

Memorandum

To: Deirdre Morris and Tom Knauer, Vermont Public Utility Commission

CC: Vermont Clean Heat Standard Technical Advisory Group (TAG)

From: Kevin Ketchman, Joe Plummer, and Zach Ross, Opinion Dynamics

Date: August 29, 2024

Re: Draft Vermont Clean Heat Standard Lifecycle Emissions Rate Schedule

# Introduction

This memorandum presents Opinion Dynamics’ initial draft lifecycle emissions rate schedule to support the Vermont Clean Heat Standard (Vermont CHS). Vermont Public Act 18 (Act 18) established the Vermont CHS and places obligations on various Vermont stakeholders and agencies to develop the CHS. As part of Act 18, the Vermont Public Utility Commission (“the Commission”) is required to:

*“establish a schedule of lifecycle emissions rates for heating fuels and any fuel that is used in a clean heat measure, including electricity, or is itself a clean heat measure, including biofuels.”[[1]](#footnote-1)*

In fulfillment of this requirement, in our role as the Commission’s technical consultant, we have developed a draft lifecycle emissions rate schedule for the Commission’s review and approval. Combined with measure characterization work currently being conducted by Opinion Dynamics, this schedule will be used to estimate carbon dioxide equivalent (CO2e) reductions resulting from Vermont CHS measures – measure characterizations will be used to estimate changes in use of heating fuels,[[2]](#footnote-2) and the lifecycle emissions rate schedule will then be used to estimate the total lifecycle CO2e reduction associated with that change in fuels.

# Legislative Background and Requirements

Act 18 provides explicit requirements for the development of the schedule with which our methodology complies:

*“The schedule shall be based on transparent, verifiable, and accurate emissions accounting adapting the Argonne National Laboratory GREET Model, Intergovernmental Panel on Climate Change (IPCC) modeling, or an alternative of comparable analytical rigor to fit the Vermont thermal sector context, and the requirements of 10 V.S.A. § 578(a)(2) and (3).”[[3]](#footnote-3)*

*“For each fuel pathway, the schedule shall account for greenhouse gas emissions from biogenic and geologic sources, including fugitive emissions and loss of stored carbon. In determining the baseline emission rates for clean heat measures that are fuels, emissions baselines shall fully account for methane emissions reductions or captures already occurring, or expected to occur, for each fuel pathway as a result of local, State, or federal legal requirements that have been enacted or adopted that reduce greenhouse gas emissions.”[[4]](#footnote-4)*

# Summary of Approach to Emissions Analysis

The fuels we analyzed[[5]](#footnote-5) and the approach we used in developing emissions rates for them are listed in Table 1. Several fuels are produced from more than one feedstock, e.g., biomethane from animal waste or landfill gas. Table 1 lists all of the combinations of fuel and feedstock, referred to as a fuel pathway, for which emissions rates were developed.

Table 1. Fuels Pathways Analyzed and Emissions Source by Lifecycle Phase

|  |  |  |
| --- | --- | --- |
| Fuel Pathway | Emissions Source | |
| Upstream Emissions | Combustion Emissions |
| Grid Electricity |  |  |
| **Grid electricity** | * Opinion Dynamics analysis using GREET1 2023rev1 and other sources | * CO2,CH4,and N2O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub |
| Liquid and Gaseous Fuels |  |  |
| **Natural gas** | * Opinion Dynamics analysis using GREET1 2023rev1 | * CO2,CH4,and N2O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub |
| **Fuel oil #2** |
| **Propane** |
| **Kerosene** |
| **Coal** |
| **Hydrogen** from steam methane reforming (SMR) | * Opinion Dynamics analysis using GREET1 2023rev1 | * No CO2,CH4,or N2O combustion emissions |
| **Hydrogen** from dedicated renewables |
| **Biomethane** from animal waste | * Opinion Dynamics analysis using GREET1 2023rev1 | * CH4 and N2O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub * CO2 emissions are considered biogenic and are considered zero |
| **Biomethane** from landfill gas |
| **Biomethane** from fats, oils, and greasesa |
| **Biomethane** from wastewater |
| **Biodiesel** from soybeans |
| **Biodiesel** from canola |
| **Biodiesel** from corn |
| **Biodiesel** from used cooking oila |
| **Renewable diesel** from soybeans |
| **Renewable diesel** from canola |
| **Renewable diesel** from corn |
| **Renewable diesel** from used cooking oila |
| Wood Fuels |  |  |
| **Wood** chips | * Opinion Dynamics analysis using GREET1 2023rev1 | * CH4 and N2O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub * CO2 emissions considered to be biogenic carbon; partially accounted for using GWPbio factor |
| **Wood** pellets |
| **Firewood**, commercial |
| **Firewood,** non-commercial | * Vermont Energy Sector Life Cycle Assessment |

a These pathways were denoted as “from residues and wastes” in earlier deliverables.

We used different resources to estimate emissions rates by lifecycle phase (i.e., upstream and combustion).[[6]](#footnote-6) Broadly speaking, we relied upon Argonne National Laboratory’s Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model[[7]](#footnote-7) to estimate upstream emissions and the U.S. EPA Emission Factors Hub to estimate combustion emissions.[[8]](#footnote-8) This information was supplemented for certain fuels with information from the Vermont Energy Sector Life Cycle Assessment report published by the Vermont Agency of Natural Resources,[[9]](#footnote-9) information from the Vermont Greenhouse Gas Emissions Inventory and Forecast,[[10]](#footnote-10) and information from an analysis conducted by Sustainable Energy Advantage on behalf of the Vermont Department of Public Service.[[11]](#footnote-11)

# Emissions Schedule

Table 2 presents our draft lifecycle emissions rate schedule. For further detail, including the disaggregation of lifecycle emissions rates into combustion and upstream emissions rates, please refer to the Excel workbook provided with this memo.

Note that more detail around measure characterizations for clean heat measures that are themselves liquid or gaseous fuels will be provided in our forthcoming measure characterizations. These measure characterizations will define the details of how each clean heat measure that is a fuel shall be defined and analyzed for the purpose of clean heat credit development.

Table 2. Draft Lifecycle Emissions Rate Schedule

| Fuel | Lifecycle Average Emissions Rate (gCO2e/MJ) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 |
| Grid Electricity |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Grid electricity | 37.8 | 37.8 | 37.8 | 35.1 | 32.5 | 29.9 | 27.3 | 24.6 | 22.0 | 19.4 | 16.8 | 14.1 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 |
| Liquid and Gaseous Fuels |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Natural gas | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.7 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 |
| Fuel oil #2 | 83.4 | 83.4 | 83.5 | 83.5 | 83.5 | 83.5 | 83.5 | 82.9 | 82.9 | 82.9 | 82.9 | 82.9 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.8 | 82.7 |
| Propane | 73.3 | 73.7 | 73.8 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 | 73.1 |
| Kerosene | 83.6 | 83.6 | 83.7 | 83.7 | 83.7 | 83.7 | 83.7 | 83.1 | 83.1 | 83.1 | 83.1 | 83.1 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 82.9 |
| Coal | 94.6 | 94.6 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.5 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 | 94.4 |
| Hydrogen from SMR | 92.9 | 92.9 | 91.1 | 91.1 | 91.1 | 91.1 | 91.1 | 86.5 | 86.5 | 86.5 | 86.5 | 86.5 | 85.6 | 85.6 | 85.6 | 85.6 | 85.6 | 85.4 | 85.4 | 85.4 | 85.4 | 85.4 | 85.2 | 85.2 | 85.2 | 85.2 | 85.2 | 84.6 |
| Hydrogen from dedicated renewablesc | 14.2 | 14.2 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 7.3 | 7.3 | 7.3 | 7.3 | 7.3 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.3 |
| Biomethane from animal waste | 15.2 | 15.2 | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.6 | 14.5 |
| Biomethane from landfill gas | 7.7 | 7.7 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.3 |
| Biomethane from fats, oils, and greases | 29.0 | 29.0 | 26.2 | 26.2 | 26.2 | 26.2 | 26.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 17.6 | 17.6 | 17.6 | 17.6 | 17.6 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 16.6† |
| Biomethane from wastewater | 40.3 | 40.3 | 37.6 | 37.6 | 37.6 | 37.6 | 37.6 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 28.6 | 28.6 | 28.6 | 28.6 | 28.6 | 28.2 | 28.2 | 28.2 | 28.2 | 28.2 | 27.6† |
| Biodiesel from soybeans | 26.4 | 26.4 | 25.9 | 25.9 | 25.9 | 25.9 | 25.9 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.8 | 24.8 | 24.8 | 24.8 | 24.8 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.6† |
| Biodiesel from canola | 25.8 | 25.8 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 24.6 | 24.6 | 24.6 | 24.6 | 24.6 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.2† |
| Biodiesel from corn | 9.9 | 9.9 | 9.3 | 9.3 | 9.3 | 9.3 | 9.3 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 |
| Biodiesel from used cooking oil | 14.8 | 14.8 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 12.6 |
| Renewable diesel from soybeans | 32.7 | 32.7 | 32.2 | 32.2 | 32.2 | 32.2 | 32.2 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.7 | 30.7 | 30.7 | 30.7 | 30.7 | 30.6† |
| Renewable diesel from canola | 32.3 | 32.3 | 31.9 | 31.9 | 31.9 | 31.9 | 31.9 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 30.7 | 30.7 | 30.7 | 30.7 | 30.7 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.4† |
| Renewable diesel from corn | 12.3 | 12.3 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.7 | 10.7 | 10.7 | 10.7 | 10.7 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 10.5 |
| Renewable diesel from used cooking oil | 17.8 | 17.8 | 17.3 | 17.3 | 17.3 | 17.3 | 17.3 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 15.7 | 15.7 | 15.7 | 15.7 | 15.7 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.6 | 15.4 |
| Wood Fuels |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Wood chips | 31.6 | 31.6 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.2 | 31.2 | 31.2 | 31.2 | 31.2 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.1 | 31.0 |
| Wood pellets | 56.2 | 56.2 | 55.5 | 55.5 | 55.5 | 55.5 | 55.5 | 53.5 | 53.5 | 53.5 | 53.5 | 53.5 | 53.2 | 53.2 | 53.2 | 53.2 | 53.2 | 53.1 | 53.1 | 53.1 | 53.1 | 53.1 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 52.8 |
| Firewood, commercial | 32.0 | 32.0 | 31.9 | 31.9 | 31.9 | 31.9 | 31.9 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.7 | 31.6 |
| Firewood, non-commercial | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 | 29.8 |
| Eligible Emissions Limit |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eligible emissions limit (reference value)a | N/A | N/A | 66.8 | 66.8 | 66.8 | 66.8 | 66.8 | 49.8 | 49.8 | 49.8 | 49.8 | 49.8 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 49.7 | 16.5 |

Note: Emissions rates are inclusive of both combustion and upstream emissions. For further information, please see the Excel workbook provided with this memo.

a Calculated in accordance with 30 V.S.A. § 8127(f).

† As currently analyzed, these liquid or gaseous fuels exceed the carbon intensity values as defined in 30 V.S.A. § 8127(f) and therefore would be nominally ineligible as clean heat measures beginning January 1, 2050, notwithstanding the provisions stated in 30 V.S.A. § 8127(f)(1)(C).

# Methodology

The emissions rate schedule presented in this document characterizes carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) emissions for fuels. Emissions of CH4 and N2O were converted to CO2e using 100-year global warming potential (GWP) factors produced by the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, 2014 (AR5).[[12]](#footnote-12) Emissions are converted to emissions rates based on the volume of energy that is generated by an electricity generating unit (EGU) or delivered to a delivery agent (e.g. VGS or a fuel wholesaler); e.g., gram of CO2e per megajoule (CO2e/MJ) of electricity generated.

Our emissions rate schedule, in line with the requirements of Act 18, reflects both **upstream** and **combustion** emissions of the greenhouse gases (GHGs) detailed above.

* **Upstream** emissions reflect the volume of GHG releases resulting from activities occurring during the upstream lifecycle phase of a fuel, such as resource extraction, feedstock processing, fuel production, and transportation to distributors or electricity generation units (EGU).
* **Combustion** emissions reflect the volume of GHG emissions that are released at the time of combustion of a fuel, such as an EGU burning coal to generate electricity or from combustion of fossil fuels in forced-air furnaces.

Summing these emissions rates produces a lifecycle emissions rate for the fuel being studied.

The following sections detail the methodology we used in estimating upstream and combustion emissions rates. Grid electricity, liquid/gaseous fuels, and wood fuels use somewhat different methodologies. Further details on the methodology we used and our underlying analytical files are available on request.

## Emissions Rate for Grid Electricity

We developed a Vermont-specific lifecycle average emissions rate for grid electricity. To develop this emissions rate, we took the following steps:

1. We first developed a projected resource mix by year for the Vermont electric grid from 2025 through 2050.
   1. This resource mix assumes a starting resource mix as reflected in the Vermont Energy Sector Life Cycle Assessment report.[[13]](#footnote-13)
   2. This resource mix assumes that by 2035, Vermont’s resource mix will be 100% renewable per the Vermont Renewable Energy Standard (RES).[[14]](#footnote-14) To forecast the mix of the renewable resources that will make up this 100% renewable grid in 2035, we used an analysis conducted by Sustainable Energy Advantage on behalf of the Vermont Department of Public Service.[[15]](#footnote-15)
   3. We then interpolated the starting resource mix and the 2035 100% renewability benchmark to develop a year-over-year projection of the Vermont electric grid resource mix.
   4. After 2035, we hold the projected resource mix constant.
2. We then apply emissions rates to the resource mix to estimate combined grid electricity emissions.
   1. Combustion emissions rates come from the U.S. EPA Emission Factors Hub, corrected for average EGU combustion efficiencies using average plant efficiency factors.
   2. Upstream emissions rates come from Opinion Dynamics analysis using GREET1 2023rev1, following the same approach as used in the Vermont Energy Sector Life Cycle Assessment report.[[16]](#footnote-16)

This approach produces a Vermont-specific average grid electricity lifecycle emissions rate that reflects Vermont policy. We applied the annual average electric resource mix instead of the long-run marginal resource mix for several reasons; most notably limited data and an inability to combine existing datasets due to differences in geography (e.g., New England vs. Vermont) and grid perspectives (e.g., long-run marginal vs. average mixes) while reflecting the Vermont RES. We deemed approaches that attempted to estimate a marginal emissions rate while reflecting these characteristics to be internally inconsistent. We look forward to feedback from the Commission and the TAG on this approach and discussion around how we may be able to refine it moving forward.

The underlying figures in this analysis as well as additional analytical detail have been provided previously to the Commission and TAG in a file denoted “Electric Grid Emission Rates\_Revised Approach.xlsx” and are circulated again with this memo.

### Transmission and Distribution Losses

The emissions rate for grid electricity presented in this memo does not account for electric transmission and distribution losses. However, these losses do need to be accounted for in CHS emissions accounting to accurately reflect emissions changes associated with measures that use grid electricity. We intend to provide separate transmission and distribution loss factors in the CHS Technical Reference Manual (TRM) that are to be applied in the decarbonization measure calculations for each measure using grid electricity. Alternatively, we could choose to produce an emissions rate for grid electricity that adjusts the currently presented emissions rate to reflect these additional losses.

## Emissions Rates for Liquid and Gaseous Fuels

Upstream emissions for liquid and gaseous fuels were developed using GREET1 2023rev1, following a similar analytical framework as used in the Vermont Energy Sector Life Cycle Assessment report.[[17]](#footnote-17)

Combustion emissions were estimated using combustion emissions rates for CO2, CH4, and N2O from the U.S. EPA Emission Factors Hub.[[18]](#footnote-18) Note that combustion of hydrogen does not produce CO2, CH4, or N2O and therefore combustion emissions for hydrogen were set to zero.

### Treatment of Biogenic Carbon for Liquid and Gaseous Fuels

For biofuels (biomethane, biodiesel, and renewable diesel), we consider CO2 released in combustion to be a part of the biogenic carbon cycle; when biogenic carbon is emitted through combustion of these fuels, we assume it is re-sequestered by near-term regrowth of the biological material that initially led to the development of these fuels. GREET does not consistently account for carbon sequestration as part of upstream emissions, and so we therefore did not account for CO2 released during combustion of these fuels in our analysis. We did account for CH4 and N2O released by combustion of these fuels in the reported emissions rates.

### Treatment of Land Use Changes for Liquid and Gaseous Fuels

For biofuels developed from purpose grown crops and animal waste, our emissions analysis assumes that there is no change in land use associated with the biofuel that needs to be quantified in our emissions rates.

* Biofuels from purpose grown crops are currently predominately produced in the Midwestern United States. In our analysis, we assume that feedstock crops, such as soybeans, corn and canola, are grown on dedicated land for explicit use in the energy sector. This simplification, along with the uncertainty around the change in demand for these fuels nationally, and Vermont’s contribution to that demand, leads to our decision to not quantify the implications of land use change on upstream emissions.
* For biofuels from animal waste, our analysis assumes no change in land use as the feedstock is a byproduct and not the primary driver for animal farms.

### Counterfactual Emissions Scenarios

Our emissions analysis does not account for counterfactual scenarios such as the fate of waste feedstocks if not incorporated into a heating fuel or avoided methane releases for biomethane.

### Transmission and Distribution Losses and Additional Emissions

GREET accounts for transmission and distribution losses from the fuel producer to the distributor, and those losses are therefore incorporated into our emissions rates for liquid and gaseous fuels. Our emissions rates for liquid and gaseous fuels do not, however, account for any additional emissions or losses that are incurred from distribution of fuels from the distributor to the end-user (such as natural gas distribution system losses or delivery of liquid fuels to a customer from a distribution center). Similar to grid electricity line losses, we intend to provide separate distribution loss factors in the CHS TRM that are to be applied in the decarbonization measure calculations for each measure using liquid or gaseous fuels. Alternatively, we could choose to produce emissions rates for these fuels that adjust the currently presented emissions rates to reflect these additional losses.

### Inclusion of Renewable Propane

A request was submitted as part of comments in 23-2220-RULE for inclusion of renewable propane as an eligible fuel for the Vermont CHS. Renewable propane is a legitimate fuel with established use on the West Coast of the United States as part of low-carbon fuel standard (LCFS) policies, most notably in California and Oregon. However, GREET does not include a method for directly calculating renewable propane emissions rates. Our review of California renewable propane emissions rates indicates that they appear to be developed based on estimates.

Therefore, at this time, we will not be characterizing renewable propane in our analysis. We believe the inclusion of renewable propane in the CHS would be reasonable if a defensible analytic basis to substantiate Vermont-specific emissions could be identified. Alternatively, the Commission could choose to adopt emissions rates for renewable propane directly from other jurisdictions (e.g. California or Oregon) as a placeholder until analytical tools become available to study renewable propane in the same manner we have studied the other fuels presented in this schedule.

## Emissions Rates for Wood Fuels

Upstream emissions for wood fuels were developed using two sources. For wood chips, wood pellets, and commercial firewood, we used GREET1 2023rev1, following a similar analytical framework as used in the Vermont Energy Sector Life Cycle Assessment report.[[19]](#footnote-19) For non-commercial firewood, we used results presented in the Vermont Energy Sector Life Cycle Assessment report[[20]](#footnote-20) as they are Vermont-specific.

Combustion emissions were estimated using combustion emissions rates for CO2, CH4, and N2O from the U.S. EPA Emission Factors Hub.[[21]](#footnote-21)

### Treatment of Biogenic Carbon for Wood Fuels

For wood fuels, we consider CO2 released in combustion to be part of a longer biogenic carbon cycle than biofuels, in which it takes significant time for the regrowth of new trees to fully sequester the biogenic carbon emitted during combustion. In line with an alternative approach presented in the Vermont Greenhouse Gas Emissions Inventory and Forecast,[[22]](#footnote-22) we apply a GWPbio factor to CO2 combustion emissions from wood fuels to account for the regrowth period of the fuel. We apply a GWPbio factor of 0.32 in our analysis.[[23]](#footnote-23) We did not apply a factor in accounting for CH4 and N2O released by combustion of wood fuels in the reported emissions rates.

### Treatment of Land Use Changes for Wood Fuels

For wood fuels, our emissions analysis assumes that there is no change in land use associated with the wood fuel that needs to be quantified in our emissions rates.

As described in the Vermont Energy Sector Life Cycle Assessment report,[[24]](#footnote-24) GREET1 2023rev1 models energy and emissions associated with short rotation woody crops with the embedded assumption that these crops are grown for the dedicated use in the energy sector. This assumption is not consistent with typical forestry management strategies in Vermont. Nevertheless, a pathway for accounting for land use changes in Vermont is not evident to us. In addition, the decision to not account for land use change is consistent with the handling of land use change for biofuels described above. Being consistent in this accounting supports comparative results across biofuels. The implications of land use change in the forestry sector as a result of the energy sector could be further explored in future CHS updates.

1. 30 V.S.A. § 8127(g)(1). [↑](#footnote-ref-1)
2. To align with the requirements of Act 18, the term “fuel” as used in this memo includes electricity, which is not always considered to be a “fuel” as the term is generally used. [↑](#footnote-ref-2)
3. 30 V.S.A. § 8127(g)(1). [↑](#footnote-ref-3)
4. 30 V.S.A. § 8127(g)(2). [↑](#footnote-ref-4)
5. The fuels we analyzed are broadly in line with fuels presented in the previously delivered “VT CHS Measure List,” as well as the fuels itemized in the June 10 “VT CHS Lifecycle Emissions Methodology Memo,” but include several additions based on comments from the TAG, as well as clarifications around the details of the fuels we analyzed. [↑](#footnote-ref-5)
6. Upstream emissions, also referred to as embodied carbon, include GHG emissions directly associated with fuel production, such as resource extraction and fuel upgrading. We exclude emissions from extraneous activities, such as manufacturing of equipment used in transportation of fuels. [↑](#footnote-ref-6)
7. Argonne National Laboratory. (2024). The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (2023 rev1). Accessed at: <https://greet.anl.gov/> [↑](#footnote-ref-7)
8. U.S. Environmental Protection Agency (2024). 2024 GHG Emissions Factors Hub. Accessed at: <https://www.epa.gov/climateleadership/ghg-emission-factors-hub> [↑](#footnote-ref-8)
9. Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024. [↑](#footnote-ref-9)
10. Vermont Agency of Natural Resources (2024). Vermont Greenhouse Gas Emissions Inventory and Forecast: Methodologies. Accessed at: <https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/1990-2021_GHG_Inventory_Uploads/_Methodology_Vermont_Greenhouse_Gas_Emissions_Inventory_1990-2021_Final.pdf> [↑](#footnote-ref-10)
11. Sustainable Energy Advantage, LLC. (2023). Technical Analysis of a 100% Renewable or Clean Energy Standard: Final Results. November 27, 2023. Accessed at: <https://publicservice.vermont.gov/sites/dps/files/documents/VT%20RES%20Technical%20Analysis%20Final%20Report%2011.27.23.pdf> [↑](#footnote-ref-11)
12. CH4 emissions have a GWP of 28 and N2O emissions have a GWP of 265. [↑](#footnote-ref-12)
13. Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024. [↑](#footnote-ref-13)
14. Our analysis assumes that 100% renewable means truly 100% renewable including all marginal electricity supply. [↑](#footnote-ref-14)
15. Sustainable Energy Advantage, LLC. (2023). Technical Analysis of a 100% Renewable or Clean Energy Standard: Final Results. November 27, 2023. Accessed at: <https://publicservice.vermont.gov/sites/dps/files/documents/VT%20RES%20Technical%20Analysis%20Final%20Report%2011.27.23.pdf> [↑](#footnote-ref-15)
16. Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024. [↑](#footnote-ref-16)
17. Ibid. [↑](#footnote-ref-17)
18. U.S. Environmental Protection Agency (2024). 2024 GHG Emissions Factors Hub. Accessed at: <https://www.epa.gov/climateleadership/ghg-emission-factors-hub> [↑](#footnote-ref-18)
19. Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024. [↑](#footnote-ref-19)
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21. U.S. Environmental Protection Agency (2024). 2024 GHG Emissions Factors Hub. Accessed at: <https://www.epa.gov/climateleadership/ghg-emission-factors-hub> [↑](#footnote-ref-21)
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23. Our analysis assumed an equal share of spruce and pine woods from a cool temperate region. The GWPbio tool can be found at: <https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx> [↑](#footnote-ref-23)
24. Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024. [↑](#footnote-ref-24)