concentrations leading to warming of the planet.[1]

Some greenhouse gases are more effective at trapping heat in the atmosphere than others and remain in the atmosphere for different amounts of time (atmospheric lifetime). In order to make the gases comparable to each other for quantification purposes the Intergovernmental Panel on Climate Change (IPCC) developed a method using global warming potentials (GWPs), which account for the heat trapping efficiency and the atmospheric lifetime of gases other than CO_2 and set them relative to CO_2 on a per unit of mass basis. Emissions totals including applicable GWP adjustments are reported in units of CO_2 equivalent (CO_2e). The GWP values used in the Vermont GHG inventory report are listed in Table 1 and are those specified by the United Nations Framework Convention on Climate Change (UNFCCC) in the IPCC guidelines for use in national inventories and are the 100-year weighted GWP values from the IPCC Fourth Assessment Report (AR4).[2] The GWP values are essentially multipliers that are applied to masses of non-CO_2 gases to make their climate warming impacts directly comparable to CO_2.

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[1] IPCC 2013: IPCC (2013) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth* 1 *Assessment Report of the Intergovernmental Panel on Climate Change*. [Stocker, T.F., D. Qin, G.-K., Plattner, M. 2 Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 3 Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[2] IPCC Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013: Addendum; Part two: Action taken by the Conference of the Parties at its nineteenth session (2014): http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf

Table 1: AR4 – 100-year Global warming potential values.[3]

GHG Category	AR4 GWP Value	Atmospheric Lifetime (years)
CO_2	1	Variable
CH_4	25	12
N_2O	298	114
HFCs	124 - 14,800	1 - 270
PFCs	7,390 - 12,200	2,600 - 50,000
NF_3	17,200	740
SF_6	22,800	3,200

GWP values are updated over time as scientific estimates of the absorption of energy or the atmospheric lifetimes or relative concentrations of the gases change. Both the National Inventory of U.S. Greenhouse Gas Emissions and Sinks[4], and the Vermont GHG inventory continue to use the AR4 100-yer GWP values, because that is the recommendation in the most recent IPCC inventory guidelines document. However, those values have been updated in more recent IPCC Assessment Reports and the inventory guidelines are expected to be updated in the next iteration of the National GHG inventory to include the use of GWP values from the AR5 report. The choice of time horizon for the GWP values used is related to whether the emphasis of the data or analysis is on the speed of potential climate change, or the eventual magnitude. If the speed at which climate change is occurring is the main focus a shorter time horizon, such as 20 years, may be appropriate, but if the overall magnitude of the changes in the climate are the focus, a longer duration time horizon is more appropriate. For the Vermont GHG inventory the 100-year time horizon has been used to be consistent with the IPCC inventory guidelines, but it is important to strike a balance for mitigation strategies that prioritizes the mitigation of both short-lived and long-lived gases.

Biogenic CO_2 is another important foundational consideration when calculating GHG inventory totals and is defined as carbon dioxide that is emitted as a part of the natural carbon cycle, related to the combustion or decomposition of biologically based materials (excluding fossil fuels).[5] IPCC guidelines recommend excluding biogenic CO_2 from inventory totals within each sector because those emissions are captured in the net fluxes (transfers of carbon from one pool to another over a certain amount of time) within the Land-use, Land Use Change and Forestry (LULUCF) sector. This approach is difficult because of the lack of certainty in the data and flux estimates used and quantified in the LULUCF sector. State level emissions estimates[6] disaggregated from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020[4] report have been included to inform LULUCF totals, but the net values including the LULUCF totals are not the official GHG inventory totals. Estimates are provided in several inventory sectors for informational purposes including ethanol and biodiesel in the Transportation/Mobile

[3] Source: EPA Overview of Greenhouse Gases: https://www3.epa.gov/climatechange/ghgemissions/gases/n2o.html
[4] EPA - Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2020: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020
[5] EPA Science Advisory Board – Carbon Dioxide Accounting for Emissions from Biogenic Sources: https://www.epa.gov/sites/default/files/2016-08/documents/biogenic-co2-accounting-framework-report-sept-2011.pdf
[6] EPA - State GHG Emissions and Removals: https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals

Sources sector, wood combustion and renewable natural gas in the RCI sector, and wood combustion in the Electric sector, that show the emissions of biogenic CO_2 if it were counted at the point of combustion, however, this calculation has not been completed for every sector in the inventory. This Inventory also does not include sequestration estimates from land use activities in the official totals, as discussed in the LULUCF discussion.

An important distinction when considering accounting practices for biogenic CO_2 is that carbon dioxide emissions from the combustion of fossil fuels are coming from a geologic source, which is on a significantly longer time scale than carbon in the much faster carbon cycle which moves between pools on the order of months to centuries, which means that combusting fossil fuels adds more carbon that was in long term storage and effectively out of circulation into the atmosphere and into the more immediate carbon cycle.[7] Carbon dioxide emitted from the combustion or decomposition of biogenic materials which are a part of the faster carbon cycle are assumed to be sequestered by the regrowth of the biogenic material that produced them, and are captured in the flux from the land use change as described above. The distinction between short-term and long-term carbon storage is important to understand; however, depending on the timescale of carbon movement within the faster carbon cycle, the sequestration of CO_2 emitted by the combustion or decomposition of biogenic materials may still be on a longer timescale than would be required to meet mandated GHG emissions reductions.

2 Inventory Development and Methodologies Overview

Greenhouse Gas Emissions Inventory and Forecast reports are required by Vermont state statute 10 V.S.A. § 582 to establish a periodic and consistent inventory of greenhouse gas emissions for the state of Vermont. The inventory is required to incorporate data from a number of state agencies through collaborative processes and must be compatible with the Governor's Commission on Climate Change final report[8]. The Greenhouse Gas Emissions Inventory and Forecast reports also establish the 1990 and 2005 baseline GHG levels set forth in the Vermont Global Warming Solutions Act (GWSA) and are the metric which determines progress towards the State's emissions reduction requirements.

Estimates of emissions in the Greenhouse Gas Emissions Inventory and Forecast reports have been calculated using methodologies largely based on methods used in, or developed for, the *Greenhouse Gas Inventory and Reference Case Projections, 1990-2030*[8] report and are compatible with IPCC GHG inventory guidelines.[9] Data availability is a key factor influencing methodology decisions with the intention of providing the most accurate emissions estimates

[7] California Greenhouse Gas 2000-2020 Emissions Trends and Indicators Report: https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/2000-2020_ghg_inventory_trends.pdf
[8] Final Vermont Greenhouse Gas Inventory and Reference Case Projections, 1990-2030: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Vermont_GHG_Emissions_Inventory_and_Projection_2007GovCommission_Report.pdf
[9] IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

possible while maintaining comparability to historical data estimates to allow for the tracking of emissions levels over time. Because of the lack of Vermont specific datasets that both encompass the entire state as well as extend back far enough in time to inform the 1990 baseline year, several default federal datasets are used to inform the emissions calculations. Where more detailed Vermont specific data exist, the potential additional accuracy and granularity of the dataset is balanced with the need to keep the methodologies consistent through time. This approach keeps the Inventory as historically accurate and comparable as possible.

Different sectors in the inventory employ a number of methodologies using different Vermont specific datasets to estimate the associated GHG emissions. These sources include, but are not limited to, data submitted to the Agency of Natural Resources (ANR) Air Contaminant Registration Program, data provided by the Vermont Public Service Department (PSD), data from the Vermont Agency of Transportation (VTrans), data from the Vermont Department of Forest Parks and Recreation (FPR), data from the Vermont Joint Fiscal Office (JFO), and data submitted to EPA through the Greenhouse Gas Reporting Program (GHGRP).

To assist states in the comprehensive quantification of statewide anthropogenic greenhouse gas emissions EPA has created a tool and framework that both allows for ease of estimation as well as promoting consistency across state estimates. This state inventory tool (SIT) has been utilized for many sectors to calculate emissions estimates. There are a number of different modules within the SIT tool that generally correspond directly to emissions from the different inventory sectors. These SIT methodologies incorporate larger federal datasets, including data from the US Department of Agriculture (USDA), Energy Information Administration (EIA), and others, which can be updated if more accurate local data are available that meet the minimum data requirements. The inventory also incorporates additional estimates from EPA published in 2022 of state level emissions derived from disaggregating National Emissions Inventory data to a state level[10].

2.1 Vermont GHG Methodologies and Data by Sector

2.1.1 Transportation/Mobile Sources

The transportation and mobile sources sector includes emissions of greenhouse gases related to the movement of people and goods through and around Vermont. The totals include emissions from the combustion of fuels used in cars, trucks, and other vehicles on Vermont roads, the use of aviation gasoline and jet fuel for aircraft, and emissions from certain other non-road equipment like recreational vehicles, lawn equipment, boats, and rail. The current methodology used to calculate GHG emissions in the sector for the entire 1990 – 2020 time series covered in the inventory is through the use of two EPA SIT modules, one to estimate the emissions of CO_2 and one to estimate the emissions of CH_4 and N_2O.

[10] EPA State GHG Emissions and Removals: https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals

Carbon dioxide emissions estimates are based on fuel combustion totals for onroad and nonroad transportation and mobile sources and rely on the EPA CO_2 from Fossil Fuel Combustion (CO_2FFC) SIT module, which is also used for estimating emissions of CO_2 in the residential/commercial/industrial (RCI) fuel use sector. This tool uses estimates of energy consumption (based on fuel volumes) in the Transportation/Mobile Sources sector by fuel type and multiplies them by the carbon content of each fuel. The main fuels which contribute to the emission totals include motor gasoline, distillate fuel (diesel), aviation gasoline and jet fuel, but also include propane, natural gas, and the use of fossil fuels as lubricants.

The default data in the module are from the Energy Information Administration State Energy Data System (SEDS)[11] dataset, which is a federal source of comprehensive state energy statistics data that provides estimates of energy consumption by state. This default data is expressed as estimated energy consumption by sector and fuel type in billions of British thermal units (Btu). The amount of gasoline and onroad (non-dyed) diesel fuel sold in Vermont is available and reported through the Joint Fiscal Office[12] and is used to derive energy use from motor gasoline utilized in the CO_2FFC module, after first adjusting the values to remove the approximate contribution from aviation gasoline and ethanol. Diesel sales data from JFO have not been incorporated into the inventory because it is unclear to what extent the nonroad end uses covered by the JFO data match those covered in the default SEDS dataset in the tool, which could lead to under or over counting of emissions. Default SEDS data have been used for the transportation distillate fuel portion of the calculation after removal of the estimated biodiesel component of the fuel, which is also estimated in the SEDS dataset. Ethanol and biodiesel totals are removed from the emissions estimates due to their biogenic origin. Default SEDS data are also utilized for the remaining categories in the CO_2FFC module.

Emissions of CH_4 and N_2O are calculated differently from the CO_2 component. Estimation methods of some pollutants, such as CH_4 and N_2O, are technology dependent and so have differing emissions factors depending on the type and age of the vehicle producing them. Estimates of these GHGs were calculated using the EPA SIT CH_4 and N_2O Emissions from Mobile Combustion module. This module calculates emissions from onroad transportation using vehicle miles traveled (VMT) estimates by vehicle type and applying emission factors to those VMT values after they are further separated and refined by vehicle age class and applicable emissions control systems. Default data are used for the vehicle age distributions and engine emissions control technologies but the default VMT data are adjusted using vehicle class percent compositions from the Federal Highway Administration (FHWA) and applying them to Vermont specific VMT data from VTrans that goes back to the 1990 baseline.

[11] Energy Information Administration – State Energy Data System (SEDS): https://www.eia.gov/state/seds/
[12] Vermont Joint Fiscal Office – Gasoline and Diesel Gallons Sold: https://ljfo.vermont.gov/subjects/transportation/monthly-data

2.1.2 Residential/Commercial/Industrial (RCI) Fuel Use

The majority of greenhouse gas emissions from the Residential/Commercial and Industrial Fuel Use (RCI) sector are related to fossil fuels used for space heating, water heating, and cooking, in residential, commercial, and industrial buildings. Emissions are mostly CO_2 from the use of fuel oil, propane, and natural gas but do include methane (CH_4) and nitrous oxide (N_2O) from wood combustion, as well as GHG emissions from less common fuels like kerosene, and coal. The industrial subsector of the RCI sector also includes diesel fuel used in several non-road categories such as farm use, off-highway construction, and logging operations. Emissions estimates in the RCI sector are calculated for the entire time series using two EPA SIT modules, one to estimate emissions of CO_2 and the other for emissions of CH_4 and N_2O. Emissions of CO_2 from wood combustion or the use of other biofuels is not included in the gross totals of the GHG inventory reports as it is considered biogenic. See Section *1 Introduction: Foundational Information* for additional discussion related to biogenic CO_2 emissions.

The SIT module used to calculate all the CO_2 emissions from the sector is the CO_2 from Fossil Fuel Combustion module. The calculation methodology for this module multiplies the estimated total energy consumption in billion Btu for each applicable subsector (residential/ commercial/ industrial) and fuel type by a fuel specific emission factor and then by a combustion efficiency value. The data for all of the fossil fuel input values used for the RCI sector in this module are default values from the EIA SEDS dataset. Datasets used to inform the Btu consumption estimates in SEDS for this sector differ by fuel and by year but are generally based on national level reporting of sales data that is presented by state.[13] Emissions estimates are then converted into units of $MMTCO_2e$ within the tool using conversion factors as appropriate.

The SIT module utilized in the RCI sector to calculate emissions of CH_4 and N_2O is the Methane and Nitrous Oxide Emissions from Stationary Combustion module. The methodology to calculate emissions in this module is similar to the CO_2FFC module. Emissions are calculated by multiplying the estimated total energy consumption in billion Btu for each applicable subsector (residential/commercial/industrial) and fuel type by a fuel and GHG specific emission factor. Data utilized in this module are also default data from the EIA SEDS dataset in billions of Btu. Energy estimates from wood combustion for the commercial and industrial subsectors are calculated from data submitted to the ANR-DEC Air Quality and Climate Division as a part of their Point Source Registration program[14] and estimates of energy from wood combustion in the residential subsector are derived from Vermont Residential Fuel Assessment reports[15]. Emissions estimates are then converted into units of $MMTCO_2e$ within the SIT module by using conversion factors and multiplying by the GWP value for each gas as appropriate.

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[13] EIA SEDS – "Technical notes & documentation - complete 2018" – Section 4: Petroleum: https://www.eia.gov/state/seds/sep_use/notes/use_petrol.pdf

[14] VT Agency of Natural Resources – Air Quality and Climate Division – Point Source Registration Program: https://dec.vermont.gov/air-quality/point-source-registration

[15] Vermont Forest Parks and Recreation – Residential Fuel Assessment for the 2018 – 2019 Heating Season: https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Wood_Biomass_Energy/Library/2019%20VT%20Residential%20Fuel%20Assessment%20Report%20FINAL.pdf

2.1.3 Agriculture

The agriculture sector of the GHG inventory accounts for emissions of CH_4 and N_2O from agricultural practices in the state, including animals and crop production. Carbon dioxide in this sector that is produced in processes like the management of manure in a solid form or from manure that is deposited on pasture, range, or on paddock lands and decomposes in the presence of oxygen, is almost exclusively biogenic, and so not included in the sector totals. The CO_2 that is included in the sector is the CO_2 associated with liming and urea fertilization. The subsectors of the agriculture sector include enteric fermentation (CH_4 produced as a part of the digestive process of ruminant animals), manure management, agricultural soils, rice cultivation, liming of soils, urea fertilization, and agricultural residue burning, although not all subsectors have associated values or emissions within Vermont.

Greenhouse gas emissions estimates in the agriculture sector are calculated for the entire 1990 – 2020 time series using the Carbon Dioxide, Methane, and Nitrous Oxide from Agriculture SIT module. Most of the emissions in the sector are related to the size of animal populations and the enteric fermentation and management of manure associated with those animals, but emissions from agricultural soils are included that are based mainly on acres of crops and fertilizer use. Emissions from enteric fermentation are calculated using total animal populations by animal type multiplied by default region-specific per animal emission factors in the tool. Methane and nitrous oxide emissions related to manure management involve estimating the waste produced for the animal populations using the number of animals and assumptions of average animal mass and multiplying by emission factors for volatile solids production (the organic fraction of totals solids in manure that will oxidize and be driven off as a gas at a temperature of 1,112°F) and maximum CH_4 production potential, which depends on the associated manure management system. Agricultural soil emissions are based on the residues or cultivation of certain crop types or soil types and various emission factors, or on the use of fertilizers with applied emission and conversion factors. Data used in the SIT module are almost exclusively default data from various US Department of Agriculture datasets including livestock population and crop data from the National Agriculture Statistics Service. One adjustment is made to modify the population of dairy cows in the manure management portion of the tool to remove the waste that is estimated to enter anaerobic digester facilities. Manure in an anaerobic digester produces emissions of CH_4 but when that CH_4 is combusted in the process it produces CO_2, which per IPCC inventory guidelines is considered biogenic and so is not included in the inventory totals. The number of animals to remove from the manure management totals is informed by ANR point source registration data and the EPA AgSTAR database[16] for anaerobic digesters.

The agricultural sector is the only sector included within the current gross inventory framework where sequestration by vegetation and soils within the boundaries of the sector itself is a critical component. Because of the current gross emissions accounting framework, sequestration is not included in the inventory totals within the agricultural sector. If it were, it would likely be offsetting some portion of the gross emissions calculated using the SIT module. Sequestration and the potential to increase sequestration in the agricultural sector is important because reducing

[16] EPA AgSTAR – Livestock Anaerobic Digester Database: https://www.epa.gov/agstar/livestock-anaerobic-digester-database

gross emissions within the sector is difficult while maintaining viable farms which are an important climate strategy for building resilience on the landscape. It is also important because many of these practices that enhance agricultural soils have both GHG emissions benefits as well as other co-benefits, such as improving water quality. The Land-use, Land Use Change, and Forestry (LULUCF) sector does include estimates of carbon fluxes related to agriculture, specifically in the cropland, remaining cropland, and land converted to cropland categories, but those net totals are provided as supplemental information which are not included in the official inventory totals and are currently coarse representations of the agricultural landscape in the state. Updated IPCC guidelines recommend including the Agricultural sector within the LULUCF sector as a Agriculture, Forestry, and Other Land Use (AFOLU) sector, but this has not been done in the Vermont GHG inventory because of a lack of confidence and high uncertainty in the LULUCF sector emissions and flux estimates. A project is about to begin for a contractor to evaluate tools and datasets for quantification of emissions from the agricultural sector that will include both net and gross estimates and incorporate Vermont specific data and management practices to the extent possible. This analysis will provide a tool to quantify net emissions in the agricultural sector and will be one component to enable the creation of an AFOLU sector as the LULUCF sector data and flux estimates improve. The Vermont Carbon Budget[17] was an additional analysis that was completed to produce and inform agricultural sector estimates in the Vermont, as well as other land use related estimates, and is an important foundation for improving estimates in the sector.

The use of the SIT module for calculating GHG emissions from the agriculture sector produces gross emissions estimates limited in terms of the inputs and considerations it can account for, specifically in terms of GHG implications of agricultural management practices.

2.1.4 Industrial Processes

The Industrial Processes (IP) sector for the Vermont inventory includes GHG emissions from ozone depleting substances (ODS) substitutes, semiconductor manufacturing, limestone and dolomite use, electric power transmission and distribution systems, soda ash, and urea consumption. There are additional processes generally covered by this sector, but they are not currently occurring in Vermont. Greenhouse gases emitted by the processes in this sector include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3), sulfur hexafluoride (SF_6), and CO_2. Totals in this sector are estimated using several different methodologies depending upon the subsector but include the Industrial Processes SIT module, a tool developed by California for U.S. Climate Alliance (USCA)[18] states for estimation of emissions of ODS substitutes, and emissions data reported to EPA through the Greenhouse Gas Reporting Program (GHGRP).

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[17] A Carbon Budget for Vermont: Task 2 in Support of the Development of Vermont's Climate Action Plan: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/(10)%20Carbon%20Budget.pdf

[18] The U.S. Climate Alliance is a bipartisan coalition of governors committed to reducing greenhouse gas emissions consistent with the goals of the Paris Agreement. https://www.usclimatealliance.org/

Emissions related to substitutes for ODS are associated with HFCs present in end uses like refrigeration equipment, air conditioning equipment, aerosol propellants, and foams. High GWP HFCs have been incorporated into many of these end uses and products to phase out the use of ozone depleting substances (CFCs and HCFCs) following ratification of the Montreal Protocol. This initiative was successful in reducing emissions that deplete the stratospheric ozone layer, but the replacement HFCs often have very high GWP values, many of them thousands of times more potent than CO_2 in their ability to warm the planet.

Estimates of GHG emissions from the ODS Substitutes sector are derived from a tool developed by California for use by USCA states. When this methodology was adopted the California tool was considered to be a more robust and detailed methodology than the calculations contained in the SIT module. The tool is based on a detailed fluorinated gas (F-gas) model[19] which estimates annual HFC emissions from equipment by type and subtype using extensive data from research and from the California refrigerant management program including leakage rates from charging new and used equipment, leakage rates from existing equipment, and end of life equipment loses. These HFC emissions estimates for California are then apportioned to a per capita value (or per vehicle) and adjusted based on state-specific factors such as the percentage of households with air conditioning units or using heat pumps. Per capita values are then applied to the population of Vermont to produce an estimated business as usual baseline value that is incorporated into the GHG inventory. The California tool does not include estimates back to 1990 and only contains data for 2005 onward, so for all years prior to 2005 the SIT Industrial Processes module estimates for ODS substitutes have been used in the inventory. Because the California model is based on a per capita value it is not feasible to reflect on the ground changes to emissions levels based on mitigation strategies to reduce ODS substitutes on a more granular level. Reductions in emissions can really only be reflected in the tool outputs using the pre-calculated mitigation scenarios included in the tool. Because of this limitation in the tool methodology, there is a plan to explore additional calculation methods that would allow for the incorporation and use of local data.

Greenhouse gas emissions related to semiconductor manufacturing include HFCs, PFCs, SF_6, and NF_3 and are taken from emissions totals reported to EPA through the GHGRP which requires annual reporting of GHG emissions by applicable sources and facilities.[20] Emissions of the F-gases in semiconductor manufacturing occur in the plasma etching and chemical vapor deposition processes[21], and through the use of heat transfer fluids. It should be noted that historically a number of these high GWP gases were incorporated into the manufacturing process in order to phase out toxic gases that were more hazardous to human health.

The GHGRP emissions estimates for semiconductor manufacturing in the inventory are pulled directly from the EPA Facility Level Information on Greenhouse gases Tool (FLIGHT) for all

[19] California Air Resources Board – California's High Global Warming Potential Gases Emission Inventory – Emissions Inventory Methodology and Technical Support Document (2015 edition): https://www.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf
[20] EPA – Greenhouse Gas Reporting Program (GHGRP): https://www.epa.gov/ghgreporting
[21] EPA State Inventory Tools – User's Guide for Estimating carbon dioxide, nitrous oxide, HFC, PFC, NF_3, and SF_6 emissions from Industrial Processes using the State Inventory Tool: https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool

available years (2011 through 2020).[22] Emissions totals from before 2011 are estimated by projecting reported 2011 emissions totals backwards through time to 1990 based on state level estimates[6] disaggregated from the National Inventory of U.S. Greenhouse Gas Emissions and Sinks[4] report for electronics manufacturing generated by EPA.

The remaining subsectors within the Industrial Processes sector in Vermont are limestone and dolomite use, soda ash, urea consumption, and electric power transmission and distribution systems. Emissions from these subsectors are based on default values in the SIT IP module. Limestone and dolomite use, soda ash, and urea consumption emissions are all based on production or consumption data multiplied by applicable emissions factors. Emissions of SF_6 used as an insulator in electric power transmission and distribution equipment are based on an estimate of the quantity of SF_6 consumed annually, multiplied by an assumed leakage emission factor.

2.1.5 Electricity Consumption

The electric sector is comprised of emissions estimates from electricity generation based on the amount of electricity purchased by Vermont utilities for consumption by Vermonters, rather than exclusively on in-state generation. This consumption-based approach was chosen because it is consistent with the majority of states in the region and because of the interrelated nature of the New England power grid. [23] Calculations of the GHG emissions from the electricity sector are performed using a methodology previously developed in collaboration with the Vermont Public Service Department that incorporates information on electric purchases by generation type by megawatt hour (MWh) and emissions factors by generation type. The electric sector is the only sector in the inventory that accounts for emissions that are produced outside the boundaries of the state, but these out of state emissions only include emissions that occur at the point and time of electricity generation and, similar to all other sectors in the inventory, do not include any estimates of lifecycle or upstream emissions.

The after the fact deliveries of utilities by generation type and kilowatt hour (kWh) totaling the annual electric load for Vermont (Ownload) is provided by the Vermont PSD, which includes adjustments for renewable energy certificate (REC) retirements. These kWh totals are converted to MWhs and multiplied by annual average emission factors in pounds per megawatt hour MWh by generation type from the New England Power Pool Generation Information System (NEPOOL GIS)[24] Residual Mix reports. Renewable generation sources, including wind, solar photovoltaic, and hydropower, are considered to emit no GHG emissions at the point of generation for the purposes of this inventory, and nuclear generation is also considered to be zero GHG emitting. Carbon dioxide from electricity generated through biomass combustion is not included because the CO_2 is of biogenic origin, but CH_4 and N_2O emissions are included in the

[22] EPA FLIGHT Tool: https://ghgdata.epa.gov/ghgp/main.do?site_preference=normal
[23] Some states utilize the amount of in-state generation for determining GHG emissions from the electric sector. Currently, Vermont consumers more than three times as much electricity as it generates, on an annual basis. See, EIA – State Profile and Energy Estimates: https://www.eia.gov/state/?sid=VT
[24] NEPOOL GIS – Public Reports – NEPOOL Residual Mix: https://www.nepoolgis.com/public-reports/

totals. States in the region differ on this accounting practice, however, it is consistent with IPCC inventory guidelines for the treatment of biogenic CO_2.

Historical emissions calculations in the electric sector are somewhat less certain than estimates after 2002. For totals before 2002, NEPOOL GIS Residual Mix emission factor data were not available, so emissions rates by fuel type were projected backwards to 1990. Utility Ownload data were available on a fairly consistent basis throughout the time series, with several gaps for which emissions estimates were interpolated, most notably from 2006 through 2009. The methodology is consistent through the entire time series, but the uncertainty in the emission factors applied increases farther back in time.

The current inventory methodology accounts for the sale and retirement of renewable energy certificates (RECs). The Vermont legislature established a Renewable Energy Standard (RES) through 30 V.S.A. § 8002-8005 which, starting in January 2017, required electric distribution utilities to acquire and retire enough environmental attributes from qualified renewable generation to cover the required percentages of their annual retail electricity sales.[25] Required renewability portfolio percentages increase from 55% in 2017 to 75% in 2032.[26] Renewability does not necessarily equate to zero emission electricity, but generally resources considered renewable under the RES are also considered zero GHG emitting in the inventory as they tend to have no emissions at the point of generation or the emissions produced are of biogenic origin.

Renewable energy certificates, which are used by distribution utilities to meet the RES requirements, are a market-based tool that represent the environmental attributes of renewable electricity generation. A REC is issued when one MWh of electricity is generated by a defined and certified renewable generation unit and delivered to the grid. The market for RECs is separate from the energy market and they are the accepted legal mechanism for tracking, accounting for, and substantiating claims of renewable energy generation and use[27]. Accounting for REC retirements in quantifying emissions from electricity consumption acknowledges the regional nature of the electric grid. Specifically, because Massachusetts, Connecticut, and Rhode Island all include REC adjustments in their GHG inventory methodologies, attempting to quantify Vermont emissions using a methodology that doesn't account for REC adjustments would likely result in the Vermont inventory including the zero-emission generation that was also claimed as zero emission by another state in the region.

The accounting decisions associated with emissions of CO_2 from wood combustion for electricity generation in Vermont are related to issues surrounding biogenic CO_2 and the REC accounting methodology used in the electric sector. This issue is made more relevant because of two electric generation facilities that rely mainly on wood for their generation energy source. Even though the emissions from these two facilities occur within the state, they are not included in the inventory totals for two reasons. The first is because the combustion of wood for electricity generation produces CO_2 that is considered biogenic, and no biogenic CO_2 is included

[25] Vermont Renewable Energy Standard: https://legislature.vermont.gov/statutes/chapter/30/089
Public Service Department website: https://publicservice.vermont.gov/renewable_energy/state_goals
[26] Vermont Public Utility Commission: https://puc.vermont.gov/electric/renewable-energy-standard
[27] EPA Green Power Partnership: https://www.epa.gov/greenpower/renewable-energy-certificates-recs

in the GHG inventory totals per IPCC inventory guidelines[28] because it is assumed that the carbon will be captured in the fluxes in the land-use, land use change and forestry sector, and that the CO_2 released will eventually be re-sequestered through the regrowth of the biogenic material. The other reason is that under the current methodology for the electric sector, which includes adjustments for REC purchases and retirements, there are very few MWhs in the electricity purchased for consumption associated with wood generation in Vermont as the RECs from these facilities are sold to utilities outside Vermont. Biogenic CO_2 emissions from these sources would be included in the GHG inventories of the other states in the region if they were accounted for at the point of combustion (and some are), but they would also be captured in the LULUCF sector of the Vermont inventory to the degree that the biomass used in these facilities was sourced within Vermont.

2.1.6 Waste

Emissions of greenhouse gases associated with the waste sector include CH_4 and N_2O from solid waste and wastewater. Carbon dioxide associated with the waste sector is considered biogenic and is not included in the totals for the sector. Emissions estimates for the sector are calculated and compiled using several tools and methodologies including the SIT modules, state level data disaggregated from the U.S. National inventory data and reported landfill gas totals.

Calculations of the CH_4 and N_2O emissions from the wastewater subsector are completed using the EPA SIT Wastewater module and include CH_4 from municipal wastewater, direct N_2O from municipal wastewater, and N_2O from biosolids. Currently the tool is being used with default values provided by EPA with the exception of Vermont-specific modifications to the fraction of the population not on septic and to the percentage of biosolids used as fertilizer. These non-default values are from a report on Wastewater Treatment Sludge and Septage Management in Vermont from the Waste Management and Prevention Division (WMPD).[29] The SIT methodology is population-based and depends on calculated per capita values and emission factors for variables such as percentage of organic content in wastewater, protein consumption and nitrogen content, and CH_4 and N_2O emission factors. Details on the methodologies and calculations can be found in the User's Guide for the Wastewater SIT module.[30] Estimates for the industrial wastewater component have been extracted from the EPA state level GHG estimates[6] which were disaggregated from the U.S. National Emissions Inventory totals, because no default data were available in the SIT module.

The GHG emissions estimates for the solid waste subsector are derived from two different methodologies. Totals from 2009 and later use a methodology based on reported landfill gas (LFG) totals, when the data first became available. The two largest landfills in Vermont are in Coventry and Moretown, but the Coventry landfill is the only remaining open landfill in the state. Both of these landfills have landfill gas to energy (LFGTE) systems and are also required

[28] IPCC Guidelines for National Greenhouse Gas Inventories (2006): https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/
[29] WMPD report: https://dec.vermont.gov/sites/dec/files/wmp/residual/RMSWhitePaper20180507.pdf
[30] EPA State Inventory Tool – Wastewater User's Guide: https://www.epa.gov/sites/production/files/2020-10/documents/wastewater_users_guid.pdf

to register with the Vermont DEC Air Quality and Climate Division, along with two other smaller closed landfills with LFGTE systems that have also provided data previously. Methane emissions are estimated based on the reported annual LFG totals for the reporting facilities and are used to estimate the total CH_4 combusted in engines or flares versus the amount that escapes as fugitive. Landfill gas is produced from the decomposition of organic materials in landfills and is composed of approximately 50% methane and 50% biogenic CO_2 by volume, with trace amounts of non-methane organic compounds and volatile organic compounds. When the LFG is combusted either in a flare or in the LFGTE engines the CH_4 component is converted to CO_2 and because the generated CO_2 emissions are related to the decomposition of biogenic material within the landfill, they are considered biogenic and are not included in the gross emissions totals for the sector per EPA and IPCC guidelines, but are instead captured in the LULUCF sector. Fugitive CH_4 emissions and the portion not actually combusted by the flares or LFGTE systems is converted to $MMTCO_2e$ to come up with an emissions value. Because there are a number of smaller closed landfills in Vermont that are not captured in this methodology, the total is increased by 15%, which was a previously recommended value from the Waste Management and Prevention Division, to account for all of the smaller closed landfills in the state that may still be emitting some level of fugitive LFG. Because the LFG emissions from closed landfills decline over time with no new waste being added, this multiplier will need to be revisited in future iterations of the Inventory.

Historical estimates from before 2009 are from calculations completed for the 2007 *Final Vermont Greenhouse Gas Inventory and Reference Case Projections, 1990-2030* report using a previous version of the EPA SIT module for solid waste that have been adjusted for changes in GWP values since that report was released. The SIT module is based on LFG generation estimates that rely on waste-in-place totals, rather than on reported LFG values based on an amount of gas passing through engines or flares. The calculation methodology used for estimates before 2009 are not the same as those after 2009 but reported LFG totals were assumed to be more accurate than attempting to estimate the LFG generation based on waste in place data, so the methodology change was adopted.

Estimates of CH_4 emissions from composting have also been included and were taken from the EPA state level data based on the disaggregation of the National Inventory of U.S. Greenhouse Gas Emissions and Sinks report totals.

Emissions from the waste sector, and specifically the solid waste sector, are important to understand in a more holistic way. IPCC inventory guidance calls for the CO_2 emitted from the decomposition of materials in landfills to be considered biogenic and omitted from gross inventory totals. The more products and materials people consume and throw away the greater these biogenic CO_2 emissions will become. Materials recycling and diversion efforts can therefore impact overall GHG emissions from the waste sector, even though not accounted for in this inventory. Understanding details of consumption habits and the GHG emissions implications of personal choices will be critical to enable meaningful and lasting emissions reductions in this space. There is currently work being done through a collaborative project with EPA and several states in the northeast region to produce a consumption-based inventory that will provide information related to emissions from consumption in the state.

2.1.7 Fossil Fuel Industry

Emissions of greenhouse gases from the fossil fuel industry sector are relatively low in Vermont because there is no production or refining of petroleum occurring in the state. The only emissions included in this sector are fugitive emissions related to the transmission and distribution of natural gas (NG). All of the GHG emissions associated with the combustion of the various fossil fuels in the state are captured within the other sectors of the inventory.

Emissions of CH_4 from the transmission subsector are related to leakage of NG from transmission lines in the state and are calculated using the Natural Gas and Oil SIT module. The total miles of transmission lines are multiplied by an emission factor as a leakage rate per mile by type of pipeline. Leakage rates used for the calculation are default values provided in the tool by EPA, and the total transmission line mileage is from the Pipeline and Hazardous Materials Safety Administration (PHMSA).[31]

Greenhouse gas emissions associated with natural gas distribution in Vermont are calculated in a similar fashion as emissions from NG transmission, except instead of transmission lines it accounts for the smaller distribution lines and service lines. Emission factors per service and per mile of distribution pipeline by material type are developed by EPA, as published in the Electronic Code of Federal Regulations (e-CFR) [32] and are multiplied by the number of services and miles of applicable distribution line from PHMSA to come up with annual emissions of CH_4 from the NG distribution system. This CH_4 total is then converted to $MMTCO_2e$ for a total from the subsector.

2.1.8 Land Use, Land-Use Change, and Forestry

The Land-use, Land use Change, and Forestry (LULUCF) sector is an important component for understanding a more holistic picture of greenhouse gas emissions in the state of Vermont, but is also very difficult to accurately quantify. This is the main reason that the official GHG emissions inventory totals use a gross accounting framework instead of a net framework (which excludes carbon sinks). A large amount of carbon is sequestered by forests and other vegetation types as they remove CO_2 from the atmosphere and convert it into stored biological material through photosynthesis, but forest processes and changes in land use can also emit CO_2 as well as other GHGs like CH_4 and N_2O. Changes between land use types, such as converting areas to forest, draining wetlands, converting areas to agricultural land, and clearing forests for development, all have impacts on the amount of carbon and CO_2 either emitted to the atmosphere or sequestered within a system. Because these carbon fluxes, the transfer of carbon from one pool to another over a certain amount of time, from land use and land-use change are related to

[31] PHMSA – 2010+ Pipeline Miles and Facilities: https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities

[32] E-CFR: Table W-7 to Subpart W of Part 98—Default Methane Emission Factors for Natural Gas Distribution: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=328f7871a490eca0ae8ad578562d373b&mc=true&n=sp40.23.98.w&r=SUBPART&ty=HTML#ap40.23.98_1238.15

complex systems and ecosystems, reliable, accurate, and repeatable quantification on a statewide scale and on an annual basis is difficult. The difficulty in understanding and quantifying the changes and carbon fluxes from these complex systems is exacerbated by other factors that affect landscapes and ecosystems such as drought, heat, and flooding, that impact the health of forests, soils, crops, and overall ecosystem functionality.

Based on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, the land-use, land use change, and forestry (LULUCF) sector is intended to include all changes in carbon stocks within forest land, cropland, grassland, wetlands, settlements, and other land. Updated 2006 IPCC inventory guidelines and the 2019 refinement to those guidelines recommend incorporating the agricultural sector into the LULUCF sector for the creation of an Agriculture, Forest, and Other Land Use sector recognizing that processes and practices related to emissions and sequestration in the natural and working lands (NWL) space often influence both of these sectors. This aggregation of the two sectors has not yet been incorporated into the Vermont GHG inventory because of the challenge to accurately quantify emissions and fluxes from land-use and land use change, especially on an annual basis. Emissions estimated exclusively for the agricultural sector on a gross basis using methodologies consistent with the previous IPCC guidelines are based on data that is more concrete, such as animal populations and fertilizer application, and can be quantified and tracked more accurately. This separation has also been maintained within the Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990 – 2020) report and the EPA SIT modules for Agricultural emissions and LULUCF calculations. Understanding that there is a very real connection between the agricultural sector and the carbon fluxes related to land use changes, work is being completed through a contract process to investigate a number of tools and datasets that would enable the calculation of agricultural emissions in a net framework (including emissions and sequestration). This work will provide a more in depth understanding of agricultural emissions in a net framework, and specifically focus on incorporating the benefits of different agricultural management practices into the estimates. A previous investigation into a net framework methodology and the creation of an AFOLU for the state has been completed in the Vermont Carbon Budget that was used to help inform the Vermont Climate Action Plan and certain components of the LULUCF sector of the inventory.

Historically the GHG inventory has only included estimates of net sequestration associated with forests and has not included emissions or fluxes from land-use change or processes from other land use classifications. A more complete LULUCF sector has been included in the current (1990 – 2020) GHG inventory report based on recently released state level data from EPA. Forest data estimates used in this sector are produced by the U.S. Department of Agriculture, Forest Inventory and Analysis program[33] and are related to carbon flux estimates for Forest Land Remaining Forest Land, Land Converted to Forest Land, Forest Land Converted to Land, and Urban Trees in Vermont. Values for the carbon fluxes from the remaining land use categories and land use conversions between types, including croplands, grasslands, wetlands, and

[33] USDA – Forest Service - Domke, Grant M.; Walters, Brian F.; Nowak, David J.; Greenfield, Eric. J.; .Smith, James, E.; Nichols, Michael C.; Ogle, Stephen M.; Coulston, John. W.; Wirth, Tom C. 2022. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990 2020. Resource Update FS 382. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 10 p. https://doi.org/10.2737/FS-RU-382

settlements, are taken from calculations for the Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990 – 2020) report that have been disaggregated to state levels by EPA[10]. Detailed information on the methodology for these estimates can be found in the Methodology Report for Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990 – 2020[34] document from EPA.

3 Alternative Methodologies and Emissions Forecasts

3.1 20-Year GWP Values

One other option for understanding emissions impacts is to assess the emissions values on different timescales, rather than the 100-year timescale. The 20-year GWP is one such alternative that was recommended as a sensitivity analysis in the Vermont Climate Action Plan. Using 20-year GWP values prioritizes gases that have atmospheric lifetimes shorter than that of CO_2, because the values are focusing the warming impact of the gas to a timeframe closer to the atmospheric lifetime of the gas, rather than spreading the warming impact of the gas over a greater number of years. Methane is the GHG in the inventory for which this change has the most dramatic effect with a change from the AR4 100-year GWP multiplier value of 25 to an AR4 20-year GWP of 72. Other short-lived and high GWP gases, such as those in the ODS Substitutes and Semiconductor Manufacturing portions of the Industrial Processes sector also show substantial increases in emissions totals in the 20-year GWP scenario.

[34] EPA – Methodology Report for Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990-2020: https://www.epa.gov/system/files/documents/2022-08/StateGHGI_Methodology_Report_August_2022.pdf

Table 2: GHG Estimates by Sector for select years using AR4 20-year GWP values.

Sector	Emissions in $MMTCO_2e$								
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**	**2020**
Electricity Supply & Demand (consumption based)	**1.09**	**0.77**	**0.44**	**0.64**	**0.43**	**1.00**	**0.32**	**0.25**	**0.18**
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.00	0.01	0.02	0.00	0.00	0.00
Oil	0.01	0.01	0.06	0.01	0.04	0.01	0.00	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.62	0.37	0.97	0.30	0.24	0.17
Residential / Commercial / Industrial (RCI) Fuel Use	**2.66**	**2.64**	**3.13**	**3.19**	**2.70**	**3.11**	**3.12**	**3.18**	**3.03**
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.32	0.38	0.51	0.45	0.45	0.65	0.75	0.76	0.71
Oil, Propane & Other Petroleum	2.15	2.07	2.46	2.54	2.03	2.22	2.11	2.16	2.09
Wood (CH_4 & N_2O)	0.17	0.19	0.16	0.19	0.22	0.25	0.26	0.26	0.23
Transportation	**3.28**	**3.87**	**3.82**	**4.07**	**3.59**	**3.51**	**3.41**	**3.34**	**2.85**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.57	2.77	3.03	3.14	2.68	2.55	2.52	2.50	2.09
Diesel (Onroad and Nonroad) (CO_2)	0.45	0.85	0.54	0.65	0.73	0.79	0.75	0.71	0.65
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.13	0.07	0.08	0.07	0.07	0.06
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.01
All Mobile (CH_4, N_2O)	0.16	0.17	0.15	0.13	0.08	0.06	0.05	0.05	0.04
Fossil Fuel Industry	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.08**	**0.08**	**0.08**
Natural Gas Distribution	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Natural Gas Transmission	0.03	0.03	0.04	0.04	0.04	0.04	0.07	0.07	0.07
Industrial Processes	**0.20**	**0.46**	**0.70**	**0.68**	**0.80**	**1.04**	**1.05**	**1.11**	**1.15**
ODS Substitutes*	0.00	0.12	0.31	0.42	0.58	0.74	0.81	0.84	0.86
Electric Utilities (SF_6)	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.16	0.28	0.34	0.21	0.18	0.26	0.22	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.03
Soda Ash Use	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**0.75**	**0.91**	**1.01**	**0.96**	**0.79**	**0.44**	**0.41**	**0.40**	**0.39**
Solid Waste	0.61	0.77	0.86	0.80	0.62	0.28	0.24	0.23	0.22
Composting	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Wastewater	0.14	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16
Agriculture	**2.70**	**2.59**	**2.85**	**2.90**	**2.89**	**3.08**	**3.09**	**3.05**	**2.87**
Enteric Fermentation	2.01	1.92	1.99	1.82	1.78	1.83	1.85	1.82	1.77
Manure Management	0.34	0.38	0.58	0.78	0.78	0.81	0.86	0.84	0.80
Agricultural Soils	0.35	0.30	0.27	0.29	0.32	0.39	0.35	0.36	0.28
Liming and Urea Fertilization	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.04	0.03
Grand Total (gross)	**10.73**	**11.30**	**12.00**	**12.49**	**11.24**	**12.23**	**11.48**	**11.42**	**10.55**

Note *: GWP values for the ODS Substitutes category have not been adjusted directly like the other categories but have instead been scaled using a ratio from California Air Resources Board (CARB) Short Lived Climate Pollutant (SLCP) HFC inventories with AR4 100-year and AR4 20-year GWP values. Several of the 20-yr GWP values for gases in the semiconductor manufacturing process could not be found and where that was the case the AR4 100-yr values were used. Updating GWP values only impacts emissions of gases other than CO_2, so many emissions totals remain unchanged. Using 20-yr GWP values greatly increases the potency of CH_4.

3.2 Lifecycle Assessments and Consumption Based Inventories

There are multiple ways to look at GHG emissions associated with an area or attributable to a population. The GHG emissions inventory is a snapshot of anthropogenic emissions generated annually within the boundaries of the state of Vermont, with the exception of the electricity sector. It is used to track emissions generated annually that are associated with each sector in the inventory. The inventory does not include emissions associated with the entire lifecycle of a product or process, nor does it include lifecycle emissions associated with the consumption of goods or services. For example, the Inventory accounts for the emissions associated with computer chips manufactured in Vermont, but not the cars or other products in which these chips are used that are manufactured outside of the state and sold into Vermont. Because this inventory is a snapshot of annual emissions from each sector in the state, incorporating lifecycle emissions into this inventory framework is problematic as full lifecycle emissions often stretch over multiple years and could also lead to double counting of emissions if upstream emissions were already accounted for either within Vermont's own inventory in another sector or by another jurisdiction in their GHG inventory.[35]

Greenhouse gas emissions estimates using lifecycle assessments attempt to evaluate all of the associated emissions of the process or production (most often a consumer product), including the emissions related to the inputs, manufacturing, transport, use, and disposal.[36] Lifecycle analyses are an important way to view and understand emissions associated with products or activities. They provide a different, but more holistic and complex, representation of the GHG emissions associated with a product or service. As an example, a lifecycle analysis might estimate emissions from the extraction, refining, transport, and combustion of natural gas, the emissions associated with the materials and construction of hydroelectric dams and flooding of land area, or the mining, transport, production, use, and disposal of electric vehicle batteries and the associated materials. A lifecycle analysis is a highly complex exercise that requires the setting of specific accounting boundaries that depend on the desired analysis but can provide important information for informing decisions on policies or mitigation strategies.

Consumption-based inventories incorporate lifecycle emissions factors but focus on the entirety of emissions associated with a consumed good or service and assign those to the final consumer of that good or service, which in this case would be consumers within the state of Vermont. Because consumption-based inventories focus on the consumption of goods rather than production, they provide an alternative understanding of the climate impacts with a greater focus on consumer choices and behaviors.[37] A consumption-based inventory does not include emissions associated with the production of goods or services within a state, unless they are also consumed within the state. Whether a consumption-based inventory for Vermont would show

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[35] EPA – Life-Cycle GHG Accounting Versus GHG Emission Inventories: https://www.epa.gov/sites/production/files/2016-03/documents/life-cycle-ghg-accounting-versus-ghg-emission-inventories10-28-10.pdf

[36] Association of Environmental Professionals, California Chapter, Climate Change Committee (August 2017) – Production, Consumption and Lifecycle Greenhouse Gas Inventories: Implications for CEQA and Climate Action Plans: https://califaep.org/docs/Draft_AEP_White_Paper_Lifecycle_CEQA_CAPs_082017.pdf

[37] Oregon DEQ – Oregon's Greenhouse Gas Emissions through 2015: https://www.oregon.gov/deq/FilterDocs/OregonGHGreport.pdf

higher emissions totals than seen in the sector based in-boundary framework of the current inventory would depend on factors including the emissions profiles of Vermont's imports vs exports, how they net out, and which GWP timescale was chosen for the analysis. Oregon has produced a consumption-based emissions inventory[38] to supplement their sector-based inventory, which is an illustrative example of how a consumption-based emissions inventory can help to inform a more complete picture of how the state contributes to climate change.

3.3 GWP_{bio}

The growing recognition of the need for immediate reductions in GHG emissions has led to investigations to better understand and appropriately account for biomass combustion. As mentioned above, biogenic CO_2 is considered carbon neutral because the emissions are assumed to be re-sequestered by the regrowth of new biogenic material. One of the difficulties with this assumption is that when biomass is combusted, much of the carbon stored in that material is emitted directly to the atmosphere as CO_2. That pulse of CO_2 then remains in the atmosphere for as long as it takes for new vegetation to regrow and store that same amount of carbon. The longer the vegetation takes to regrow the longer that pulse of CO_2 remains in the atmosphere and contributes to the warming of the planet. GWP_{bio} is a method that adjusts emissions from biomass, including biomass combustion, to account for the regrowth rotation period of the fuel. GWP_{bio} factors are designed to be applied to lifecycle emissions estimates but are applied to biogenic CO_2 estimates in the GHG inventory to provide an alternative view between a fully carbon neutral approach and a full accounting of biogenic CO_2 at the point of combustion. This acknowledges both the issues around timescales of carbon neutrality and the difference between CO_2 from fossil fuels and from biogenic sources. Factors for GWP_{bio} for biomass combustion depend on a number of factors, but especially on climate, tree species, and baseline forest assumptions. For the GHG inventory an estimated factor of 0.32 has been used based on a GWP_{bio} tool[39] from the World Wildlife Federation with assumptions for a cool temperate climate. The use of a GWP_{bio} factor acknowledges the importance, as well as the challenge, of accounting for biogenic CO_2 emissions in an annual inventory in a way that accurately reflects the short-term fate of those emissions. This is a key issue that ANR plans to work to better understand and incorporate as appropriate.

3.4 Emissions Forecasts

Estimating emissions levels in future years requires many assumptions related to a number of societal factors including the economy, personal and consumer choices, policies and regulations impacting emissions levels, and unforeseen events such as the COVID-19 pandemic, many of which are difficult to predict. Some of this detailed projection work was completed to help inform the Climate Action Plan using the Low Emissions Analysis Platform (LEAP)[40], which is

[38] Oregon Consumption-based Emissions Inventory: https://www.oregon.gov/deq/mm/Pages/Consumption-based-GHG.aspx
[39] Biogenic Carbon Footprint Calculator for Harvested Wood Products – World Wildlife Fund: https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx
[40] Low Emissions Analysis Platform (LEAP): https://leap.sei.org/default.asp?action=introduction

an integrated energy planning and climate change mitigation assessment model. The modeling process produced business-as-usual (BAU) scenario estimates as well as several scenarios with possible mitigation pathways by which Vermont might meet the state's mandatory GHG emissions reduction requirements out to 2050. Because the LEAP model does not utilize the same methodologies as the GHG inventory, emissions projections in the Inventory for 2025 and 2030 are based on percent changes in the LEAP modeling values applied to the Inventory estimates for the applicable sector. Percent changes from LEAP outputs were used from 2018 to 2025 and from 2018 to 2030 and applied to the 2018 Inventory totals because 2018 was the most current year of historical data when the LEAP model was run. The projections utilize the percent changes in the BAU LEAP scenario for all sectors besides the Transportation/Mobile Sources. For the Transportation/Mobile Sources sector one of the mitigation scenarios was used that incorporated a higher electric vehicle (EV) adoption rate that roughly corresponds to the potential influx in EVs from the adoption of the of the Advanced Clean Cars II (ACCII) and Advanced Clean Trucks (ACT) rulemaking. The projections in the Inventory do not incorporate the percent changes from the LEAP mitigation scenario for the electric sector, even though these would be impacted by the adoption of ACCII and ACT, because it was not possible to parse out the contribution to emissions projections in the electric sector attributable to increases in EV adoption from those related to other sectors that rely on beneficial electrification as their main mitigation strategy.

Appendix C: Vermont LIDAC Census Tracts

County	Census Tract ID of Disadvantaged Tract	Population of Census Tract
Bennington	50003970900	2,280
	50003971200	4,485
	50003971300	3,427
Caledonia	50005957400	3,540
	50005957500	3,684
Chittenden	50007000400	3,262
	50007001000	2,311
	50007002400	3,286
Essex	50009950100	1,657
	50009950500	3,358
Franklin	50011010300	3,507
	50011010700	3,334
Orange	50017959000	2,241
	50017959800	2,713
Orleans	50019951100	2,069
	50019951500	2,400
	50019951600	5,291
	50019951800	2,728
	50019952000	1,777
Rutland	50021963100	3,480
	50021963300	4,764
	50021963700	2,585
Washington	50023955200	4,179

Windham	50025967000	3,017
	50025968500	5,279
	50025968600	2,412
Windsor	50027965200	2,913
	50027966300	1,828

State of Vermont, Agency of Natural Resources

Environmental Justice Focus Population Fact Sheet and Visual Aids

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VERMONT

EJ Law Definition

Vermont's Environmental Justice Law (Act 154 or the "EJ Law") defines the term "Environmental Justice Focus Population" (EJFP, 3 V.S.A. §6002(4)) as:

> "Any census block group in which:
>
> - the annual median household income is not more than 80 percent of the State median household income;
> - Person of Color and Indigenous Peoples comprise at least six percent or more of the populations; or
> - at least one percent or more of households have limited English proficiency."

This definition informs where and how covered agencies will consider environmental justice in making policy decisions, directing investments, and other activities. (3 V.S.A. §6004). The EJ Law does not specify what data to use when determining which census block groups would meet the definition of EJFP. The EJ Law tasks the EJ Advisory Council and Interagency EJ Committee to "consider and recommend to the General Assembly, on or before December 1, 2023, amendments to the terminology, thresholds, and criteria of the definition of environmental justice focus populations, including whether to include populations more likely to be at higher risk for poor health outcomes in response to environmental burdens." (3 V.S.A. §6006(c)(3)(A)).

Visualizing the Definition

To help visualize the information described in the EJFP definition, the Vermont Department of Environmental Conservation (VT DEC) created visual aids to compare two potential census block group data sources and present the data geospatially on a map of Vermont. VT DEC performed this work to provide administrative and technical assistance to the Advisory Council per the EJ Law (3 V.S.A. §6006(d)(6)).

The two data sources used in the visual aids are described below and in Table 1.[1]

- 2020 Census Data, which is based on the count of all people living in the United States and conducted every 10 years.

[1] VT's Office of Racial Equity in their 2023 Language Access Report has acknowledged that Census and ACS data should not be the only data used when evaluating population demographics as there may be undercounting and/or labels that do not fit all identities/family structures. The U.S. Census has also acknowledged both under and overcounting in their release on the 2020 Census's Post-Enumeration Survey.

- 2021 American Community Survey (ACS) (5-year estimate), which relies on estimates from annual data collected from a small number of people to present the larger population, over a five-year period.

What are Census Block Groups? (Census.gov)

- Statistical divisions of census tracts.
- Consist of clusters of blocks within the same census tract.
- The smallest geographic entity for which the census tabulates and publishes sample data.
- Generally defined to contain between 600 and 3,000 people.

Table 1. Data sources available for EJFP definition in the EJ Law.

Environmental Justice Focus Population	Description	Block Group Data Source Available	Census Data Layer ID
Annual Median Household Income (MHI)	Not more than 80 percent of the State median household income. • Median: $67,674 • $54,139 is 80%	2021 ACS 5-year	ACSDT5Y2021.B19013
Black, Indigenous, and People of Color (BIPOC)	At least six percent or more of the population. • Data rounded to nearest tenths place (ex: 5.97 = 6.0 & 5.94 = 5.9)	2021 ACS 5-year & 2020 Census	ACSDT5Y2021.B02001 DECENNIALPL2020.P1
Limited English Proficiency (LEP)	At least one percent or more of households that do not have a member 14 years or older who speaks English “very well” as defined by the U.S. Census Bureau.	2021 ACS 5-year	ACSDT5Y2021.C16002

Upon review of the Census data available, VT DEC found the 2020 Census does not have data available for the MHI and LEP variables (Table 1). The most recent census where both were collected was in 2000.[2] Based on the available data, VT DEC created the following 10 visual aids using different combinations of data sources and EJFP variables:

1. The 2021 ACS 5-year data available for BIPOC, MHI, and LEP was used to develop:
    - One layer visualizing all three variables of the EJFP using the current definition (block group is triggered by at least one of three variables)
    - One layer visualizing all three variables of the EJFP with a legend indicating the number of EJFP thresholds met (shows communities that have multiple variables impacting them)
    - Three layers each visualizing one variable of the EJFP definition (BIPOC, LEP, MHI)
    - Three layers each visualizing two variables of the EJFP definition both being met (BIPOC & LEP, BIPOC & MHI, LEP & MHI)
2. The available 2020 Census BIPOC variable data was used to develop one layer visualizing BIPOC communities.
3. Both 2021 ACS 5-year & the 2020 Census data source were used to develop one layer visualizing all three variables of the EJFP using current definition (block group is triggered by at least one of three variables). Where:
    - 2020 Census BIPOC data was used and 2021 ACS 5 – year MHI and LEP data was used.

It is important to note these visual aids are not a proposed diagnostic or mapping tool for the State of Vermont. The purpose of the visual aids is to inform the Environmental Justice Advisory Council and Interagency Committee as these working groups consider the definition of Environmental Justice Focus Population. Table 2, below, is a guide for the visual aids developed and the Census data sources used.

[2] VT DEC reviewed the Census Questionnaires from the 2020, 2010, and 2000 Census to determine when the MHI and LEP variables were last collected.

Table 2: Visual aids developed for comparing the 2020 Census and 2021 ACS 5-year data sources.

Visual Aid Number	Visual Aid Document Name	EJ Focus Population Variables Presented	Description	Block Group Data Source	Number of Census Block Groups	Percent of Total VT Population
Visual Aid 1	ACS 2021 5 Year Survey: MHI	MHI	Visualizing the definition for the MHI variable.	2021 ACS 5-year	195	19.13%
Visual Aid 2	ACS 2021 5 Year Survey: BIPOC	BIPOC	Visualizing the definition for the BIPOC variable.	2021 ACS 5-year	229	44.53%
Visual Aid 3	ACS 2021 5 Year Survey: LEP	LEP	Visualizing the definition for the LEP variable.	2021 ACS 5-year	78	15.18%
Visual Aid 4	ACS 2021 5 Year Survey: Any EJFP Threshold Met	MHI, BIPOC & LEP	Where a block group is triggered by at least one of three variables.	2021 ACS 5-year	348	62.16%
Visual Aid 5	ACS 2021 5 Year Survey: 1, 2, or 3 EJFP Thresholds	MHI, BIPOC & LEP	Where communities have multiple variables impacting them.	2021 ACS 5-year	348	62.16%
Visual Aid 6	ACS 2021 5 Year Survey: LEP and BIPOC	BIPOC & LEP	Where communities have two variables that overlap.	2021 ACS 5-year	51	10.63%
Visual Aid 7	ACS 2021 5 Year Survey: MHI and BIPOC	BIPOC & MHI		2021 ACS 5-year	93	17.14%
Visual Aid 8	ACS 2021 5 Year Survey: MHI and LEP	LEP & MHI		2021 ACS 5-year	33	6.55%
Visual Aid 9	Census (2020): BIPOC	BIPOC	Visualizing the definition for the BIPOC variable.	2020 Census	488	90.32%
Visual Aid 10	ACS (2021) and Census (2020): Any EJFP Threshold	BIPOC	Where a block group is triggered by at least one of three variables, with the BIPOC threshold taken from the 2020 census and the MHI and LEP thresholds taken from the 2021 ACS 5-year survey.	2021 ACS 5-year & 2020 Census	509	92.81%

Created: September 21, 2023

Federal Mapping Tool Data Sources

VT DEC researched what the federal environmental justice mapping tools use for data sources as well and found that at the federal level that ACS data is used for mapping tools.

- EPA's EJScreen Tool's socioeconomic data source is US Census Bureau's American Community Survey (ACS) 2016-2020 5-Year Estimates at the Census block group level.
- Climate and Economic Justice Screening Tool (CEJST) uses the American Community Survey from 2015-2019 at the Census tract group level.

Visual Aids Considerations

- Visual aids were developed to be thoughtful of viewers who may experience color blindness. Coblis — Color Blindness Simulator – Colblindor (color-blindness.com) was used to select the colors and textures presented in the visual aids.
- Colors associated with an implicit bias of "bad", like red, were not used for visualizations.
- Textures were applied to ease viewing if these files were printed in black and white.

Data Limitations

- As mentioned previously, the 2020 Census did not collect the MHI or LEP data. Over the next decennial period, this may change as these questions may be included in the next Census.
- These visuals were not adjusted for a margin of errors or buffers. The Census Bureau makes clear in documentation of the American Community Survey (ACS), the margin of error for an estimate in each block group is often very large relative to the estimate, so an estimate of percent low-income, for example, is often very uncertain for a single block group.
- Data presented may be missing for some communities where the data source may have margin of error or buffers embedded in both the 2020 Census and the ACS 5-year data.

- ESRI uses Census and ACS data as their example for explaining the importance of margins of errors. This should be considered for VT's development of a mapping tool.
- The U.S. Census does have well-documented limitations that include undercounting BIPOC, revising racial categories over time, and a controversial history of racist policies.
- Data quality for socioeconomic indicators can be worse for rural communities (Headwaters Economics, 2022).
- ACS has non-overlapping datasets that allow comparisons of current ACS data to past ACS data. The 2017-2021 ACS 5-Year estimates can be compared with 2012-2016 ACS 5-Year estimates. Meaning the data set will be updated next when the 2022-2026 data is available for the 1-year ACS. Similarly, the data collected for the census would be updated every 10 years. Changes to how this data is adjusted for census maps may change within these time periods.
- ACS 5-year estimates were selected as it is more reliable than the alternative 1-year estimate. 3-year estimates were discontinued by the US Census Bureau. This is best described by a table comparison available on the US Census Bureau Website: Distinguishing features of ACS 1-year, 1-year supplemental, 3-year, and 5-year estimates.

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The Vermont Agency of Natural Resources (ANR) operates its programs, services, and activities without discriminating on the basis of race, religion, creed, color, national origin (including limited English proficiency), ancestry, place of birth, disability, age, marital status, sex, sexual orientation, gender identity, or breastfeeding (mother and child).

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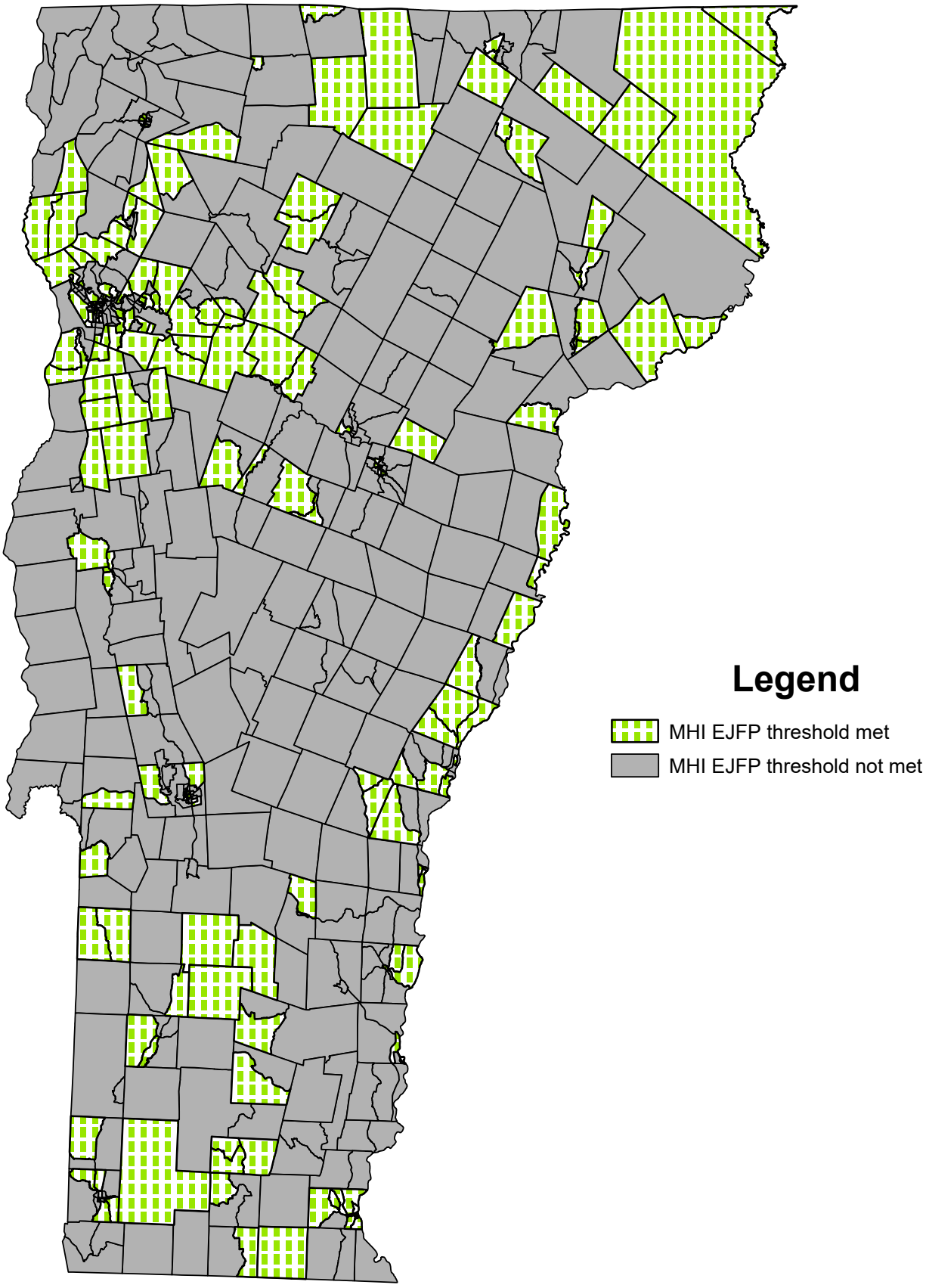
EJFP Visual Aid 1

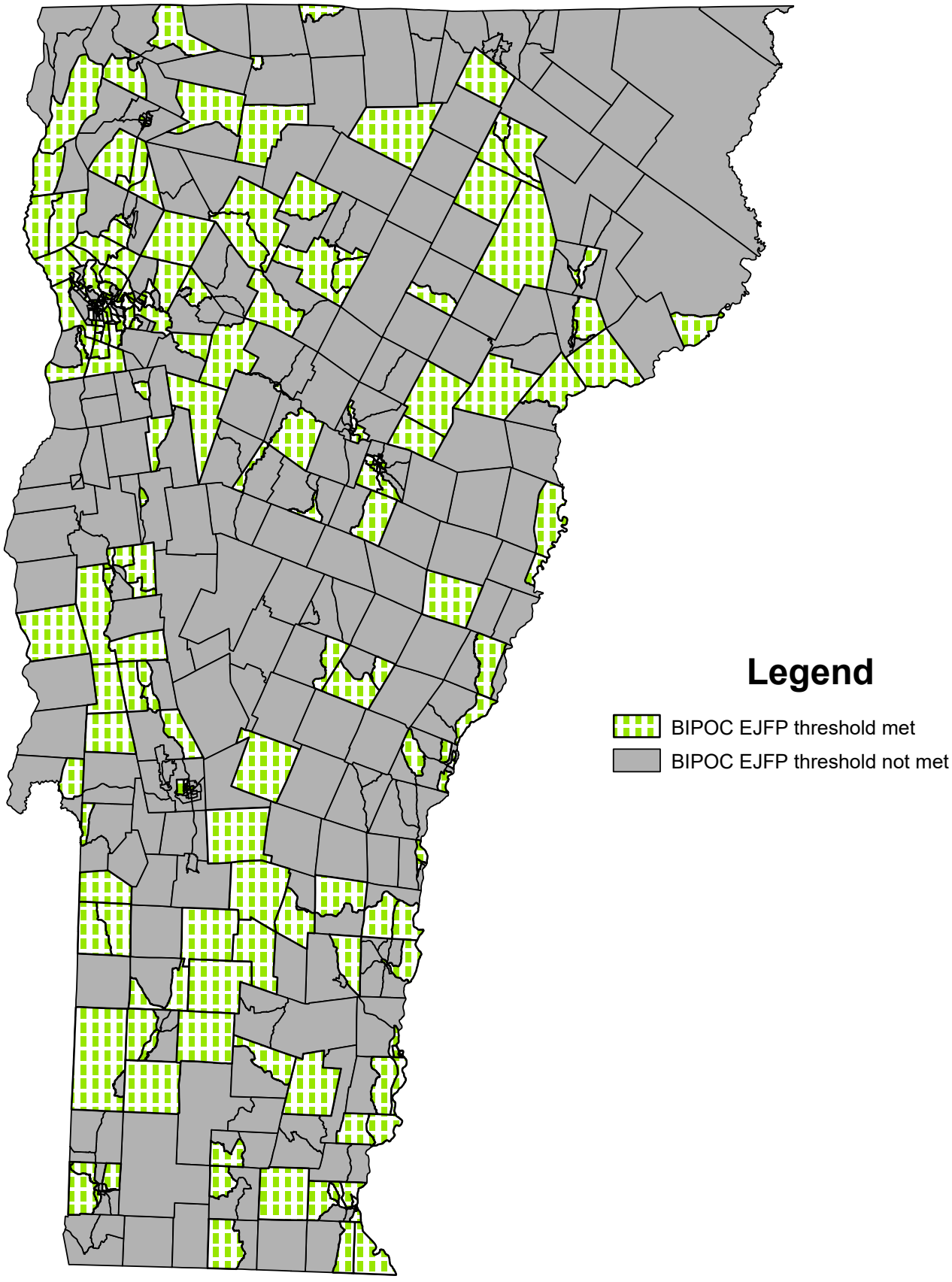
Census Block Groups that meet the Median Household Income (MHI) threshold in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

EJFP Visual Aid 2

Census Block Groups that meet the Black, Indigenous, and People of Color (BIPOC) threshold in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



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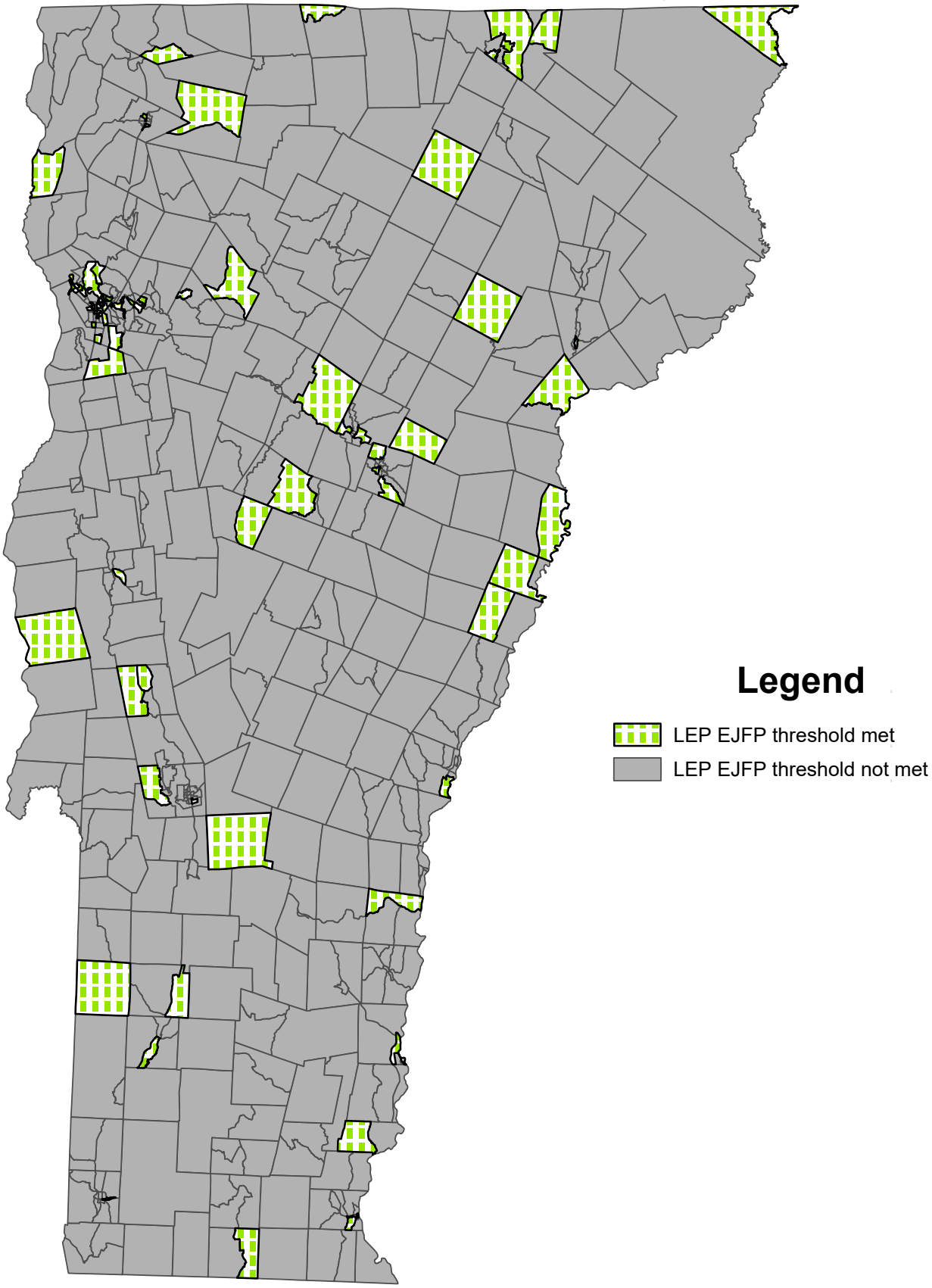
EJFP Visual Aid 3

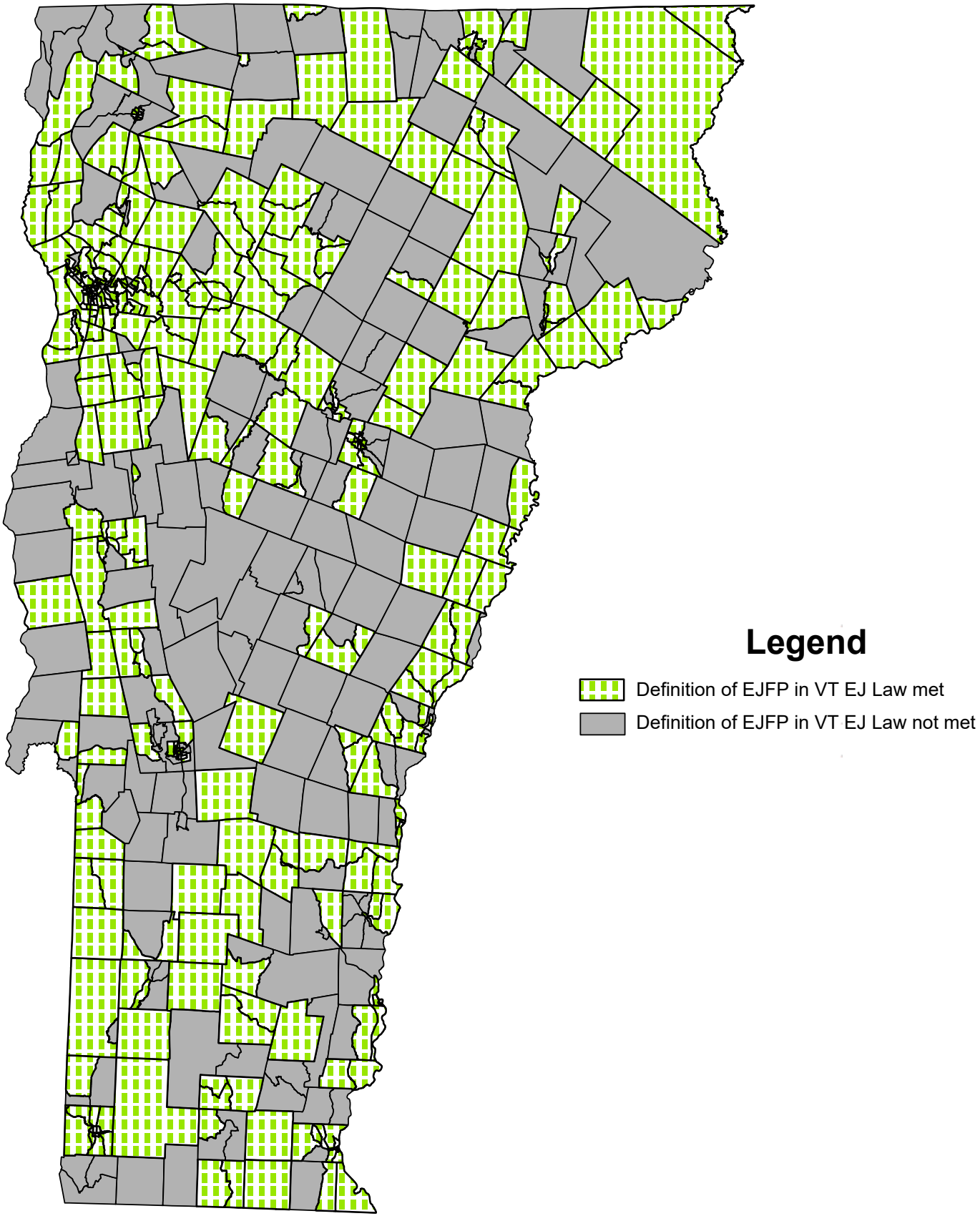
Census Block Groups that meet the Limited English Proficiency (LEP) threshold in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

EJFP Visual Aid 4

VT Census Block Groups that meet the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



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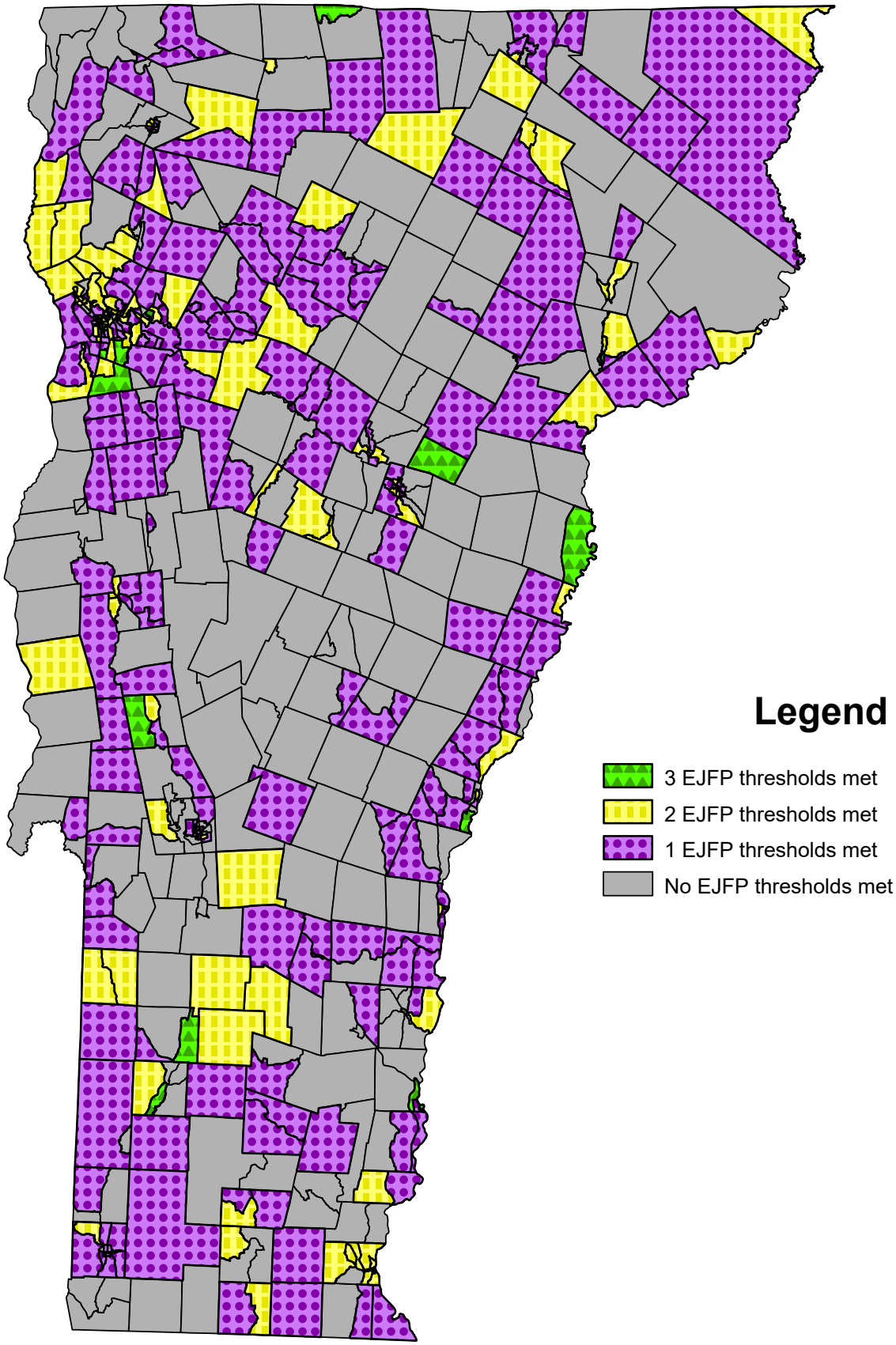
EJFP Visual Aid 5

Census Block Groups that meet 1, 2, or 3 thresholds in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



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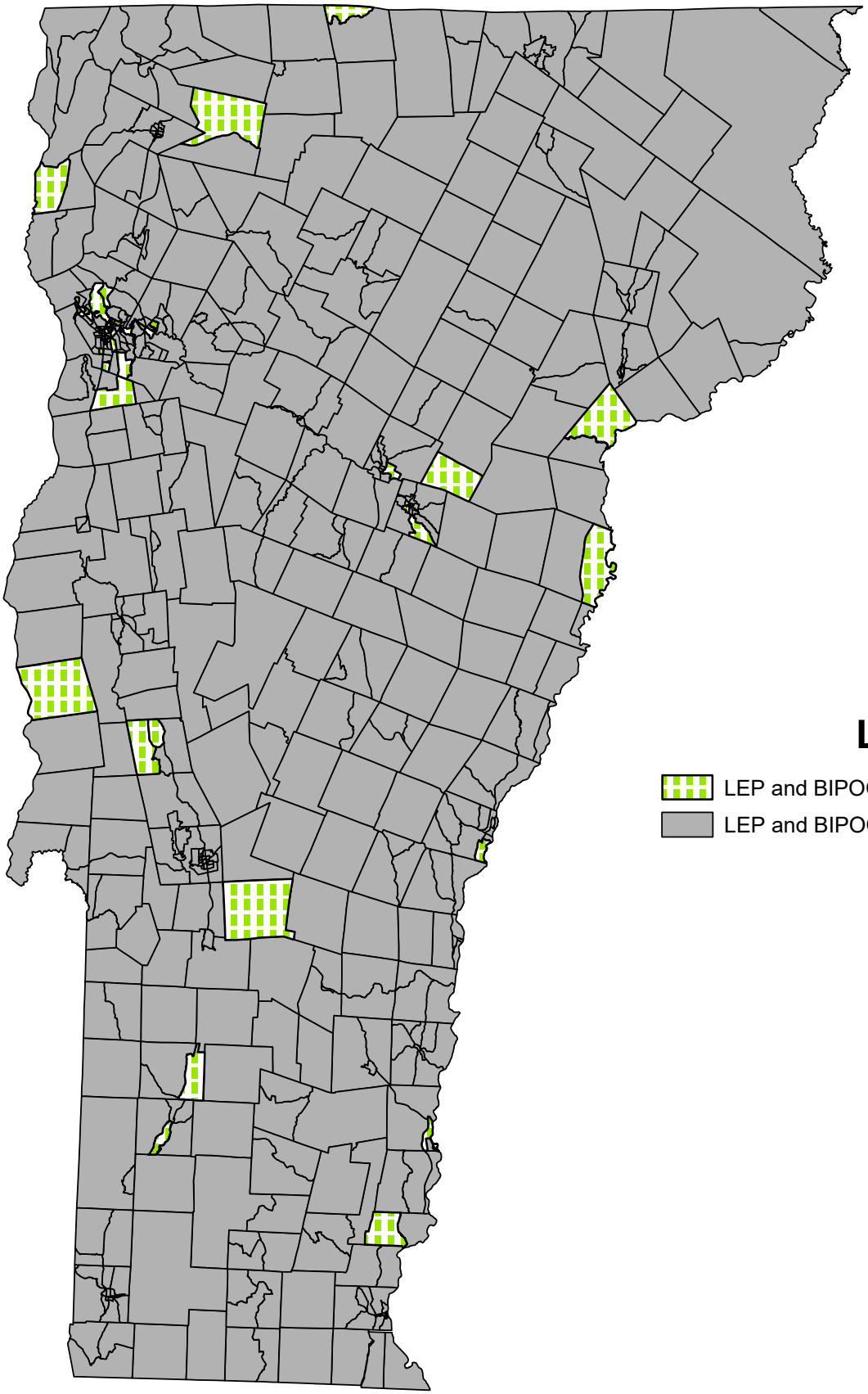
EJFP Visual Aid 6

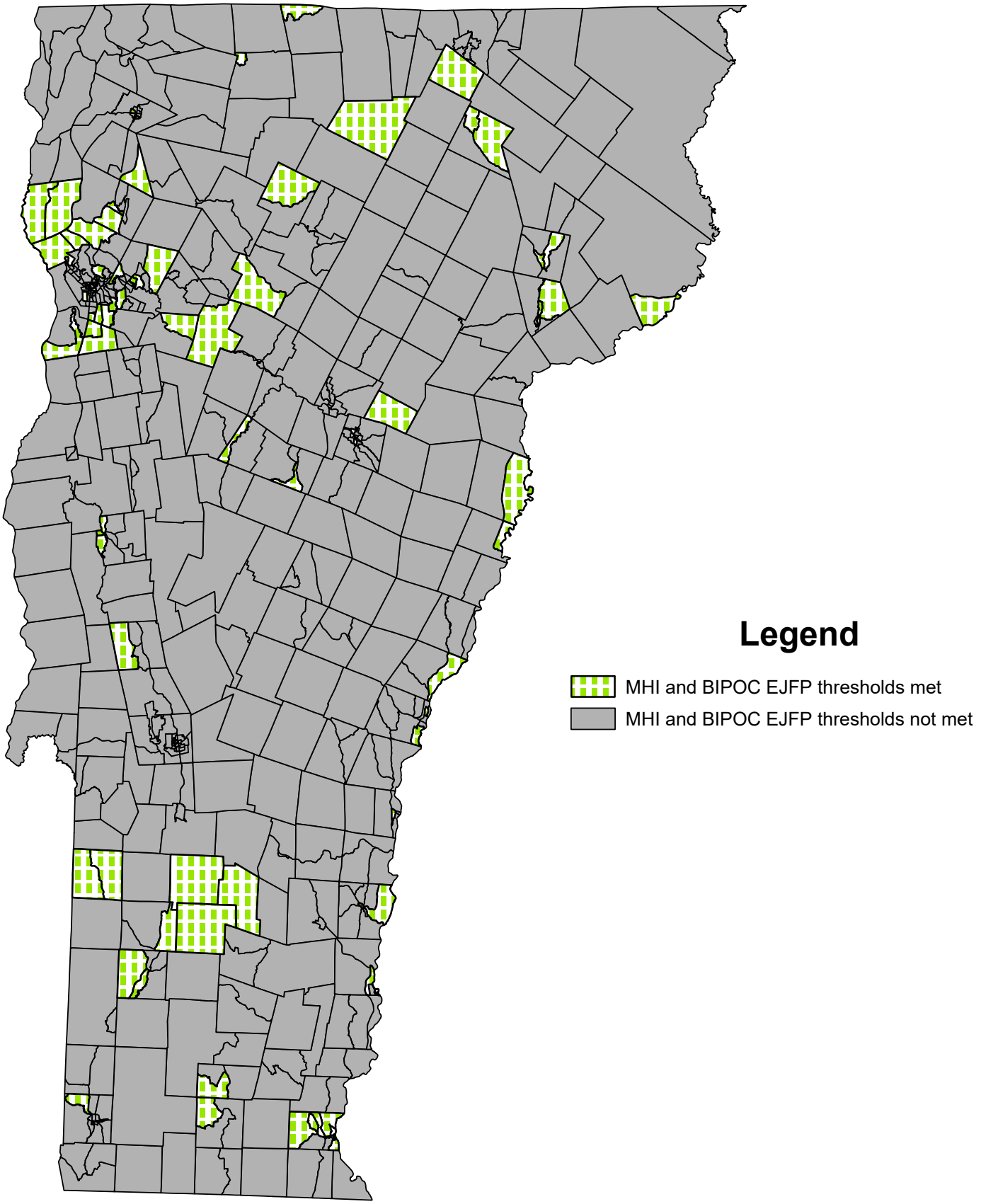
Census Block Groups that meet both the Limited English Proficiency (LEP) and Black, Indigenous, and People of Color (BIPOC) thresholds in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

EJFP Visual Aid 7

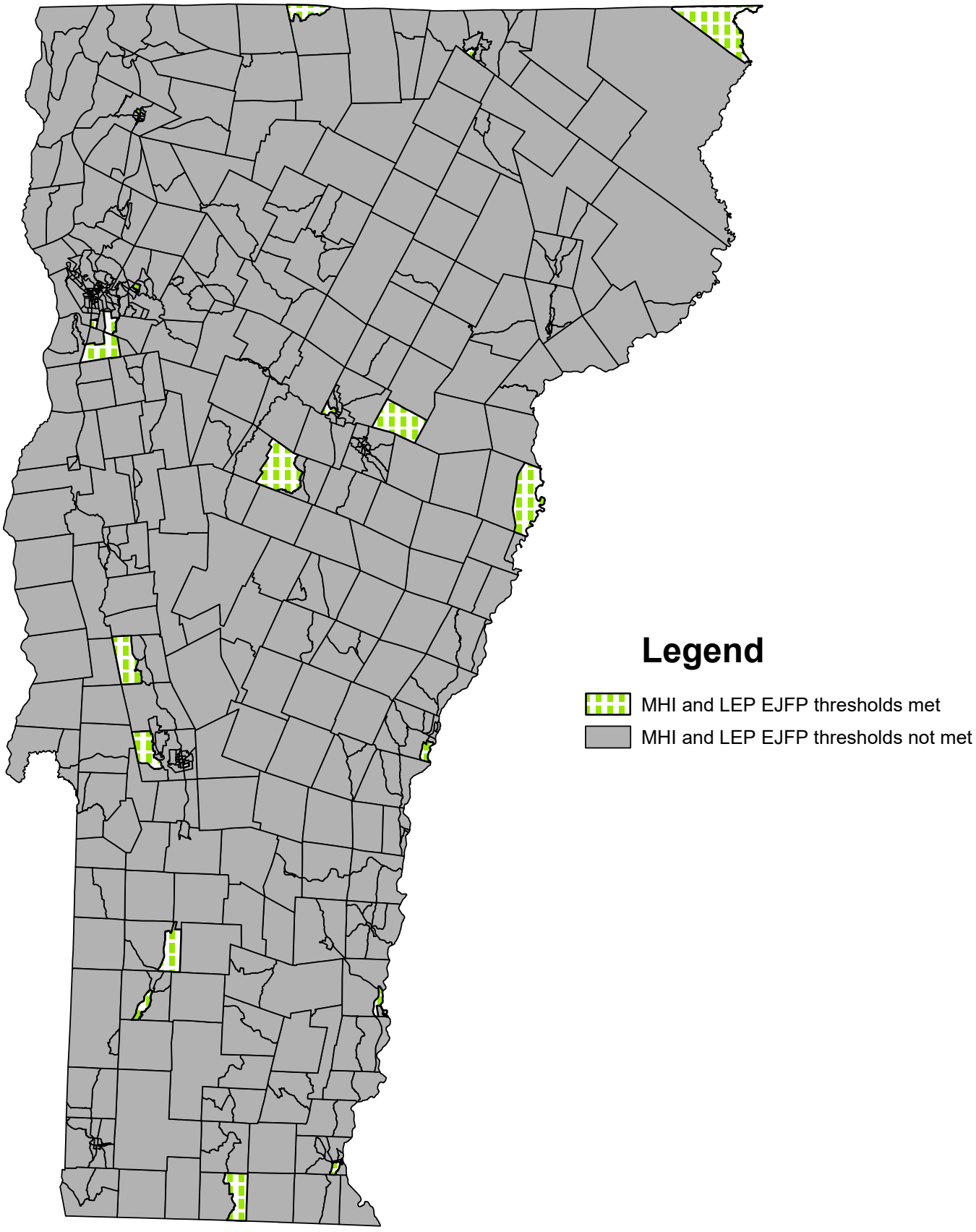
Census Block Groups that meet both the Median Household Income (MHI) and Black, Indigenous, and People of Color (BIPOC) thresholds in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

EJFP Visual Aid 8

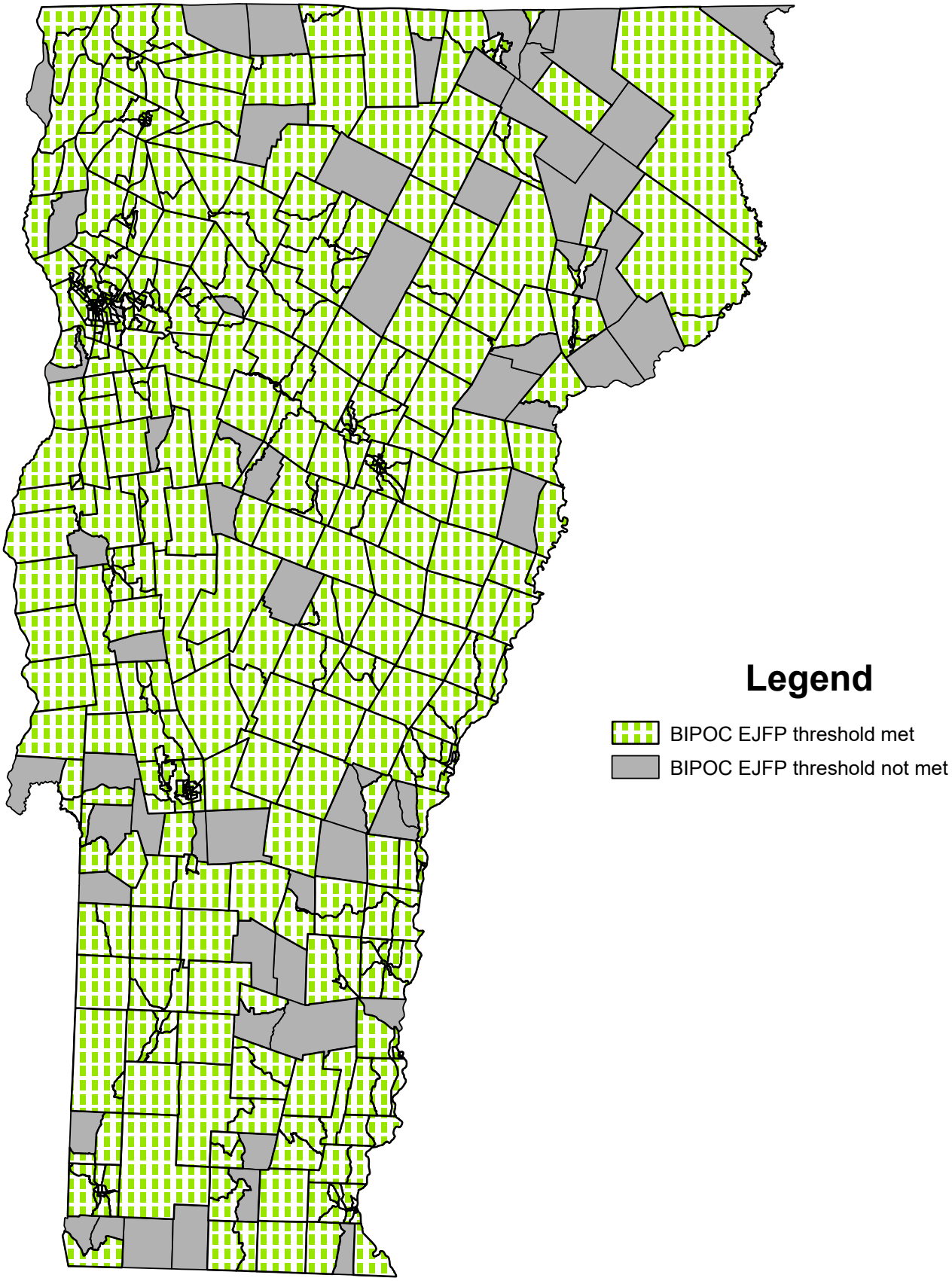
Census Block Groups that meet both the Median Household Income (MHI) and Limited English Proficiency (LEP) thresholds in the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

EJFP Visual Aid 9

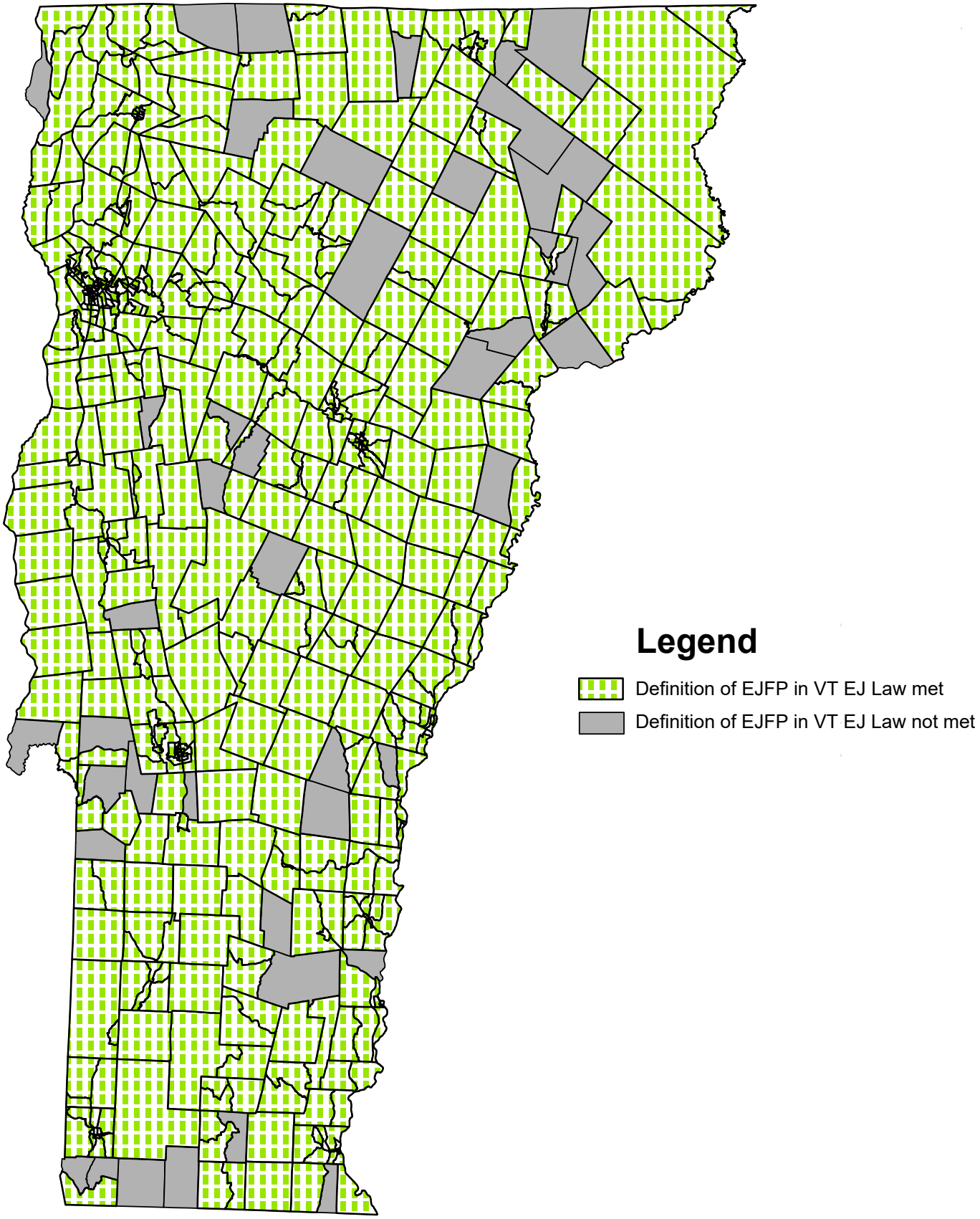
Census Block Groups that meet the Black, Indigenous, and People of Color (BIPOC) threshold in the definition of EJFP in VT EJ Law using 2020 Census Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

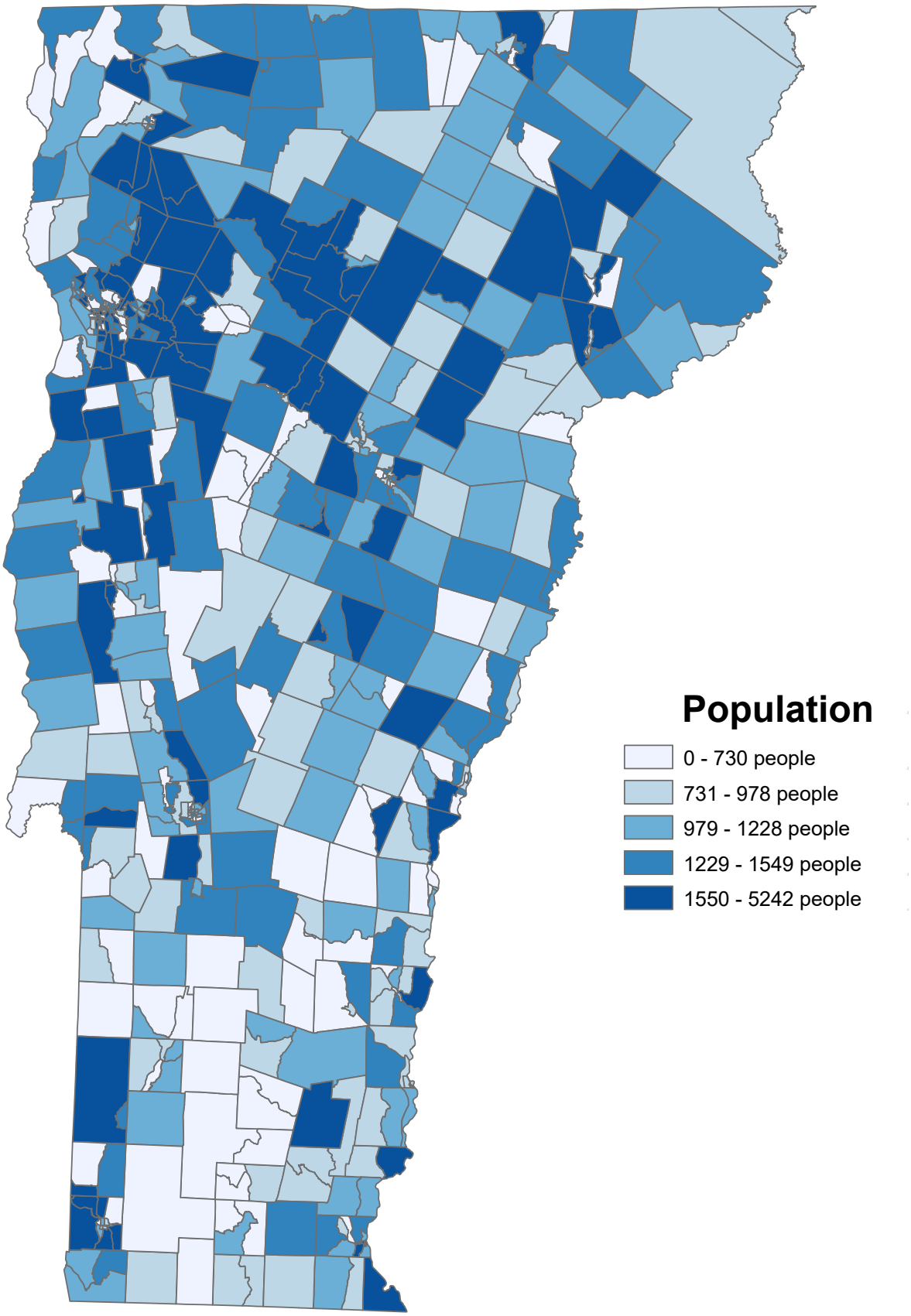
EJFP Visual Aid 10

Census Block Groups that meet the definition of EJFP in VT EJ Law using 2021 American Community Survey 5 Year and 2020 Census Data



Note: The purpose of this visual aid is to present this data geospatially for the Environmental Justice Advisory Council and Interagency Committee to review the definition of Environmental Justice Focus Population in VT's EJ Law (Act 154 of 2022). This visual aid is not a proposed diagnostic or mapping tool for the State of Vermont.

Total Population by Census Block Group using 2021 American Community Survey 5 Year Data



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