Opinion Dynamics

MEMORANDUM

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

CC: Vermont Clean Heat Standard Technical Advisory Group

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

Date: June 10, 2024

Re: Vermont Clean Heat Standard Lifecycle Emissions Analysis Methodology

INTRODUCTION

This memorandum presents Opinion Dynamics' proposed methodology for estimating the lifecycle greenhouse gas (GHG) emission factors for fuels that may be impacted by 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]

In fulfillment of this requirement, in our role as the Commission's technical consultant, we expect to develop a draft emissions 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 (CO_2e) reductions resulting from Vermont CHS measures – measure characterizations will be used to estimate changes in use of heating fuels,[2] and the lifecycle emissions rate schedule will then be used to estimate the total lifecycle CO_2e 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]

[1] 30 V.S.A. § 8127(g)(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.

[3] 30 V.S.A. § 8127(g)(1).

"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]

SUMMARY OF APPROACH

The fuels of interest are listed in Table 1 along with identified resources that we intend to use in developing emission factors. Notably, we expect to use different resources to estimate emission factors by lifecycle phase (i.e., upstream and combustion).[5] We also include brief notes regarding how we expect to handle temporal changes to lifecycle carbon intensities (resulting from exogenous factors such as the Vermont Renewable Energy Standard [RES]).

Table 1. Primary Sources for Lifecycle Emission Factors by Lifecycle Phase with Temporal Adjustment Considerations

<table>
<tr><th rowspan="2">VT CHS Fuels of Interest</th><th colspan="2">Lifecycle Phase</th><th rowspan="2">Temporal Adjustments</th></tr>
<tr><th>Upstream</th><th>Combustion</th></tr>
<tr><td>Grid electricity</td><td>AESC 2024</td><td>AESC 2024</td><td>Application of a renewability adjustment factor[b] to account for Vermont's RES.</td></tr>
<tr><td>Fuel oil #2</td><td rowspan="7">GREET1 2023 [a]</td><td rowspan="18">US EPA Emission Factors Hub

Biogenic CO_2 emissions are accounted for in the upstream lifecycle phase. CH_4 and N_2O emissions are accounted for in both phases.</td><td rowspan="18">Upstream and combustion emission factors will remain static over the life of the measure, with exceptions for any relevant Vermont or federal regulations that require changes to existing fuel carbon intensities or pathways (e.g. as the RES does for grid electricity or vehicle fuel efficiency standards affecting delivery trucks for delivered fuels).</td></tr>
<tr><td>Kerosene</td></tr>
<tr><td>Natural gas</td></tr>
<tr><td>Propane</td></tr>
<tr><td>Biodiesel from purpose-grown crops</td></tr>
<tr><td>Biomethane from animal manure</td></tr>
<tr><td>Biomethane from landfill gas</td></tr>
<tr><td>Biomethane from residues and waste</td><td rowspan="7">GREET1 2023</td></tr>
<tr><td>Biomethane from wastewater</td></tr>
<tr><td>Renewable diesel from purpose-grown crops</td></tr>
<tr><td>Renewable diesel from residues and waste</td></tr>
<tr><td>Hydrogen from SMR (natural gas reforming)</td></tr>
<tr><td>Hydrogen from dedicated renewables</td></tr>
<tr><td>Cord wood</td><td rowspan="3">Vermont Energy Sector Life Cycle Assessment</td></tr>
<tr><td>Wood chips</td></tr>
<tr><td>Wood pellets</td></tr>
</table>

[a] We will use the *VT Energy Sector Life Cycle Assessment* methodology updated for GREET1 2023 model version. For the other fuels not included in the study, e.g., biomethane from wastewater, we will develop GREET1 models following the study's framework.

[b] The renewability adjustment factor is a weighted average percent of purchased electricity by Vermont's utilities that is expected to be met with renewable generation resources as required by Vermont's RES.

[4] 30 V.S.A. § 8127(g)(2).

[5] Upstream emissions, also referred to as embodied carbon, will include GHG emissions directly associated with fuel production, such as resource extraction and fuel upgrading. We will exclude emissions from extraneous activities, such as manufacturing of equipment used in production of fuels.

We will rely on four key resources to develop lifecycle emission factors. These resources include Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model,[6] the Vermont Energy Sector Life Cycle Assessment report published by the Vermont Agency of Natural Resources (ANR),[7] the Avoided Energy Supply Components in New England: 2024 Report (AESC 2024),[8] and the U.S. Environmental Protection Agency's (US EPA) Emission Factors Hub.[9]

LITERATURE REVIEW

We reviewed key literature on lifecycle modeling of GHG emissions from fuel production and the electricity sector. Three studies are notable for their methodology and applicability to Vermont. We provide high-level notes on the applicability of these three studies in Table 2.

Table 2. Key Literature Reviewed and Notes on Applicability to the Vermont CHS

Literature	Notes on Applicability	
Vermont Energy Sector Life Cycle Assessment (April 2024)	Pros	▪ Presents the methodology used in developing upstream lifecycle emissions for different fuels used in Vermont across the residential, commercial, industrial, and electricity sectors. ▪ GREET, an open-source model by Argonne National Lab, is the primary source of lifecycle accounting, with supporting information from literature. ▪ Reports Vermont-specific results and is expected to be conducted annually.
	Cons	▪ Lifecycle emissions are historical (1990-2020) and not forward looking. ▪ For the electric grid, emission factors reflect the average fuel mix and not the marginal fuel mix. ▪ Does not include all fuels of interest for the Vermont CHS.
Avoided Energy Supply Components in New England: 2024 Report (February 2024)	Pros	▪ Reports on electric grid long-run marginal emission rates (LRMER) for the New England area, including upstream emission rates. ▪ Considers Renewable Portfolio Standard (RPS) compliance in estimating LRMERs. ▪ Aligns with US EPA's AVERT and NREL's Cambium models.
	Cons	▪ EnCompass, a privately-owned model, is the primary source of LRMER analysis, meaning replicability could present challenges for future CHS updates. ▪ Not Vermont-specific and develops regionalized average LRMERs based in part on the region's collective energy policies.
Greenhouse gas emissions of local wood pellet heat from northeastern US forests (September 2017)	Pros	▪ ForGATE, a publicly available GHG assessment tool, is the primary source of lifecycle accounting. ▪ The ForGATE model was built for Maine but is adaptable to northeast region.
	Cons	▪ ForGATE is singularly focused on forest management practices and GHG emissions associated with wood products, including biofuels.

The Vermont Agency of Natural Resources (ANR) study presents a methodology for estimating upstream lifecycle impacts of fuels consumed within Vermont. The study primarily relies on GREET1 2022 and GREET2 2022 models with

[6] Argonne National Laboratory. (2023). The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (2022 rev1). Accessed at: https://greet.anl.gov/

[7] Eastern Research Group, Inc. (2024). Vermont Energy Sector Life Cycle Assessment. Prepared for the VT Agency of Natural Resources. April 30, 2024.

[8] Synapse Energy Economics, et al. (2024). Avoided Energy Supply Components in New England: 2024 Report. Prepared for the AESC 2024 Study Group. February 7, 2024.

[9] U.S. Environmental Protection Agency (2024). 2024 GHG Emissions Factors Hub. Accessed at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

updates to reflect Vermont's fuel pathways. GREET is a detailed lifecycle modeling tool that is seen as a gold standard for lifecycle accounting for fuels. While it was first developed for the transportation sector as a well-to-wheel lifecycle emissions model, the well-to-tank fuel production pathways are applicable to the building sectors. In addition to GREET, the study utilized data from the Consortium for Research on Renewable Industrial Materials (CORRIM) lifecycle assessment (LCA) for woody biomass[10] and peer-reviewed research on hydroelectric GHGs. The framework presented in the study will inform our methodology for natural gas and delivered fuels. It is also notable that if the Vermont ANR adopts the upstream lifecycle accounting methodology used in the 2024 study for their future annual GHG emission inventory reports, the annual reports could potentially support future updates to the CHS.

The *Avoided Energy Supply Components in New England: 2024 Report* (AESC 2024) is a triennial report for the Independent System Operator of New England (ISO NE) service territory. One outcome of this study is a schedule of electric grid lifecycle long-run marginal emission rates (LRMER) for the ISO-NE region running out to year 2050. The study includes the LRMER for combustion as well as upstream lifecycle phases. However, the reported LRMERs are not Vermont-specific and reported upstream emission rates are based on summer on-peak period only. As a leading resource for the ISO-NE region, the AESC 2024 study will serve as a key input of electric grid emission rates for the Vermont CHS. Steps will be taken to account for the Vermont RES for the LRMERs included in the VT CHS.

We also reviewed a scientific journal article that employed a forest management model, ForGATE, to estimate changes in GHG emissions from increased use of pellet fuels in Maine.[11] The ForGATE model was developed in partnership with the U.S. Department of Agriculture Forest Service to assess the forest sector's GHG resources, with a specific focus on Maine and the Northeast forest region. The Vermont ANR study provides emission factors for cord wood, wood chips and wood pellet fuels which are the wood fuels of interest for the CHS, while use of the ForGATE model would require adaptation for Vermont. To ensure timely delivery of the Vermont CHS emission factors, we will utilize the Vermont ANR values for the first CHS. We recommend that additional exploration of the ForGATE model for use in future CHS updates should be considered, as the model may allow for more accurate emissions accounting.

METHODOLOGY

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. Both upstream and combustion emissions are converted to emission rates based on the volume of energy that is generated by an EGU or delivered to a delivery agent (e.g. VGS or a fuel wholesaler); e.g., gram of CO_2e per megajoule (CO_2e/MJ) of electricity generated.

The following sections detail the proposed methodology for estimating upstream and combustion emission factors for all fuels. The electric grid is separated from other fuels due to differences in the proposed methods.

[10] CORRIM. (2019). CORRIM: Forestry and Forest Products [dataset]. Federal LCA Commons. https://www.lcacommons.gov/lca-collaboration/CORRIM/Forestry_and_forest_products/datasets

[11] Thomas Buchholz, Gunn, J.S., Saah, D.S. (2017). Greenhouse gas emissions of local wood pellet heat from northeastern US forests. Energy 141 (2017) 483-491.

ELECTRIC GRID EMISSION FACTORS

The AESC 2024 reported combustion and upstream LRMERs will form the foundation of the Vermont electric emission factors used in the CHS. To account for Vermont's RES, a renewability adjustment factor will be applied to the combustion and upstream emission factors reflecting VT's anticipated change in electricity generation mix.

For context, the recent legislative house bill 289 (H.289) is updating the VT RES by moving forward (to 2035) the target year when Vermont's retail electricity providers must supply 100% renewable generation to meet annual load growth over their 2022 load baseline.[12,13] Moreover, the AESC 2024 study reports LRMERs for the ISO-NE region, and is not reflective of the recent RES revisions, due to timing of the reports publication and H.289 signing.

In collaboration with the Vermont Department of Public Service (PSD) and the contractor hired by the PSD to conduct a potential study for the CHS (NV5) we will apply an annual weighted average renewability factor that estimates the electric grid system-wide share of renewable energy. This factor will be applied to the combustion emission factors for all fuels with the eventual combustion emission rate going to zero in 2035.

For upstream emissions, a second adjustment factor will be applied that is developed using information from the Vermont ANR lifecycle study. The Vermont ANR study provided upstream emission factors for different electric grid fuel pathways, e.g., hydroelectric, coal, and renewable natural gas, and the volume of electricity generated through those fuels in 2020. This information will be used to develop annual weighted average emission factors for renewable and non-renewable fuels in aggregate. This will result in the upstream weighted average emission factors for nonrenewable fuels going to zero by 2035, in accordance with the RES, while upstream emissions for renewable fuels will remain, eventually accounting for 100% of upstream emissions in 2035.

NON-ELECTRIC UPSTREAM EMISSION FACTORS

The Vermont ANR report presented a framework for estimating upstream emission factors using the GREET1 2022 model version for natural gas and most delivered fuels, and the CORRIM LCA model for woody biomass. We will follow the framework presented in the Vermont ANR report using the more recent GREET1 2023 model version for natural gas, the delivered fuels included in the study, and expand to other delivered fuels that were not included in the ANR study.

For wood fuels, notably wood cord, wood pellets, and wood chips, we plan to use the CORRIM model results presented in the ANR study as they are Vermont-specific and relevant to the CHS framework for emission factors.

NON-ELECTRIC COMBUSTION EMISSION FACTORS

For combustion emission factors of natural gas and delivered fuels, we will employ the US EPA's Emission Factors Hub, which includes combustion emission factors for the fuels of interest. The Emission Factors Hub is a widely used resource for estimating total combustion-specific emissions for a variety of fuels. The reported emission factors explicitly exclude upstream activities, avoiding double counting of emissions.

[12] VT Legis. An act relating to the Renewable Energy Standard, H.289, retrieved at https://legislature.vermont.gov/bill/status/2024/H.289

[13] Note that this bill has been vetoed; if the veto is not overridden, the RES requirements will not be changed.

OUTPUTS

As outputs of this analysis, we expect to produce a set of lifecycle emissions factors for each fuel. For grid electricity, consistent with the PSD's consultant, NV5, we expect to provide a schedule of emissions factors that varies by year. We will also consider presenting emissions factors by "energy period" (i.e., Winter On-Peak, Winter Off-Peak, Summer On-Peak, and Summer Off-Peak). We expect to provide the grid electricity schedule through 2050, consistent with the longest lived measures we expect to be characterizing as part of the CHS, so that lifecycle emissions can be accurately quantified for the entire period a measure will remain installed.