

# Greenhouse Gas Inventory Review

Vermont's Current Methods, Comparison with Accepted Practices, and Recommendations

Prepared by:

**David G. Hill, Ph.D.**

**Elizabeth Bourguet**

**Gabrielle Stebbins**

**Chris Neme**

**August 10, 2021**

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## Contents

About the Authors .....	4
Acknowledgements.....	4
Acronyms & Abbreviations.....	6
Introduction .....	7
Executive Summary.....	8
Vermont’s GHG Inventory .....	8
Comparisons to Guidelines and Select Other States.....	9
Issues.....	10
Key Findings.....	12
Recommendations .....	13
Vermont’s Greenhouse Gas Inventory .....	16
Statutory Authority .....	16
Vermont 1990-2017 Inventory .....	17
Methods and Data.....	17
Global Warming Potentials.....	18
Key Category Analysis.....	20
Biogenic Emissions and Sequestration .....	20
Comparing Vermont to Guidelines and Other States.....	21
IPCC Guidelines.....	21
EPA Guidance .....	22
Comparison and Examples from Select Leading States .....	23
Emissions Inventory Crosswalk and Good Practices.....	24
Consumption-Based Emissions Inventories.....	25
Review of Key Differences and Similarities between Consumption- and Sector- Based Inventories .....	25
Consumption-Based Inventory Experience from Oregon and Minnesota .....	26
Best Uses of Consumption-Based Inventory for Vermont .....	29

### Energy Futures Group, Inc

Upstream Emissions vs Lifecycle Emissions Accounting .....	30
Issues and Opportunities .....	31
Issues with Vermont Inventory.....	31
Adopt a Comprehensive Carbon Footprint Accounting.....	31
Modify Global Warming Potential for Methane.....	32
Account for the Upstream Emissions of Purchased Fossil Fuels.....	33
Modify Accounting for Emissions from Regional Electric Grid .....	33
Land Use Carbon Footprint Accounting.....	34
Account for Upstream Biofuel Impacts .....	34
Hydropower Upstream GHG Emissions.....	34
Opportunities .....	35
Conclusions .....	36
Key Findings.....	36
Recommendations .....	37
Appendices .....	40
A. Vermont Method and Data Summary .....	40
B. Cross Walk Table .....	43
C. Key Category Analysis.....	51
D. Select Material from IPCC 2019 Refinement .....	56
E. An Open Letter to the Vermont Climate Council.....	58

**Energy Futures Group, Inc**

## About the Authors

Energy Futures Group (EFG) is a clean energy consulting firm based in Hinesburg, Vermont and with offices in Boston and New York. EFG specializes in the design, implementation and evaluation of programs and policies to promote investments in energy efficiency, renewable energy, other distributed resources, and strategic electrification. EFG staff have worked on these issues on behalf of energy regulators, other government agencies, utilities and advocacy organizations across the United States, Canada, Europe, and China.

**David Hill** is a Managing Consultant who joined EFG in early 2020, after 22 years of employment with VEIC. He is known nationally for his advancement of sustainable energy program design and implementation support, scenario modeling for clean energy futures, and renewable energy policy.

**Liz Bourguet** is a Senior Analyst at EFG who joined EFG in 2020 after graduating from the Yale School of Forestry and Environmental Studies with a Master of Environmental Management degree and who focuses on energy policy analysis and climate change mitigation strategies.

**Gabrielle Stebbins** is a Senior Consultant at EFG and specializes in the development of policy and programs for promotion of renewable energy, strategic electrification and energy efficiency, with a special focus on efforts to integrate all three.

**Chris Neme** is a Principal and Co-Founder of EFG. During his more than 25 years in the industry, Chris has helped clients in 30+ states, 7 Canadian provinces and several European countries with a variety of energy efficiency, demand response, strategic electrification and other distributed energy resource market assessments, programs and policies.

## Acknowledgements

The EFG team would like to thank members of the Vermont Climate Council, its subcommittees and task leaders, members of the public, and the private and public sector employees for numerous organizations for their contributions and concern on the topic of climate change and Vermont's Greenhouse Gas Inventory. We would also like to thank our colleagues at the Cadmus Group, the University of Vermont, and others working as part of the technical consultant team under contract to the Agency of Natural Resources. We deeply appreciate the project management and oversight provided by the Agency of Natural Resources and their efforts to move the complex process of developing a Climate Action Plan forward in a timely, constructive, engaging, and inclusive fashion. The Agency staff who have worked on Vermont's

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  [info@energyfuturesgroup.com](mailto:info@energyfuturesgroup.com)

recent and historic inventory methods and reports are to be commended for their work and attention to detail. Our work on the Greenhouse Gas Inventory draws upon and has benefited greatly from the work of countless others from institutions and organizations in Vermont and from around the globe. We are hopeful that our collective efforts will help Vermont demonstrate leadership in addressing the challenges and opportunities posed by climate change in a just, equitable, proactive, and inspiring fashion. Any errors or omissions in this report are the responsibility of the EFG team authors

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## Acronyms & Abbreviations

<b>ANR</b>	Vermont Agency of Natural Resources
<b>AR4</b>	IPCC Fourth Assessment Report
<b>AR5</b>	IPCC Fifth Assessment Report
<b>CAP</b>	Climate action plan
<b>CARB</b>	California Air Resources Board
<b>CBEI</b>	Consumption-based emissions inventory
<b>CH4</b>	Methane
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>CO<sub>2</sub>E</b>	Carbon dioxide equivalent
<b>DEC</b>	Department of Environmental Conservation
<b>EFG</b>	Energy Futures Group
<b>EIA</b>	Energy Information Administration
<b>EPA</b>	United States Environmental Protection Agency
<b>FLIGHT</b>	EPA's Facility Level Information on GreenHouse gases Tool
<b>GHG</b>	Greenhouse gas
<b>GREET</b>	Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model
<b>GWP</b>	Global warming potential
<b>GWSA</b>	Vermont Global Warming Solutions Act
<b>HFC</b>	Hydrofluorocarbon
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>KCA</b>	Key categories analysis
<b>LULUCF</b>	Land use, land use change, and forestry
<b>MMTCO<sub>2</sub>E</b>	Million metric tonnes of carbon dioxide equivalent
<b>NREL</b>	National Renewable Energy Laboratory
<b>NWL</b>	Natural and working lands
<b>N<sub>2</sub>O</b>	Nitrous oxide
<b>ODS</b>	Ozone depleting substance
<b>OLVCC</b>	Open letter to the Vermont Climate Council
<b>REC</b>	Renewable energy credits
<b>SEDS</b>	State Energy Data System
<b>SIT</b>	EPA's State Inventory Tool
<b>SLCP</b>	Short-lived climate pollutant
<b>VCC</b>	Vermont Climate Council
<b>VMT</b>	Vehicle miles travelled

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | 📧 info@energyfuturesgroup.com

## Introduction

Tracking and reporting on emissions of greenhouse gases (GHGs) through “GHG inventories” is an important tool to help inform policy and decision making at the local, state, regional, national, and international levels. A consistent and comprehensive accounting framework helps to insure full accounting of emissions and the establishment of emissions reduction targets and strategies.

Energy Futures Group (EFG) is engaged as part of a team led by Cadmus Group LLC (Cadmus), serving as technical consultants to support the development of Vermont’s Climate Action Plan (CAP) by the Vermont Climate Council (VCC). Our scope of work includes a review of Vermont’s GHG inventory and methods. The overarching objective is to support the VCC in development of the CAP by comparing Vermont’s inventory to national and international guidelines, to practices in other states, and to discuss issues and opportunities for enhancements or modifications to Vermont’s current methods. In support of this objective our research includes:

- Review and document Vermont’s current GHG Inventory methodology.
- Compare the current method to guidance from the U.S. Environmental Protection Agency (EPA), and the Intergovernmental Panel on Climate Change (IPCC).
- Compare Vermont’s GHG inventory methods with California, Massachusetts, and New York.
- Review Consumption Based Emissions Inventory (CBEI) methods as developed and applied by Oregon and Minnesota.
- Review of issues raised by stakeholders regarding Vermont’s current GHG methods.

Research methods and activities have included detailed review of the inventory tool and spreadsheets, multiple telephone interviews with the Agency of Natural Resources (ANR) staff who compile the inventory, several remote working sessions with Science & Data Subcommittee task leads and members to discuss issues and opportunities for modifications or improvements, and literature review of guidance documents from the EPA and IPCC, and inventory documents from comparison states.

### Energy Futures Group, Inc

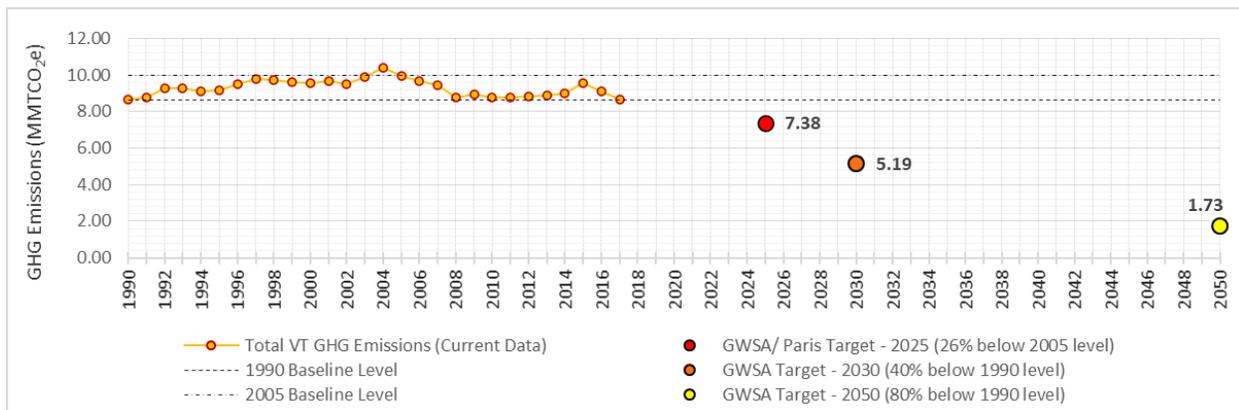
PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## Executive Summary

### Vermont’s GHG Inventory

Vermont’s most recent GHG Inventory prepared by the Air Quality and Climate Division (AQCD) of the Department of Environmental Conservation (DEC) within the Agency of Natural Resources (ANR), was released in May 2021.<sup>1</sup> This newest comprehensive report is the latest in a series of briefs, updates, and comprehensive reports dating back to 2008.

The official emissions reported by the inventory are gross emissions including levels from 1990 and 2005 which serve as a basis for the emissions reduction targets established by the Global Warming Solutions Act 153 (GWSA) of 2020, and the associated targets for 2025 (26% below 2005), 2030 (40% below 1990) and 2050 (80% below 1990).



**Figure ES 1:** Vermont statewide greenhouse gas emissions levels and mandated reduction targets as defined in 10 V.S.A. § 578.<sup>2</sup>

The Vermont inventory classifies emissions by seven sectors and multiple categories for each sector, based on IPCC guidelines. The sectors in Vermont’s are: 1) Transportation mobile sources, 2) Residential, Commercial, and Industrial fuel use, 3) Agriculture, 4) Industrial processes, 5) Electricity consumption, 6) Waste, and 7) Fossil fuel industry.

<sup>1</sup> Vermont Greenhouse Gas Inventory and Forecast: 1990-2017, Prepared by the Air Quality and Climate Division, May 2021, available [here](#).

<sup>2</sup> Ibid. Figure 1, page 8.

### Energy Futures Group, Inc

The methods for the current Vermont inventory generally follow guidelines for each sector from the EPA and IPCC and are mostly consistent with the preceding inventories. A notable exception is a change in method for estimating emissions from the transportation sector. The latest inventory uses data on fuel sales from the Joint Fiscal Office as a basis for estimating transportation sector emissions, whereas prior inventories used methods based on estimates of vehicle miles travelled (VMT). The switch to fuel sales data was made to provide estimates that are more readily calculated on a regular basis, and that reflect guidance from the IPCC on estimating fuel consumption for the transportation sector.

Appendix Table A-1 provides a summary of the primary methods and data as well as supporting methods and data for each sector in the Vermont inventory. The EPA and IPCC guidance on inventory development recommend the use of key category analysis to identify the sectors, and the categories within each sector, with the most importance for each jurisdiction.<sup>3</sup> Key category analyses can be conducted on the scale, trends, and uncertainty for individual categories. We recommend key category analyses be added to Vermont's inventory, and provide scale and trend key category examples in Appendix C.

## Comparisons to Guidelines and Select Other States

The methods and presentation of Vermont's GHG inventory are broadly consistent with the practices of three states (California, Massachusetts, and New York) with similar legislative and planning objectives for GHG emissions reductions. Appendix B provides a crosswalk table comparing Vermont's inventory methods with these three states and the U.S. National Inventory across twenty-five topical dimensions. While there are some differences in the details, all four inventories follow the basic inventory guidelines and practices provided by the EPA and IPCC.

For another comparative analysis we reviewed consumption-based emissions inventory (CBEI) methods, research and results conducted in Minnesota and Oregon. The CBEI approach is designed to account for emissions from products manufactured outside of the jurisdictions and consumed within the jurisdiction. Emissions under this method are based on allocating emissions from production of goods and services to the consumer. Differences in methodology

---

<sup>3</sup> See U.S. EPA, *U.S. Inventory of Greenhouse Gas Emissions and Sinks, 1990-2019*, Section 1.5, and IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Chapter 4 Methodological Choice and Identification of Key Categories.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

result in differences in greenhouse gas emission results between sector-based and consumption-based inventories. For example, in Oregon in 2015, sector-based emissions were 63 million metric tonnes of carbon dioxide equivalent (MMT $\text{CO}_2\text{e}$ ) while consumption-based emissions in 2015 were 89 MMT $\text{CO}_2\text{e}$ .<sup>4</sup> Meanwhile the Minnesota in-boundary emissions in 2012 were 139.8 MMT $\text{CO}_2\text{e}$  and the consumption-based emissions were 133.1 MMT $\text{CO}_2\text{e}$  in the same year.<sup>5</sup> Whether a state has greater sector-based or consumption-based inventories depends on a state's economy and consumption patterns.

Both Oregon and Minnesota consider their consumption-based inventories to be complementary to their sector-based or in-boundary inventories and consider the consumption-based inventory as a supplement to, rather than a replacement of, the sector-based inventory.

If adopted in Vermont, a CBEI could account for emissions from the upstream production of products imported to Vermont. To be complete, the upstream emissions for the production, transportation, use, and disposal of any commodity would be accounted for in a CBEI. Ideally, the CBEI approach allows for a fuller understanding of the full impact of policy and consumer decisions made within Vermont on global climate change.

## Issues

Inventory methods and approaches need to remain open to changes in response to new data, new issues, or methodological or science advances leading to new accounting. The methodology for Vermont's 2019 Inventory was changed in the transportation sector, which now relies on fuel sales data as opposed to past inventories which relied more on data and estimates of vehicle miles travelled by vehicle class. The revised method benefits from data that are more readily available and updated on an annual basis. When changes are considered, it is important to consider how any new methods may need to be applied retroactively to historic inventories to re-estimate target baselines. Alternatively, there may be a need or

---

<sup>4</sup> "Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions," Greenhouse Gas Reporting Program and Materials Management, May 2018, Portland, OR, page 39.

<sup>5</sup> Consumption-related emissions, Minnesota Pollution Control Agency, <https://www.pca.state.mn.us/air/consumption-related-emissions>

## Energy Futures Group, Inc

explicit objective to establish new targets and apply new methods from a newly established baseline using the new methodologies.

Stakeholders, including members of the VCC subcommittees and participating members of the public, have identified a range of issues, and potential modifications for Vermont's GHG Inventory through formal comments and as feedback during various Climate Council subcommittee meetings.<sup>6</sup> Stakeholder recommendations for key items to be addressed in the current or future inventories include:

1. Adopt a Comprehensive Carbon Footprint Accounting
  - a. Cites lifecycle accounting language in the GWSA statute, advocates for consumption-based and upstream accounting for emissions as complement to current sector-based accounting.
2. Modify Global Warming Potential for Methane
  - a. Assess the GWP for Methane based on a 20-year lifetime to account for the higher near-term impacts of gas.
3. Account for the Upstream Emissions of Purchased Fossil Fuels
  - a. Assign and account for upstream emissions with the production, processing, and transportation of purchased fossil fuels.
4. Modify Accounting for Emissions from Regional Electric Grid
  - a. Recommend emissions from the regional grid be adjusted upwards to reflect associated upstream gas emissions and transmission system losses,
  - b. Base emissions on monthly mix and do not adjust for Renewable Energy Credits

---

<sup>6</sup> Recommendations to the Vermont Climate Council, Open Letter Submitted March 9, 2021. George M. Gross.

## 5. Land Use Carbon Footprint Accounting

- a. Do not permit land use carbon offsets to offset energy related GHG emissions.

## 6. Account for Upstream Biofuel Impacts

- a. Including potential competing and current land uses (and loss of sequestration) when calculating the emissions impacts of biofuels.

## 7. Hydropower Upstream GHG Emissions

- a. Estimate the GHG emissions for large hydro projects, including changes to carbon and other GHG fluxes due to inundation and hydro project development.

## Key Findings

Key findings from our Inventory Review are:

- Vermont's current inventory methods are generally consistent with guidelines from the EPA, IPCC and with the practices of California, New York, and Massachusetts. They are also consistent with the primary inventory methods for Oregon and Minnesota.
- Vermont can demonstrate leadership in the development of an actionable Climate Action Plan, and its implementation based on the current GHG inventory, and its methods.
- Vermont's current sector-based inventory method does not represent, nor claim to be representing, lifecycle accounting of greenhouse gas emissions. Upstream and lifecycle emissions can be analyzed to inform decision making without necessarily including them in the Inventory.

## Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

- Supplemental approaches and analyses are being used by other jurisdictions to complement a sector-based inventory method. Examples include CBEI in Oregon and Minnesota, and reporting on short-lived climate pollutant impacts (SLCP) in California.
- There are important opportunities to complement the inventory with supplemental analyses to inform decision making and the development and implementation of mitigation policies, strategies, and actions.
- The IPCC, while not recommending lifecycle accounting as a greenhouse gas inventory method, does recommend lifecycle analyses, and consideration of impacts on emissions outside of jurisdictional boundaries, as important elements in mitigation analyses.
- The complexities of full lifecycle inventory accounting and reporting are immense and could divert resources from inventory and mitigation efforts that have more direct and practical connections to actions that reduce emissions.
- Public awareness and education are foundational for inclusivity.

## Recommendations

Based on our Task 1 research and the interactions we have had with the Climate Council Subcommittees and other stakeholders, we offer the following recommendations for consideration of the ANR and the VCC. These recommendations are those of the report authors, and do not necessarily reflect the views of all members of the technical consultant team.

- Vermont should maintain primary inventory consistency with international and national level guidelines and the practices of other leading states. Vermont can contribute to the development and implementation of supplemental analyses at the same time.
- The possible development and adoption of a CBEI for Vermont should not, and cannot, replace the sector-based emissions inventory and the associated reporting. The GWSA

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

targets are based on the sector-based reporting, and Vermont should maintain a primary annual inventory reporting method and accounting that is consistent with national and international guidelines.

- Vermont should acknowledge the scope and ongoing scale of scientific and international community efforts to create a complete and non-duplicative accounting framework.
- Clarifying and indicating that the Inventory is not used for all purposes, and that upstream emissions can be considered without being counted in the Inventory may be helpful.
- Vermont should remain open to change as new data and methods emerge.
- Vermont should conduct and maintain key category analyses, and summary reporting by GHG.
- Each Inventory should also contain a sector-based summary of existing and emerging issues, possible changes to data and methods, and a presentation and discussion of supplemental analyses that can inform decision making.
- Examples of supplemental analyses include reporting on the impacts from shorter time horizons and GWP modifications for methane, sensitivity analysis to reflect the use of different IPCC Assessment Report values (i.e. AR4 vs. AR5), and accounting for upstream emissions from energy use.
- Literature and tools for lifecycle analyses should be used to analyze the relative impacts of mitigation pathways and consideration of policy and behavior without becoming the basis for the inventory.
- Upstream emissions estimates should be applied as sensitivities and to inform mitigation pathway analyses without being adopted as formal inventory protocols.
- When possible, Vermont should use upstream emissions analysis to account for out of state emissions of energy use in order to inform the analysis of mitigation strategies and opportunities.
- Increased staffing and resources devoted to maintaining, updating, and communicating results from the Inventory are warranted.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  [info@energyfuturesgroup.com](mailto:info@energyfuturesgroup.com)

- Increasing public understanding and familiarity with the Inventory will help with the development and implementation of mitigation policy action and strategies.

## Vermont's Greenhouse Gas Inventory

### Statutory Authority

The Vermont Greenhouse Gas Emissions Inventory and Forecast reports are required in Vermont statute 10 V.S.A. § 582 to establish historic 1990 and 2005 baseline GHG levels and to track changes in emissions through time to determine progress toward the state's GHG reduction targets as established in 10 V.S.A. § 578. Greenhouse gas reduction targets previously listed in 10 V.S.A. § 578 were modified by the passage of the Global Warming Solutions Act (Act 153) in 2020. The updated targets are now mandatory reductions of 26% below 2005 levels by 2025, 40% below 1990 levels by 2030, and 80% below 1990 levels by 2050.

10 V.S.A. §582(g) directs the ANR Secretary to research and adopt by rule GHG accounting protocols that achieve transparent and accurate lifecycle accounting of greenhouse gas emissions.<sup>7</sup> Our discussion in this report of the current inventory methods, lifecycle accounting methods, and comparisons to good practice in other jurisdictions is based on technical review of the issues and opportunities, and does not provide an interpretation of statutory language or compliance.

The GWSA emissions reduction targets are based upon Vermont's current inventory method and the associated historic emissions levels for 1990 and 2005, resulting in gross emissions targets of 7.38 million metric tonnes of carbon dioxide equivalent (MMT<sub>CO<sub>2</sub>e</sub>) in 2025, 5.19 MMT<sub>CO<sub>2</sub>e</sub> in 2030, and 1.73 MMT<sub>CO<sub>2</sub>e</sub> in 2050. Figure 1 illustrates these gross emissions reduction targets along with estimates of historical emissions from 1990-2017.

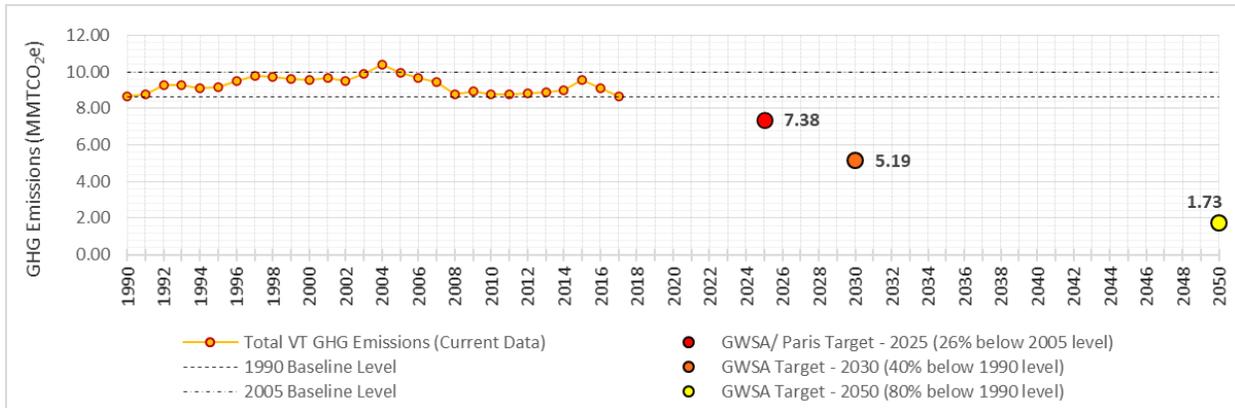
---

<sup>7</sup> Act 153, Section 582 g).

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## Vermont 1990-2017 Inventory



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

## Methods and Data

Vermont’s inventory relies heavily on methods and data sources recommended in the EPA’s State Inventory Tool (SIT). The SIT contains individual sector modules, and workbooks for each module are used by ANR staff to compile the inventory. This section provides an overview and select examples of methods and data used. Appendix Table A-3 provides a summary and further details on the primary and supporting methods and data by sector the Vermont inventory.

The SIT includes state specific default data and assumptions that can be modified by the user. The default data sources include information compiled by the Energy Information Administration (EIA) and reported through the State Energy Data System (SEDS) on items such as time series for fossil fuel consumption, fuel carbon content, and non-energy uses of fossil fuels. The inventory also uses information collected by the Vermont Department of Public Service on items such as the share of annual electric generation (GWh) by generation type and annual fuel assessment reports. A specific sector may use more than one module. For example, Vermont’s inventory for the transportation module uses the SIT module for combustion of fossil fuels to estimate the CO<sub>2</sub> emissions from mobile sources, and it uses the SIT module for mobile combustion to estimate the methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions.

Sectors and categories where the Vermont Inventory does not use the SIT tool as the primary method for estimating emissions include Ozone Depleting Substance (ODS) Substitutes, where

## Energy Futures Group, Inc

a tool developed by California for the use by U.S. Climate Alliance states uses per capita and per vehicle estimates that are adjusted to reflect Vermont specific data for the number of households with air conditioners and heat pumps. The EPA's Facility Level Information on GreenHouse gases Tool (FLIGHT) is used to estimate emissions of fluorinated gases from semiconductor manufacturing, with data prior to 2011 based on national averages.

The Vermont Inventory currently uses the SIT tool for the agriculture sector. Emissions from the agriculture sector are largely the result of CH<sub>4</sub> and N<sub>2</sub>O emissions from enteric fermentation, manure management, and soils. The technical consultant team, in work being led by Dr. Gillian Gallford from University of Vermont under Task Area 2, is examining use of the EX-ACT model(s) developed by the Food and Agriculture Organization of the United Nations<sup>8</sup> as an alternative method to the SIT tool. In comparison to the SIT tool, which estimates agriculture emissions based on livestock census data, the EX-ACT models are better suited to addressing changes in management practices that reduce emissions and for assessing opportunities to increase sequestration from agriculture and forested lands.

## Global Warming Potentials

Global warming potentials (GWPs) are a method developed by the IPCC to account for differences in the average atmospheric lifetime and heat trapping potency of the most important GHGs. The use of GWPs permits an inventory to present results in carbon dioxide equivalent (CO<sub>2</sub>e) values and provides an estimate of the emissions across all included GHGs.

Vermont's inventory accounts for, but does not report on, the contributions of the individual GHGs to Vermont's total emissions. Carbon dioxide emissions from combustion of fossil fuels is consistently the most important contributor to inventories, typically accounting for 80 percent or more of the total emissions impact by gas, with methane (CH<sub>4</sub>) often being the second largest contributor.

Vermont's Inventory reports on seven major GHGs using the 100-year GWP values to calculate CO<sub>2</sub>e values. This is consistent with IPCC guidance from the Fourth Assessment Report (AR4). The IPCC's Fifth Assessment Report (AR5) contains updated GWPs and the IPCC has also issued

---

<sup>8</sup> See EX-ACT tab on the Economic and Policy Analysis of Climate Change of the Food and Agriculture Organization website [here](#).

## Energy Futures Group, Inc

reports indicating that shorter time horizons may be appropriate for estimation of some GWPs including CH<sub>4</sub>.<sup>9</sup>

GHG Category	AR4 GWP Value	Atmospheric Lifetime (years)
CO <sub>2</sub>	1	Variable
CH <sub>4</sub>	25	12
N <sub>2</sub> O	298	114
HFCs	124 - 14,800	1 - 270
PFCs	7,390 - 12,200	2,600 - 50,000
NF <sub>3</sub>	17,200	740
SF <sub>6</sub>	22,800	3,200

**Table 1:** Global Warming Potentials and Atmospheric Lifetime for the GHGs in Vermont’s Inventory – Based on IPCC AR-4.

GHG Category	AR5 GWP Value	Atmospheric Lifetime (years)
CO <sub>2</sub>	1	Variable
CH <sub>4</sub>	28	12.4
N <sub>2</sub> O	265	121
HFCs	1 – 12,400	<1 – 242
PFCs	<1 – 11,100	<1 – 50,000
NF <sub>3</sub>	16,100	500
SF <sub>6</sub>	23,500	3,200

**Table 2:** Global Warming Potentials and Atmospheric Lifetime for the GHGs in Vermont’s Inventory – Based on IPCC AR-5<sup>10</sup>

<sup>9</sup> IPCC, Assessment Report 5, Working Group 1, Table 8.A.1.

<sup>10</sup> [https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5\\_Chapter08\\_FINAL.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf), pages 73-79.

**Energy Futures Group, Inc**

## Key Category Analysis

Key category analysis (KCA) is recommended by the IPCC Guidelines and is included in the U.S. National Inventory of Greenhouse Gas Emissions compiled by the EPA. KCA provides a framework for identifying the most important categories in a GHG inventory. KCA methods and calculations can help to identify key categories based on the scale of their contributions to total emissions, on their contributions to emission trends, and on uncertainty.

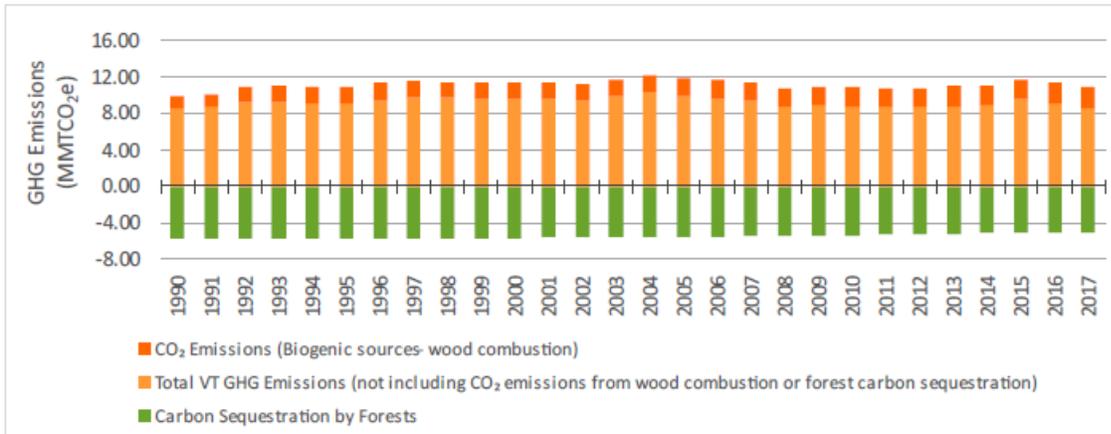
The Vermont Inventory does not include KCA. The calculations and method for the scale and trend KCA's are not burdensome, and in Appendix C we provide two KCA's based on Vermont's Inventory results: one based on scale, and one based on trend analysis. ODS Substitutes are an example of how key categories can change over time. In 1990 they were not a key category, but as substitutes for ozone depleting substances have become more widespread, these emissions and steps to reduce them have become a key category.

We recommend including a key category analysis in Vermont's GHG emissions inventory and regularly maintaining this information. The IPCC suggests that a key category analysis helps to identify priority categories for which a jurisdiction should more regularly review, update, and improve its methods, data, emissions factors and other parameters related to these categories. This could serve as a useful exercise for Vermont to understand its most significant changes in emissions and to assess its priorities. See Appendix C for the key categories analysis tables as well as an explanation for how the key categories were calculated.

## Biogenic Emissions and Sequestration

Consistent with IPCC and EPA guidelines, the Vermont Inventory does not include CO<sub>2</sub> emissions from biogenic sources. The changes in carbon stocks within forest, agriculture, and other land categories, are accounted for in Land Use, Land Use Change, and Forestry (LULUCF) analyses. The technical consultant team under Task Area 2 is developing a report and recommendations on Vermont's carbon budget including land use changes and carbon stocks. While biogenic CO<sub>2</sub> is not included in the official inventory, complementary information is provided on these emissions and on estimated sequestration from anthropogenic activity in land use, land use change, and forestry. This complementary information provides context for the gross estimated emissions as reported and on the state's net emissions.

## Energy Futures Group, Inc



**Figure 2: Vermont Estimated Biogenic CO<sub>2</sub> Emissions and Forest Sequestration**

Analyses on carbon budgets by land use categories are being undertaken to help further account for land use sources and sinks. These efforts are being addressed by the Cadmus team in the Task 2, Carbon Budget Report.

## Comparing Vermont to Guidelines and Other States

Vermont’s Inventory is generally consistent with IPCC and EPA guidelines and with California, Massachusetts, and New York. This section briefly describes these guidelines and the other states inventory methods. We highlight select areas where practices adopted by other states may enhance Vermont’s future inventories. A crosswalk table comparing Vermont with the other states and the U.S. National Inventory can be found in Appendix B.

### IPCC Guidelines

The IPCC has issued multiple rounds of guidance (2006, 2013 and 2019) aimed at supporting comprehensive, consistent, and transparent accounting that is up to date on emerging trends, data, and methods on climate science. The multi-volume IPCC documents are drafted and reviewed by international teams of subject matter experts, peer reviewed, and widely discussed and reviewed in the scientific literature. The 2013 and 2019 guidelines are refinements to the 2006 document, which remains foundational for emissions inventories.

The 2019 Refinement recommends supplementary methodologies for sources and sinks where there are gaps and/or differences new scientific data. One example is the updated guidance on fugitive emissions related to oil and gas systems to account for an increase of fugitive emissions

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

from hydraulic fracturing.<sup>11</sup> The 2019 Refinement also includes recommendations for CO<sub>2</sub> and CH<sub>4</sub> emissions from flooded land.<sup>12</sup>

The technical consultant team notes these refinements are intended to improve the estimation of upstream emissions for fossil fuel and large hydro, but that for inventory accounting, these emissions would still be counted in the inventory of the jurisdiction where the gas production or flooded lands are located, and not be allocated to Vermont's inventory. A further discussion of the IPCC's recommendations on the use of upstream or lifecycle accounting methods for analysis of mitigation options is provided later in our report under the Issues and Opportunities Section.

The 2019 Refinement also provides new guidance on generic inventory management tools such as workplans, improvement plans, data management systems, quality systems, training and capacity building and documentation procedures. The management tools presented are not prescriptive but provide some suggested approaches and examples.<sup>13</sup>

## EPA Guidance

The EPA provides guidance to states for inventories through the SIT tool. The EPA is also responsible for preparing the U.S. National GHG Inventory, and the methods and processes used therein also provide a reference point. A quote from the Executive Summary of the National Inventory Report indicates adherence to common inventory reporting formats need not preclude alternative examinations...

“The presentation of emissions and removals provided in this Inventory **does not preclude alternative examinations**, but rather this Inventory presents emissions and removals in a common format consistent with how countries are to report Inventories under the UNFCCC.”<sup>14</sup>

---

<sup>11</sup> IPCC 2019 Methodology Refinement, Vol. 1 Overview, page 12.

<sup>12</sup> Ibid. p. 12.

<sup>13</sup> Ibid. p. 11.

<sup>14</sup> EPA Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2019. Box ES-1 Methodological Approach.

## Energy Futures Group, Inc

The Appendix B crosswalk table includes a column for the U.S. National Inventory with further details on areas where the National Inventory is similar or different from Vermont and the other three comparison states.

## Comparison and Examples from Select Leading States

The technical consultant team also reviewed state inventories and methods for California, Massachusetts, and New York. We also reviewed and comment in a following section of this report on the CBEI methods adopted in Oregon and Minnesota. These states are taking the challenges of climate change seriously and contributing as leaders in the development of state legislation, policies, plans, and actions to reduce emissions. Select examples of where the California, Massachusetts, and New York inventories can offer insights for Vermont are provided below.

To complement the official state inventory, the California Air Resources Board (CARB) has produced supplemental reports on Short Lived Climate Pollutants (SLCP)<sup>15</sup>, and an Inventory of Natural and Working Lands (NWL).<sup>16</sup> SLCPs include hydrofluorocarbons, methane, and black carbon. The SLCP Reduction Strategy recognizes the climate and public health impacts from these gases are more immediate, targeted action is necessary, and there are viable opportunities to reduce SLCP both locally and globally. The strategy recommends adoption of gas specific SLCP reduction targets that will contribute and be consistent with overall GHG targets and will also provide health and other co-benefits.

As noted above, Vermont has already adopted a tool for estimating emissions from ODS substitutes (which are HFCs and SLCPs) developed by California. Accounting for the rising importance of ODS substitutes is important to support strategies and actions that can reduce these emissions, by for example the use of alternative refrigerants and implementation of refrigerant management programs. The California tool for ODS substitutes has also been adopted by New York and is being considered by Massachusetts. An SLCP strategy and the investigation of SLCP mitigation strategies in Vermont would address opportunities for manure management, bio-digesters, and other measures to reduce direct methane emissions from agriculture.

---

<sup>15</sup> California Air Resources Board, Short-Lived Climate Pollutant Reduction Strategy, March 2017.

<sup>16</sup> California Air Resources Board, An Inventory of Ecosystem Carbon in California's Natural & Working Lands, 2018.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

New York's Inventory uses another method to recognize the importance of accounting for the shorter-term impacts of CH<sub>4</sub> and provides a supplemental calculation of methane's contribution to total emissions based on a 20-year GWP as opposed to the 100-year period used for the main inventory. With a 100-year horizon CH<sub>4</sub> accounts for 19.83 MMTCO<sub>2</sub>e, while with a shorter 20-year horizon CH<sub>4</sub> is responsible for 57.11 MMTCO<sub>2</sub>e.<sup>17</sup> While continuing to account for methane using the 100-year horizon consistent with IPCC guidance, the supplemental analysis can support investigation of mitigation options for sources of methane emissions including the waste, agriculture, and fossil fuel production sectors. Note that mitigation strategies reducing direct methane emissions could be prioritized even if they are not emissions that occur in the state boundaries.

California's NWL Inventory provides an important complement to the GHG Inventory, providing a quantitative estimate of the existing state of ecosystem carbon and fluxes associated with stock change in the landscape. Under Task 2 the technical consultant team is working on the development of a carbon budget for Vermont.

The Massachusetts Department of Environmental Conservation (MADEC) has developed a detailed workbook to account for the settlement of Renewable Energy Credits (RECs) within New England's regional electricity markets. As utilities and project developers in Vermont both sell RECs from select renewable electricity generating plants located within Vermont, and purchase RECs, from other jurisdictions, a comprehensive and accurate system for identifying REC settlements for the region is necessary. Vermont has not used the Massachusetts DEC workbook for REC settlement information in the past but is considering adopting it for future Inventories.

## Emissions Inventory Crosswalk and Good Practices

Appendix B provides a crosswalk table with high level comparison of Vermont to the inventories discussed above. We observe there are significant areas of consistency across the inventories, as well as select areas where approaches from the other jurisdictions may be helpful to inform future changes in Vermont's Inventory. Given the inventories are consistent across most of the major methods and approaches, and that the Agencies completing the Inventories are open to future changes as data, climate science, and issues evolve the technical consultant team prefers

---

<sup>17</sup> New York State Greenhouse Gas Inventory, NYSERDA, Table S-1, page S3.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | 📧 info@energyfuturesgroup.com

the term “good practice” as more appropriate than “best practice” and we would rate all of the inventories reviewed as following good practices in the major categories.

## Consumption-Based Emissions Inventories

### Review of Key Differences and Similarities between Consumption- and Sector-Based Inventories

A consumption-based inventory is a method to estimate greenhouse gas emissions produced around the world due to the consumption of energy, goods, and services in one place, in this case, one state. This inventory estimates the lifecycle emissions of all commodities used within a state, including, for example, cars, food, fuels, appliances and clothing (taken from Oregon).<sup>18</sup> Lifecycle emissions means that the inventory measures the total emissions from producing, transporting, using, and disposing of a commodity, often referred to as a “cradle to grave” methodology.<sup>19</sup> A consumption-based inventory allows jurisdictions to account for emissions from products manufactured outside of its boundaries, imported, and consumed within its boundaries. This allows for a fuller understanding of the true impact of one jurisdiction on global climate change. Vermont does not currently use a consumption-based inventory when accounting for the greenhouse gasses attributable to Vermont.

A sector-based inventory measures greenhouse gas emissions generated by humans produced within a given boundary by economic sector. In the case of Oregon, the sector-based inventory is divided into Transportation, Electricity, Natural Gas, Residential & Commercial, Industrial, and Agriculture.<sup>20</sup> The sector-based inventory methodology is consistent with EPA and IPCC guidance and is more common practice for states than using a consumption-based inventory. Vermont currently uses a sector-based inventory to account for its greenhouse gas emissions.

Unlike a consumption-based inventory, a sector-based inventory primarily accounts for emissions generated within a state border, with an important exception often being emissions associated with electricity consumed within the state but produced elsewhere. This reflects the

---

<sup>18</sup> “Appendix A and B: Oregon’s Greenhouse Gas Emissions through 2015: An assessment of Oregon’s sector-based and consumption-based greenhouse gas emissions,” Greenhouse Gas Reporting Program and Materials Management, May 2018, Portland, OR.

<sup>19</sup> <https://www.pca.state.mn.us/air/consumption-related-emissions>

<sup>20</sup> <https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx>

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

current method in Oregon and Vermont. While the sector-based inventory is divided up by sector, a consumption-based inventory is divided up by commodity category including, for example, vehicles and parts, food and beverages, and appliances (which are the three categories contributing most to emissions in Oregon's consumption-based inventory).

## Consumption-Based Inventory Experience from Oregon and Minnesota

In 2011, Oregon published the nation's first sub-national consumption-based greenhouse gas emissions inventory. Minnesota now also conducts a consumption-based inventory. Both states use both the consumption-based inventory in addition to accounting for their emissions in the more conventional sector-based and "in-boundary" approach. Crucially, both Oregon and Minnesota consider their consumption-based inventories to be complementary to their sector-based inventories.

The Oregon Global Warming Commission primarily uses data from their sector-based inventory to evaluate progress toward the state's emissions reduction goals and to make recommendations to the Legislature.<sup>21</sup> However, they state, "assessing the consumption-based inventory relative to the goals identifies additional opportunities to reduce emissions, and helps to ensure that emission reductions occurring within Oregon, as a result of state policy, are true global reductions and Oregon is not simply shifting emissions to locations outside of the state."

In Minnesota, the in-boundary inventory is required by law and is conducted every two years. It is used to develop priorities for emissions reductions based on the sectors.<sup>22</sup>

Differences in these two methodologies result in differences in greenhouse gas emission estimates. For example, in Oregon in 2015, sector-based emissions were 63 MMTCO<sub>2e</sub>. By comparison, Oregon's consumption-based emissions in 2015 were 89 MMTCO<sub>2e</sub>. Oregon estimates that more than half of the consumption-based emissions occur in other states or nations and are not included in the sector-based inventory. By comparison, the Minnesota in-boundary emissions in 2012 were 139.8 MMTCO<sub>2e</sub> and the consumption-based emissions were

---

<sup>21</sup> "Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions," Greenhouse Gas Reporting Program and Materials Management, May 2018, Portland, OR, page 4.

<sup>22</sup> Consumption-related emissions, Minnesota Pollution Control Agency, <https://www.pca.state.mn.us/air/consumption-related-emissions>

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

133.1 MMTCO<sub>2</sub>e in the same year.<sup>23</sup> Whether a state has greater sector-based or consumption-based inventories depends on a state’s economy and consumption patterns. For example, while Oregon is a net importer of emissions, Minnesota is a net exporter. The emissions from the agricultural and other goods that Minnesota produces and exports are higher than emissions from the goods and services the state imports.<sup>24</sup> Figures 3 and 4 illustrate the two states’ inventories.

**Comparison of Oregon's 2015 sector- and consumption-based greenhouse gas emissions**



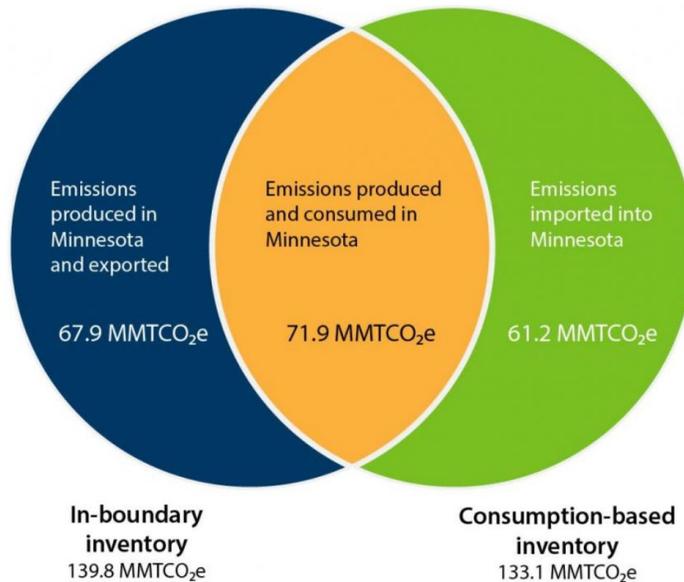
**Figure 3:** Comparison of Oregon’s 2015 sector- and consumption-based greenhouse gas emissions.<sup>25</sup>

<sup>23</sup> Ibid

<sup>24</sup> Ibid

<sup>25</sup> “Oregon’s Greenhouse Gas Emissions through 2015: An assessment of Oregon’s sector-based and consumption-based greenhouse gas emissions,” Greenhouse Gas Reporting Program and Materials Management, May 2018, Portland, OR, page 39.

**Energy Futures Group, Inc**



**Figure 4:** Comparison of Minnesota’s 2012 in-boundary and consumption-based greenhouse gas emissions<sup>26</sup>

Because Oregon considers the consumption-based inventory to be a supplement, rather than a replacement, for their sector-based inventory, the two inventories considered together provide a fuller picture of the state’s emissions. There is overlap between the two inventories and, in order to prevent double counting, the inventories are never added together. For example, according to Oregon’s analysis, the inventories share about 38 MMTCO<sub>2</sub>e in common which includes, for example, emissions from household and government use of energy and waste disposal. Rather, Oregon calculates the emissions shared by both inventories and the emissions that are uniquely attributable to each inventory, which together creates an estimate of the state’s total contribution to global emissions. Figure 4 illustrates how the two inventories complement one another.<sup>27</sup>

<sup>26</sup> Consumption-related emissions, Minnesota Pollution Control Agency, <https://www.pca.state.mn.us/air/consumption-related-emissions>

<sup>27</sup> Ibid, page 41.

**Energy Futures Group, Inc**

### Trends in Oregon sector-based and consumption-based greenhouse gas emissions, 1990-2015



**Figure 5:** Trends in Oregon sector-based and consumption-based greenhouse gas emissions, 1990-2015.<sup>28</sup>

### Best Uses of Consumption-Based Inventory for Vermont

Vermont may find value in developing a consumption-based inventory and could look to Oregon and Minnesota for guidance and potential collaboration in future efforts to refine the methods. The value, for example, could be developing a fuller understanding of a state’s impact on climate change and a more complete view of emissions attributable to a state. This could serve as a valuable resource for education, both for decision-makers in the state and for all Vermonters. For decision-makers, it could help inform mitigation strategies for Vermont and identify the best opportunities for the state to reduce emissions. For all residents, this could be an opportunity in better understanding how the choices of individual Vermonters impact global climate change. Like Oregon and Minnesota, Vermont could consider using a consumption-based inventory to supplement the existing sector-based inventory.

<sup>28</sup> “Oregon’s Greenhouse Gas Emissions through 2015: An assessment of Oregon’s sector-based and consumption-based greenhouse gas emissions,” Greenhouse Gas Reporting Program and Materials Management, May 2018, Portland, OR, page 41.

### Energy Futures Group, Inc

It is also important to note that Oregon and Minnesota are not using a consumption-based inventory as a replacement for a sector-based inventory, but rather as a complement. Both states highlight the value of a consumption-based inventory in supplementing an understanding of a state's emissions and as a tool for identifying mitigation strategies that would cut a state's emissions.

Appendix B of the *Oregon's Greenhouse Gas Emissions through 2015* report details the methodology of the consumption-based inventory, which utilizes a complex Excel model to derive consumption-based emissions estimates. There are numerous boundary and accounting considerations and assumptions to consider when adopting a consumption-based inventory. While theoretically appealing there is a great deal of complexity in assigning emissions to all goods and services consumed within the state boundaries. For example, many products today have diverse and global supply chains. Accounting for the raw materials and intermediate components for each item can become a very deep and multi-layered problem when considering whether to adopt this methodology.

## Upstream Emissions vs Lifecycle Emissions Accounting

It is important to distinguish between upstream emissions and lifecycle emissions in GHG accounting. Upstream emissions accounting looks at the estimated direct emissions associated with energy use, whether those emissions are within Vermont's boundaries or out of state. An example of upstream emissions accounting is taking into account both the energy use of natural gas and the direct atmospheric emissions of methane from gas production in other states. Tools and data sources that can be used to estimate upstream emissions include the GREET tool developed by Argonne National Laboratory. Upstream emissions analysis is sometimes referred to as "wells to wheels" to indicate that the recovery, refining, transportation and distribution of a fuel are taken into account.

By contrast, lifecycle emissions accounting attempts to account for a broader set of inputs and emissions associated with an energy source. For example, a lifecycle analysis of a wind turbine might include the emissions associated with the energy required to produce the turbine as well as the emissions produced by the transportation of the workers and equipment to the site where the wind turbine is installed and operating.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

The technical consultant team recommends that, when possible, Vermont use upstream emissions analysis to account for out of state emissions of energy use in order to inform the analysis of mitigation strategies and opportunities.

## Issues and Opportunities

A GHG Inventory is one of many “tools” that planners, policy makers, and public and private decision makers need to help understand and address the daunting climate imperative. Evidence from around the globe and across a broad range of geophysical, human health, economic, and ecosystem indicators illustrate the importance of immediate, sustained, deep, and broad action. Inventories inform, but don’t create actions, policies, or mitigation strategies.

The variety of methods and approaches to GHG Inventories can be thought of as different types of saws (keyhole or hacksaw) or screwdrivers (straight bladed or angled Phillips-head) that might be more used or useful for a particular task and purpose.

This section discusses issues and opportunities for improvements to Vermont’s Inventory. We structure this discussion around a set of comments provided in an open letter to the Vermont Climate Council (OLVCC), as these are broadly speaking representative of other feedback and comments that have been considered and discussed in public meetings convened by the Science and Data Subcommittee of the Climate Council, and of issues considered by the ANR, the DPS, advocates, and other concerned parties in Vermont and elsewhere.

### Issues with Vermont Inventory

Seven main issues are identified in the OLVCC.

#### Adopt a Comprehensive Carbon Footprint Accounting

As discussed above, Vermont’s current sector-based methods account primarily for emissions from in-state activity. The electricity sector is an important exception, where a consumption-based approach is applied, so the emissions from electricity generation from out of state that is imported to Vermont are counted.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

The OLVCC cites lifecycle accounting language in the GWSA statute, and advocates for a CBEI and upstream emissions accounting as required and to run in parallel as complements to the current accounting system.

The experience from Oregon and Minnesota with CBEI methods and models discussed above provide tangible examples of how states can include CBEI to complement a sector-based inventory.

Complementary CBEI emission results can inform policy, planning, and consumer decision making, and accounting for upstream emissions can inform analyses of mitigation strategies, scenarios, and actions.

The OLVCC provides upstream emissions estimates based on the use of lifecycle analysis models including the Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET) developed by the Argonne National Laboratory. These types of upstream emissions estimates can be used in the analysis of mitigation options.

However, the complexity of truly addressing a comprehensive carbon accounting footprint is immense, and there are not methods and tools, including those recommended or discussed above, that can fully account for this complexity. Many modern products and services have inputs and raw materials that draw from multiple sources, and fully accounting for the emissions with the lifecycle production of just one such product requires a huge effort. Conducting such detailed analyses for an entire state's economy is not realistic without significant levels of abstraction. Adopting these approaches needs to be guided by consideration of available time and resources and by consideration of the incremental value gained to inform decision making.

In the end, inventory methods and approaches are tools meant to inform and enable climate action policy, strategies, implementation, and actions.

### Modify Global Warming Potential for Methane

The OLVCC recommends assessing the GWP for methane based on a 20-year lifetime to account for the higher near-term impacts of gas. As discussed above in the Comparison and Examples from Leading States section, New York and California have both taken steps to identify and address the more serious short-term GWP for methane. New York provides an estimate of a 20-year GWP for methane in their Summary Inventory report, and California has developed an entire strategy to identify and address opportunities and issues with short lived climate

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

pollutants, including methane. Both efforts can inform mitigation planning, investment, and actions, and may focus mitigation strategies on key categories responsible for high levels of CH<sub>4</sub> emissions. At the same time, New York and California continue to use the 100-year GWP for CH<sub>4</sub> based on guidance from the IPCC AR-4 report in official inventory reporting.

### Account for the Upstream Emissions of Purchased Fossil Fuels

The OLVCC also recommends assigning and accounting for upstream emissions with the production, processing, and transportation of purchased fossil fuels. Vermont imports fossil fuels. Following sector-based accounting protocols, these upstream emissions are accounted for in producing states. For example, emissions from gas production, processing and transport would be counted under fossil fuel production categories in Pennsylvania, Louisiana, and other states through which pipelines pass. If such upstream emissions were counted in Vermont's inventory, and they continued to be counted in the sector-based inventory of other states, double counting would occur.

The guidelines for inventory reporting developed by the IPCC and EPA through extensive peer-reviewed design, comments, and refinements, aim to produce results that are comprehensive, that do not under or over count emissions, and that provide a replicable, transparent, and consistent results across jurisdictions. These guidelines generally inform Vermont's inventory and the inventories for the other states reviewed by our team. It is also understood that complementary and supplemental methods can and should be used to analyze mitigation strategies and to communicate inventory results to decision makers. Complementary analyses of mitigation strategies using the upstream emissions factors for fossil fuels provided in the OLVCC can be used to help Vermont design and implement actions that result in the greatest reductions in emissions – whether these emissions are counted in Vermont's inventory, or elsewhere.

### Modify Accounting for Emissions from Regional Electric Grid

The OLVCC recommends emissions from the regional grid be adjusted upwards to reflect associated upstream gas emissions and transmission system losses. It also recommends emissions be calculated based on monthly generating mixes and emissions estimates not be adjusted for Renewable Energy Credits (RECs).

Accurate accounting for emissions from the electric grid is vitally important, as most mitigation scenarios and strategies in Vermont and across the United States rely heavily on strategic electrification in the transportation and building sectors and on a decarbonized grid. The

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | @info@energyfuturesgroup.com

interstate, international, and regional exchange of electricity and RECs makes emissions accounting complicated. Vermont's inventory accounts for electricity imports, exports, and REC adjustments. Vermont is also considering use of the spreadsheet model, developed, and maintained by the Massachusetts Department of Environmental Conservation that includes a more comprehensive accounting by state for the settlement of RECs regionally.

### Land Use Carbon Footprint Accounting

The OLVCC recommends separate land use carbon footprint accounting and recommends the State not permit land use carbon offsets to offset energy related GHG emissions. The work undertaken by the technical consultant team under the Task 2 Carbon Budget is directly addressing the carbon sources and sinks for Vermont land use, and the potential for reduced emissions, and increased sequestration. California's NWL Inventory, discussed above is an example of an inventory that will also be used in this fashion. Carbon offsets, of any type, need to meet a range of criteria including additionality, duration, transparency, and the avoidance or delay of direct actions.

### Account for Upstream Biofuel Impacts

Biofuels, like fossil fuels, have upstream impacts that are not captured by the current Vermont sector-based inventory approach. Biogenic CO<sub>2</sub> emissions are not counted in Vermont's main Inventory, and this is consistent with the approach of other states and with the EPA and IPCC guidelines. Following these guidelines, changes in the carbon stock related to biogenic fuel combustion should be counted in land use, land use change and forestry (LULUCF) accounting. As complementary information, Vermont and other states provide estimated gross emissions including and excluding biogenic CO<sub>2</sub>, estimates of sequestration from LULUCF, and the net emissions. Stakeholders have been working on the development of a Clean Heat Standard for Vermont, and this work has recognized the necessity of considering upstream impacts for biofuels. Where possible these should include potential competing and current land uses (and loss of sequestration) when calculating the emissions impacts of biofuels.

### Hydropower Upstream GHG Emissions

Finally, the OLVCC recommends the need to estimate the GHG emissions for large hydro projects, including changes to carbon and other GHG fluxes due to inundation and hydro project development. The 2019 IPCC refinement includes recommendations on improvements to estimate emissions from flooded lands. The levels, types and duration of emissions will vary from site to site based on many factors. Stakeholders have provided the Science and Data

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | ✉ info@energyfuturesgroup.com

Subcommittee with citations for research on estimating the GHG emissions from Hydro Quebec.<sup>29</sup> As part of its Open EI, multi-source energy information initiative and services, The National Renewable Laboratory (NREL) has compiled literature and research on analyses of LCA emissions from Hydro and other renewable energy resources.<sup>30</sup>

Under IPCC and EPA guidance and Vermont's current inventory practices these types of emissions are accounted for in Quebec's Inventory, which does include such estimates. At the same time, in complementary fashion, Vermont's assessment of electrification as a mitigation strategy can incorporate analyses based on a range of the literature based LCA emissions for large hydropower.

## Opportunities

The issues, comparative analyses and research discussed above provide numerous examples of areas where Vermont has opportunity to enhance and complement its current GHG inventory. Looking forward, the importance of providing education, information and engagement that is sustained and inclusive can't be overstated. Addressing climate change is an issue that impacts every citizen and organization in Vermont. It will require significant shifts and reallocations from business as usual. Some of these decisions will be able to be made proactively as legislation, regulation, or through consumer choices. Others may be reactive in response to climate driven damages and system adaptations.

Examples of complementary communications and analysis tools include the SLCP and NWL reports from California, and New York's complementary results using a shorter horizon GWP for methane, and the CBEI's from Oregon and Minnesota. Other tools, such as "Cool California"<sup>31</sup> from the California Air Resources Board provide information for households, local governments, schools, and small businesses to help inform decision making. This tool includes links to funding resources and is designed to help facilitate action.

Mitigation analyses and scenarios to be analyzed for the Climate Action Plan can incorporate upstream emissions and alternative GWPs for methane to help identify policies, actions, and

---

<sup>29</sup> Levasseur, et. al., 2021. Improving the accuracy of electricity carbon footprint: Estimation of hydroelectric reservoir greenhouse gas emissions, Renewable and Sustainable Energy Reviews, [www.elsevier.com/locate/rser](http://www.elsevier.com/locate/rser).

<sup>30</sup> NREL, Open EI, See LCA Harmonization research [here](#).

<sup>31</sup> Cool California available [here](#).

## Energy Futures Group, Inc

strategies with the largest and most cost-effective emissions reductions, whether or not those emissions reductions are counted under Vermont's inventory methodology.

## Conclusions

This report represents a rapid assessment (2 months) and review of Vermont's GHG Inventory. We have compared the Vermont Inventory with the guidance from national and international agencies and with experience from other select states. Our review and analysis have also considered issues with the Vermont Inventory identified by stakeholders engaged with the VCC's development of the Climate Action Plan.

The EFG team, as a part of the larger Technical Consultant Team supporting the VCC, provides the following key findings and recommendations based on this research.

## Key Findings

- Vermont's current inventory methods are generally consistent with guidelines from the EPA, IPCC and with the practices of California, New York, and Massachusetts. They are also consistent with the primary inventory methods for Oregon and Minnesota.
- Vermont can demonstrate leadership in the development of an actionable Climate Action Plan, and its implementation based on the current GHG inventory, and its methods.
- Vermont's current sector-based inventory method does not represent, nor claim to be representing, lifecycle accounting of greenhouse gas emissions. Upstream and lifecycle emissions can be analyzed to inform decision making without necessarily including them in the Inventory.
- Supplemental approaches and analyses are being used by other jurisdictions to complement a sector-based inventory method. Examples include CBEI in Oregon and Minnesota, and reporting on short-lived climate pollutant impacts (SLCP) in California.

## Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

- There are important opportunities to complement the inventory with supplemental analyses to inform decision making and the development and implementation of mitigation policies, strategies, and actions.
- The IPCC, while not recommending lifecycle accounting as a greenhouse gas inventory method, does recommend lifecycle analyses, and consideration of impacts on emissions outside of jurisdictional boundaries, as important elements in mitigation analyses.
- The complexities of full lifecycle inventory accounting and reporting are immense and could divert resources from inventory and mitigation efforts that have more direct and practical connections to actions that reduce emissions.
- Public awareness and education are foundational for inclusivity.

## Recommendations

- Vermont should maintain primary inventory consistency with international and national level guidelines and the practices of other leading states. Vermont can contribute to the development and implementation of supplemental analyses at the same time.
- The possible development and adoption of a CBEI for Vermont should not, and cannot, replace the sector-based emissions inventory and the associated reporting. The GWSA targets are based on the sector-based reporting, and Vermont should maintain a primary annual inventory reporting method and accounting that is consistent with national and international guidelines.
- Vermont should acknowledge the scope and ongoing scale of scientific and international community efforts to create a complete and non-duplicative accounting framework.
- Clarifying and indicating that the Inventory is not used for all purposes, and that upstream emissions can be considered without being counted in the inventory may be

## Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

helpful.

- Vermont should remain open to change as new data and methods emerge.
- Vermont should conduct and maintain key category analyses, and summary reporting by GHG.
- Each Inventory should also contain a sector-based summary of existing and emerging issues, possible changes to data and methods, and a presentation and discussion of supplemental analyses that can inform decision making.
- Examples of supplemental analyses include reporting on the impacts from shorter time horizons and GWP modifications for methane, sensitivity analysis to reflect the use of different IPCC Assessment Report values (i.e. AR4 vs AR5), and accounting for upstream emissions from energy use.
- Literature and tools for lifecycle analyses should be used to analyze the relative impacts of mitigation pathways and consideration of policy and behavior without becoming the basis for the inventory.
- Upstream emissions estimates should be applied as sensitivities and to inform mitigation pathway analyses without being adopted as formal inventory protocols.
- When possible, Vermont should use upstream emissions analysis to account for out of state emissions of energy use in order to inform the analysis of mitigation strategies and opportunities.

### Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | @info@energyfuturesgroup.com

- Increased staffing and resources devoted to maintaining, updating, and communicating results from the Inventory are warranted.
- Increasing public understanding and familiarity with the Inventory will help with the development and implementation of mitigation policy action and strategies.

## Appendices

### A. Vermont Method and Data Summary

Appendix Table A-1: Vermont Greenhouse Gas Inventory – Methods and Data Summary					
<u>Level/Sector</u>	<u>Primary Method</u>	<u>Primary Data</u>	<u>Supporting Method(s)</u>	<u>Supporting Data</u>	<u>Notes</u>
<b>Overall</b>	Environmental Protection Agency State Inventory Tool (EPA SIT)	Energy Information Administration (EIA) State Energy Data System (SEDS)			Vermont Greenhouse Gas Emissions Inventory and Forecast:  1990 – 2017, page 7.
<b>Overall</b>	Global Warming Potentials	100-year weighted GWP			IPCC Fourth Assessment Report (AR4)
<b>Overall</b>	Greenhouse Gases Covered	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O for Transportation and RCI,  Industrial: CO <sub>2</sub> , HFCs, PFCs, NF <sub>3</sub> , and SF <sub>6</sub> (95% Flourinated gases).			
<b>Transportation Mobile Combustion</b>	SIT Module for CO <sub>2</sub> from fossil fuel combustion. CH <sub>4</sub> and N <sub>2</sub> O SIT mobile combustion.	Fuel sales data from Joint Fiscal Office for Gasoline, Diesel from SEDs.	National Emissions Inventory – EPA MOVES model	Department of Motor Vehicles and VTrans	Major change in method for the 2017 inventory. Historical

### Energy Futures Group, Inc

					estimate of on/off road.
<b>Residential Commercial Fuel Use</b>	SIT Module for CO2 from fossil fuel combustion. CH4 and N2O SIT stationary combustion.	EIA SEDs data	Vermont Department of Public Service and Agency of Natural Resources Air Quality Division	VT fuel assessment reports, ANR Point Source Emissions	CO2 from wood combustion reported as supplement
<b>Agriculture</b>	EPA SIT Tool	US Department of Agriculture Census Data	US EPA AgStar database		Key category for scale and trend. Current method is “cow based” and doesn’t capture improved management opportunities well.
<b>Industrial Processes</b>	ODS substitutes – California tool for Climate Alliance States – per capita and per vehicle	Adjusted for VT by number of HH with AC or heat pumps.	SF6 based on annual consumption estimate.  Limestone and dolomite, soda ash and urea all consumption and default SIT emissions  Semi-conductor Historical	Electric utilities	ODS substitutes ~60% and Semi-conductor manufacturing ~34%

**Energy Futures Group, Inc**

	Semi-conductor manufacturing EPA FLIGHT Tool	Facility level Greenhouse gas reporting (GHGRP).	national trends prior to 2011.		
<b>Electric Consumption</b>	Electricity consumption not just in-state generation, Public Service Department Tool	ISO-NE GIS, utility purchase decisions, Renewable Energy Certificate settlements.			Wind, solar PV, hydropower, and nuclear zero GHG emitting. Biomass zero CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O are estimated.
<b>Waste</b>	EPA SIT Wastewater module, CH <sub>4</sub> and N <sub>2</sub> O	Default EPA data w adjustments Waste Management and Prevention Division data for septic systems and biosolid fertilizer use.	Solid Waste – fugitive CH <sub>4</sub> from LFG. CO <sub>2</sub> is biogenic and not included in main inventory		Not a key category based on scale.
<b>Fossil Fuel Industry</b>	EPA SIT module	Pipeline miles and emission factor from Pipelines and Hazardous Materials Safety Administration			Not a key category based on scale. Fugitive emissions based on transmission and distribution of gas

## B. Cross Walk Table

### Appendix Table B-1:

### Comparison of Vermont’s GHG Inventory to New York, Massachusetts, California, and U.S. National Inventory

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Citation	Vermont Greenhouse Gas Inventory and Forecast 1990-2017, Prepared by the Air Quality and Climate Division, Department of Environmental Conservation, Agency of Natural Resources. May 2021.	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. U.S. Environmental Protection Agency.	New York State Greenhouse Gas Inventory: 1990-2016, Final Report July 2019. NYSERDA and NY DEC.	Statewide Greenhouse Gas Emissions Level: 1990 Baseline Update. May 2021. Massachusetts Department of Environmental Protection.	California Greenhouse Gas Emissions 2000 to 2018: Trends and Other Indicators. California Air Resources Board.
Global Warming Potentials	IPCC Fourth Assessment Report (AR-4)	IPCC Fourth Assessment Report (AR-4), Table 1-3 compares with AR-5 and Annex 6 has emissions estimates using revised GWPs	IPCC Fourth Assessment Report (AR-4), See Appendix Table A-2	IPCC Fourth Assessment Report (AR-4)	IPCC Fourth Assessment Report (AR-4)
Gases to include in Inventory	Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3)	6 major gases with relatively long atmospheric lifetimes and mixing, leading to average concentrations. More local short-lived gases and background also discussed. Precursor gases discussed Section 2.3.	6 major gases - Summary Table S1 includes cross tab by gas and sector	Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3).	6 major gases, ODS not included in inventory, presented as supplemental Figure 17.a.

### Energy Futures Group, Inc

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Period for GWPs.	100 years	100 years	100 Yr. - includes supplemental information on increase if Methane is 20 year.	100 Yr. Spreadsheet in Appendix C allows users to toggle between certain 100-year and 20-year GWPs	100 Yr. for Inventory. SLCP report for uses 20-year period for CH4, BC, HFCs informative.
Sectors	Seven Sectors, Transportation mobile sources, Residential, Commercial, Industrial (Fuel), Industrial (Process), Electricity Consumption, Waste, Agriculture, Fossil Fuel Industry	5 IPCC defined Sectors Table 1-8. Section 2 presents emissions by economic sector - Box 2.1 for methodology. Figure 2-19 allocates electricity to economic sector.	Follows IPCC sector guidelines	Transportation, Electricity Consumption, Residential, Commercial, Industrial (Fuel), Industrial (Process), Waste, Agriculture, Natural Gas Systems	Categorization based on Scoping for Study for Assembly Bill (AB 32), by Economic Sector and IPCC categories.
Key Categories	Recommendation for VT	Table 1-4 .		Not calculated	
Trend Analysis	Recommendation for VT	Table 1-4 includes level and trend analyses using two approaches (approach 2 includes stochastic uncertainty analysis) and with and without consideration of LULUCF sector. Table 1-5 includes estimate with uncertainty by gas. CO2 emissions from wood biomass and biofuel consumption are not included specifically in summing energy sector totals.	Figure S-7. Total and by sector every 5 years from 1990-2016. Notes increase in ODS substitutes contribution to non-combustion from 0% to 25% from 1990 to 2016. Electric sector natural gas increase from 19% in 1990 to 79% in 2016. Follows EPA inventory guidelines and biogenic fuels treated as carbon neutral. CH4 and N2O estimated. Future inventories	Not calculated Uses the convention for biogenic sources adopted by the United Nations Framework Convention on Climate Change	By sector and category. By gases in some cases.  Excluded in combustion and electric generation. Supplemental information provided.
Treatment of Biogenic CO2	Supplemental information				

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
		However, they are presented here for informational purposes and to provide detail on wood biomass and biofuels consumption	may include information on carbon stocks as well as biomass combustion to inform policy (RCI p.9).	(UNFCCC) and others, which report biogenic CO2 emissions separately from other GHG emissions.	
Electricity Direct/Indirect	Consumption based, so accounts for indirect emissions from generation out of state.	Not clear on how net electricity imports/exports accounted for	Includes estimates including and excluding net imports of electricity. In 2016 net imports use NYS Generation Attribute System for net imports	Includes emissions associated with electricity generated within MA and out-of-state. Takes a regional approach? The inventory apportions a percentage of megawatt hours of losses and associated emissions associated with pumped hydro	In state generation and emissions from imported electricity.
Large Hydro	Treated as zero emission	Appears to be zero emissions - not discussed	Not discussed, but appears to be treated as zero emission		Documentation for Columbia River Hydro 0 CO2 and 0 N2O
Nuclear	Treated as zero emission	Appears to be zero emissions - not discussed	Treated as zero emission	Not mentioned in inventory	

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Blended Fuels	Ethanol and biodiesel are removed from fuel combustion calculations to determine emission from transportation sector. Not mentioned otherwise	<p>Section 3.11 on biofuel consumption and Table A-81 in Annex 3.2. Carbon dioxide emissions from ethanol added to motor gasoline and biodiesel added to diesel fuel are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs accounted for in LULUCF, therefore, fuel consumption adjusted to remove ethanol and biodiesel.</p> <p>Currently emission estimates from biomass and biomass-based fuels included in this Inventory are limited to woody biomass, ethanol, and biodiesel.</p> <p>Biogas, the biogenic components of MSW, and other renewable diesel fuels currently not included. EPA will examine if EIA data allow these to be included in future inventories.</p>	Gasoline in NYS contains up to 10% ethanol, no CO2 emissions assigned to ethanol in the inventory per EPA guidance. Biodiesel also zero CO2.	MassDEP's inventory divides biodiesel equally between the transportation and residential sectors. Biodiesel is subtracted from distillate for the transportation and residential sectors as per EPA guidance, parallel to the way ethanol is subtracted from motor gas for the transportation sector.	Biogenic CO2 not counted per international and national standards. Tracked separately and reported as supplemental information. Figure 6 and 7. Low Carbon Fuel Standard renewable blends for diesel have grown from 0.5 in 2011 to 18.5% in 2018.

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Carbon stored in industrial products		Non Energy use of fuels in IPPU	Industrial fuel consumption adjusted to account for carbon stored in petrochemical feedstocks not used for energy.		
Black Carbon other Short lived Climate Pollutants	Black carbon emissions are calculated using elemental carbon component of PM2.5 totals for combustion related activities from the 2017 National Emissions Inventory (NEI)	Precursor and short-lived gases increasing, ODS covered under Montreal protocol and not accounted, ODS substitutes included.		Black carbon: does not have black carbon emissions data for 1990 to include in the GHG inventory. Emissions of other SLCPs, such as methane and fluorinated gases, are included in this inventory	Separate SLCP Strategy Report. ODS not counted in inventory, ODS substitutes significant rise. California tool for accounting.
ODS Substitutes	California Model		Most recent inventory adopts California model developed by CARB	Listed under Issues for Future GHG Inventories	ODS substitutes significant rise. California tool for accounting.
Data sources	Mix of Federal and State	Summary in Figure 1-1. Note each sector contains notes on planned improvements.	Mix of Federal and State	Federal data sources: EPA State GHG Inventory Tool (SGIT); EPA FLIGHT tool; US DOT PHMSA data and EIA data. State data sources: MWRA	Mix of Federal and State, Facility specific reports required for >10,000 metric tons, and verified for >25,000 metric tons
Frequency	Annual Update Briefs, Comprehensive Every 3 years	Annual reporting required by Annex 1 countries, by April. Public review and comments Feb. 12, 2021- March 15, 2021.		MassDEP publishes a detailed GHG inventory at least every three years as required by MGL chapter 21N, section 2, subsection (c)	Annual

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Comparison to National and Per Capita Averages by Sector	Yes, Figure 2 compares U.S. and Vermont gross GHG emissions	Annual reporting required by Annex 1 countries, by April. Public review and comments Feb. 12, 2021- March 15, 2021. QA/QC process summarized Figure 1-2.	Yes, Figure S-6 Emissions by Sector US and NYS.		
Indicators	Consideration of GHG emissions per capita	Table 2-14, Figure 2-21. Intensities and per capita. Figures 3-7 and 3-8 provide Heating and Cooling Degree day trends. Industrial production indexes Figure 3-11. Table 3-16 Carbon intensity per Qbtu by sector.	Per capita and per GSP emissions, reported lowest of all 50 states.		Per capita and per GDP. Both declining. Emissions per unit commercial floor space Figure 15.a, and per residence 15.b.
Consumption Based Emissions	Discusses value for informing policy and behavior	Not discussed except for some accounting of imports.	Electricity consumption allocated to sectors in cross tabulations	With the exception of electricity sector emissions (discussed in section 3 above), emissions that occur during the out-of-state manufacture of products used in Massachusetts are not included in this inventory.	

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Upstream Accounting	Discusses value of LCA and upstream accounting for analysis of mitigation options	Emissions by category treated in detail, e.g. Section 3.7 Natural Gas Systems.	Upstream mid-stream and downstream for gas but in state boundaries. Figure 13 Midstream contributions larger than up and downstream combined. NYSERDA separate Oil and Gas Methane Emissions Report.	See above	
Emissions Projections	Short term 2018 and 2019 and 5- and 10-year projections.	Not included		Estimated a 2020 BAU projection	
Land Use, land use change, forestry	Included as "additional emissions inventory consideration". Focuses exclusively on data for carbon fluxes related to forests	Addressed in Section 6. Key category and trend analyses in Table 1-5 conducted with and without LULUCF sector. Reporting on gross and net with LULUCF in Figure 2.1.	Not included	Includes Agriculture & Land Use as part of non-fuel combustion GHG emissions by sector	Not included to be consistent with international and national inventories. Treated in separate report: Natural and Working Lands Ecosystem Carbon Inventory.
Waste Methods	Includes CH4 and N2O from solid waste and wastewater	Section 7.	Landfills and Wastewater, landfills account for gas to energy, flaring and capture.	Includes wastewater and municipal solid waste (landfills only) in non-fuel combustion emissions by sector. Calculates CH4 and N2O emissions from disposal and treatment of municipal wastewater.	Landfill emissions accounting for remaining degradable carbon and deposit trends. Accounts for methane capture and control systems.

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Agriculture Methods	Includes emissions of CH <sub>4</sub> and N <sub>2</sub> O from agricultural practices. CO <sub>2</sub> in this sector is almost exclusively biogenic, and so not included in the sector totals (exception of liming and urea fertilization). The subsectors of the agriculture sector include enteric fermentation, manure management, agricultural soils, rice cultivation, liming of soils, urea fertilization, and agricultural residue burning	Section 5.	Non combustion N <sub>2</sub> O and CH <sub>4</sub> emissions. Energy related Agriculture reported in other categories. Used state level data from National Inventory and SIT. EPA DAYCENT for Ag. Soils.	Accounts for anaerobic digestors which capture and combust biogas for energy. Includes combustion of solid waste for industrial and electricity and combustion of landfill gas  Includes Agriculture & Land Use as part of non-fuel combustion GHG emissions by sector	Includes energy consumption emissions for Agriculture, water pumping, heating cooling and processing in Ag. Sector.

**Energy Futures Group, Inc**

Inventory Item	Vermont	US National Inventory	New York	Massachusetts	California
Transportation Methods	Recently transitioned away from the triennial National Emissions Inventory (NEI) vehicle miles traveled (VMT) based values to a method based on fuel sales data, which is the method suggested by the IPCC	Sales weighted fuel economy of new passenger vehicle sales Figure 3-15. Discussed in Energy Section 3.	SIT mobile combustion module with state DOT and Federal Highway Administration data on VMT by vehicle type.		Tail pipe emissions - doesn't include petroleum extraction and refining which are counted in industrial (in-state). Fuel purchases in state.

### C. Key Category Analysis

Vermont’s GHG inventory’s key categories were calculated according to the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 4 Methodological Choice and Identification of Key Categories*. This document defines key categories as, “inventory categories which... are prioritised within the national inventory system because their estimates have a significant influence on a country’s total inventory of greenhouse gases in terms of the absolute level, the trend, or the level of uncertainty in emissions or removals.”<sup>32</sup>

The consultant team took two approaches to evaluating key categories: by scale and by trend assessment. To calculate scale, we divided the GHG emissions (MMTCO<sub>2</sub>e) of a source of emissions in a given year by the total GHG emissions that year. Any category ranking in the top largest 95% of categories by emissions in the state was determined to be a key category in that year. To calculate trend assessment, we calculated the change in the category’s emissions over time compared to the total trend of emissions. We then determined the contribution of the category to the trend and ranked the categories by greatest to least contribution to trend. A recommendation is to include a key categories analysis for the Vermont Inventory in the future.

<sup>32</sup> *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 4: Methodological Choice and Identification of Key Categories.*

### Energy Futures Group, Inc

Appendix Table C-1: Vermont Key Category Analysis by Scale

Sector	Scale 1990	Key Category in 1990?	Scale 2005	Key Category in 2005?	Scale 2019	Key Category in 2019?
<b>Electricity Supply &amp; Demand (Consumption - based)</b>						
Coal- Electricity Supply & Demand (Consumption - based)	0.000%	No	0.000%	No	0.000%	No
Natural Gas- Electricity Supply & Demand (Consumption - based)	0.539%	No	0.003%	No	0.000%	No
Oil- Electricity Supply & Demand (Consumption - based)	0.163%	No	0.110%	No	0.000%	No
Wood (CH <sub>4</sub> , N <sub>2</sub> O)- Electricity Supply & Demand (Consumption - based)	0.032%	No	0.140%	No	0.142%	No
Residual System Mix- Electricity Supply & Demand (Consumption - based)	11.884%	Yes	6.177%	Yes	1.337%	Yes
<b>Residential/ Commercial/ Industrial (RCI) Fuel Use</b>						
Coal- Residential/ Commercial/ Industrial (RCI) Fuel Use	0.244%	No	0.026%	No	0.000%	No
Natural Gas- Residential/ Commercial/ Industrial (RCI) Fuel Use	3.649%	Yes	4.428%	Yes	8.753%	Yes
Oil, Propane, & Other Petroleum- Residential/ Commercial/ Industrial (RCI) Fuel Use	24.492%	Yes	25.243%	Yes	24.223%	Yes
Wood (CH <sub>4</sub> , N <sub>2</sub> O)- Residential/ Commercial/ Industrial (RCI) Fuel Use	0.765%	No	0.737%	No	1.157%	No
<b>Transportation/Mobile</b>						
Motor Gasoline (Onroad and Nonroad) (CO <sub>2</sub> )	29.732%	Yes	31.509%	Yes	29.494%	Yes
Diesel (Onroad and Nonroad) (CO <sub>2</sub> )	5.198%	Yes	6.493%	Yes	8.369%	Yes
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO <sub>2</sub> )	0.050%	No	0.027%	No	0.020%	No

**Energy Futures Group, Inc**

Jet Fuel & Aviation Gasoline (CO <sub>2</sub> )	0.889%	No	1.342%	No	1.257%	No
Non-Energy Consumption - Lubricants (CO <sub>2</sub> )	0.252%	No	0.188%	No	0.186%	No
All Mobile (CH <sub>4</sub> , N <sub>2</sub> O)	2.253%	Yes	1.444%	No	0.273%	No
<b>Fossil Fuel Industry</b>						
Natural Gas Distribution	0.079%	No	0.028%	No	0.050%	No
Natural Gas Transmission	0.131%	No	0.139%	No	0.272%	No
<b>Industrial Processes</b>						
ODS Substitutes	0.006%	No	1.817%	Yes	4.181%	Yes
Electric Utilities (SF <sub>6</sub> )	0.466%	No	0.135%	No	0.068%	No
Semiconductor Manufacturing (HFC, PFC & SF <sub>6</sub> )	1.873%	No	3.336%	Yes	2.297%	Yes
Limestone & Dolomite Use	0.000%	No	0.313%	No	0.267%	No
Soda Ash Use	0.071%	No	0.054%	No	0.045%	No
Urea Consumption	0.004%	No	0.004%	No	0.027%	No
<b>Waste Management</b>						
Solid Waste (CH <sub>4</sub> , N <sub>2</sub> O)	2.459%	Yes	2.769%	Yes	0.942%	No
Wastewater	0.575%	No	0.603%	No	0.681%	No
<b>Agriculture</b>						
Enteric Fermentation	8.062%	Yes	6.353%	Yes	7.483%	Yes
Manure Management	2.066%	Yes	3.323%	Yes	4.121%	Yes
Agricultural Soils	4.035%	Yes	3.222%	Yes	3.802%	Yes
Liming and Urea Fertilization	0.031%		0.035%		0.552%	

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

Appendix Table C-2: Vermont Key Category Analysis by Trend Assess.

Sector	Trend Assessment (1990-2019)	Contribution to the trend (1990-2019)	Cumulative total (1990-2019)
Residual System Mix- Electricity Supply & Demand	18.491	0.316	0.316
Natural Gas- Residential/ Commercial/ Industrial (RCI) Fuel Use	8.854	0.151	0.467
ODS Substitutes	7.274	0.124	0.592
Diesel (Onroad and Nonroad) (CO <sub>2</sub> )	5.472	0.094	0.685
Manure Management	3.558	0.061	0.746
All Mobile (CH <sub>4</sub> , N <sub>2</sub> O)	3.471	0.059	0.805
Solid Waste (CH <sub>4</sub> , N <sub>2</sub> O)	2.666	0.046	0.851
Enteric Fermentation	1.089	0.019	0.869
Natural Gas- Electricity Supply & Demand	0.944	0.016	0.886
Semiconductor Manufacturing (HFC, PFC & SF <sub>6</sub> )	0.719	0.012	0.898
Oil, Propane, & Other Petroleum- Residential/ Commercial/ Industrial (RCI) Fuel Use	0.713	0.012	0.910
Motor Gasoline (Onroad and Nonroad) (CO <sub>2</sub> )	0.712	0.012	0.922
Electric Utilities (SF <sub>6</sub> )	0.698	0.012	0.934
Wood (CH <sub>4</sub> , N <sub>2</sub> O)- Residential/ Commercial/ Industrial (RCI) Fuel Use	0.676	0.012	0.946
Jet Fuel & Aviation Gasoline (CO <sub>2</sub> )	0.632	0.011	0.956
Limestone & Dolomite Use	0.465	0.008	0.964
Agricultural Soils	0.447	0.008	0.972
Coal- Residential/ Commercial/ Industrial (RCI) Fuel Use	0.428	0.007	0.979
Oil- Electricity Supply & Demand	0.286	0.005	0.984
Natural Gas Transmission	0.245	0.004	0.988
Wood (CH <sub>4</sub> , N <sub>2</sub> O)- Electricity Supply & Demand	0.192	0.003	0.992
Wastewater	0.179	0.003	0.995

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

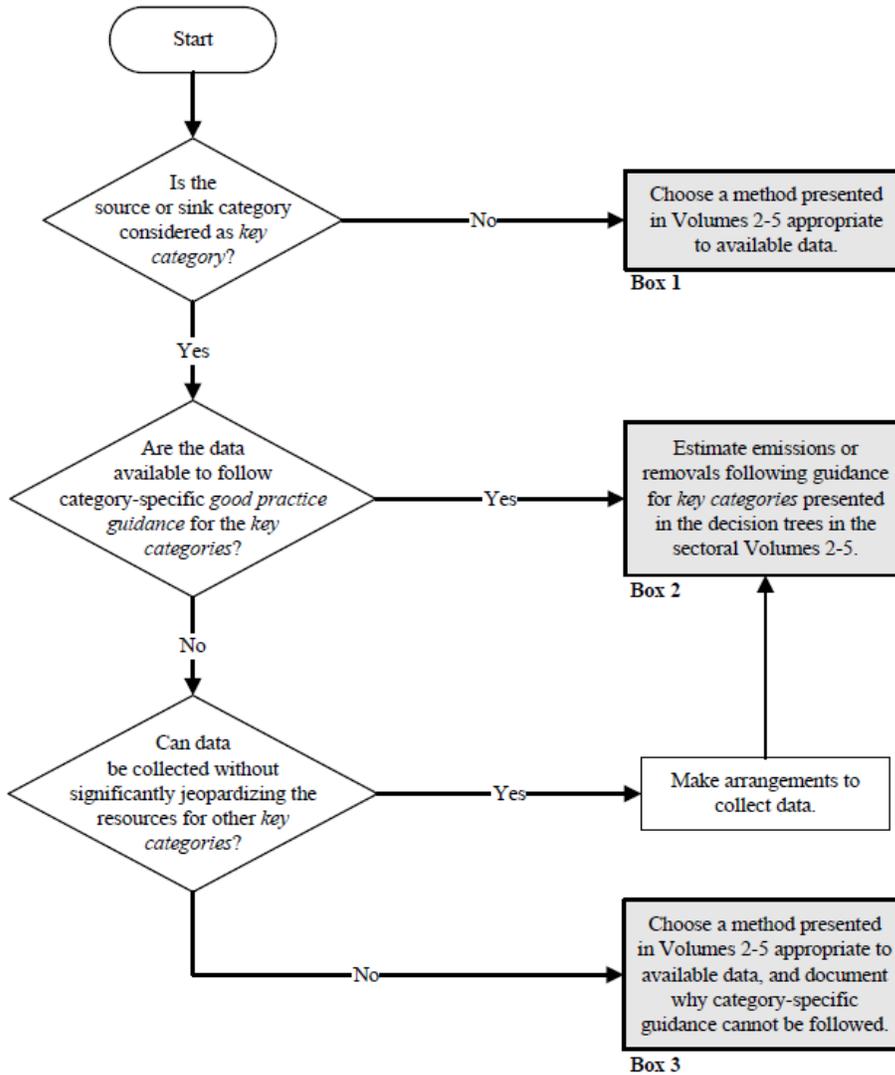
Non-Energy Consumption - Lubricants (CO <sub>2</sub> )	0.117	0.002	0.997
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO <sub>2</sub> )	0.052	0.001	0.998
Natural Gas Distribution	0.050	0.001	0.999
Soda Ash Use	0.046	0.001	0.999
Urea Consumption	0.041	0.001	1.000
Coal- Electricity Supply & Demand	0.000	0	1.000

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## D. Select Material from IPCC 2019 Refinement

Figure 4.1 Decision Tree to choose a Good Practice method



(Chapter 2)

*Uncertainty analysis:* The *2019 Refinement* provides an update on uncertainties associated with activity data. It also incorporates guidance on how to derive uncertainty estimates from activity data generated based on random samples. This elaborated guidance has useful applications

**Energy Futures Group, Inc**

PO Box 587, Hinesburg, VT 05461 – USA | ☎ 802-482-5001 | 📠 802-329-2143 | 📧 info@energyfuturesgroup.com

particularly in the AFOLU sector in dealing with uncertainty estimates from land use surveys or forest cover surveys.

*Key category analysis:* No major modifications with respect to the 2006 IPCC Guidelines have occurred but a simplification of the equation to perform key category analysis using trend assessment (Approach 1) has been implemented in the 2019 Refinement.

*National GHG inventory coverage:* The 2019 Refinement provides updated guidance on specific issues to be taken into account in national GHG inventories. The guidance now includes reporting of non-CO<sub>2</sub> emissions from the biochar production and CO<sub>2</sub> and CH<sub>4</sub> emissions from flooded land.

Vol 2 Refinements: All methodological updates in the 2019 Refinement are in the fugitive emissions category.

Vol 3: Industrial Processes and Product Use – Electronics production Tier 2 and 3 methods. Refrigeration and air-conditioning cook-book style guidance on building and HFC inventory, identify and distribution of Ozone depleting substances.

Vol 4: AFOLU – tier 1 factors updated.

Vol 5: CH<sub>4</sub> from landfills based on management, CH<sub>4</sub> and N<sub>2</sub>O from wastewater treatment.

## Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA |  802-482-5001 |  802-329-2143 |  info@energyfuturesgroup.com

## E. An Open Letter to the Vermont Climate Council

Attach as a pdf.