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The following contains a summary of the carbon and carbon dioxide emissions from the McNeil Generating Station in Burlington, Vermont, and the offsetting carbon capture in the region's forests. This assessment uses data from 2022 whenever possible, though in some cases the most recent data available is older.

BACKGROUND - Accounting for Biomass Emissions – State, National and International Guidance

According to the US Energy Information Agency, "[b]urning either fossil fuels or biomass releases carbon dioxide (CO_2), a greenhouse gas. However, the plants that are the source of biomass for energy capture almost the same amount of CO_2 through photosynthesis while growing as is released when biomass is burned, which can make biomass a carbon-neutral energy source."[i]

This federal agency further notes that "According to current international convention (see the Intergovernmental Panel on Climate Change's "2006 IPCC Guidelines for National Greenhouse Gas Inventories"), carbon released through biomass combustion is excluded from reported energy related emissions. The release of carbon from biomass combustion is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net emissions over some period of time."[ii]

The State of Vermont has adopted this guidance as well, noting in the recently released (April 2023) *Vermont Greenhouse Gas Emissions Inventory and Forecast*[iii]*:*

> "Carbon dioxide from electricity generated through biomass combustion is not included [in the emissions inventory] because the CO_2 is of biogenic origin…consistent with IPCC [International Panel on Climate Change] inventory guidelines for the treatment of biogenic CO_2.", and
>
> "[B]iogenic CO_2 [e.g., emissions from biomass combustion] is considered carbon neutral because the emissions are assumed to be re-sequestered by the regrowth of new biogenic material."

The Intergovernmental Panel on Climate Change has noted "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber, or energy from the forest, will generate the largest sustained mitigation benefit."[iv] See the section below on McNeil Generating Station's specific sustainable harvesting requirements.

Carbon in Regional Timberlands

While the combustion of biomass to generate electricity generates carbon emissions at the stack, this is balanced by the fact that forests absorb carbon from the atmosphere as they grow. Carbon contained in wood fuel is already part of the above-ground carbon cycle, unlike fossil fuels which take ancient carbon that has been sequestered for millions of years and adds it to the atmosphere.

Timberland in the Vermont and New York counties where Burlington Electric Department procures wood fuel for the McNeil Generating Plant have been adding tree carbon since at least 2007.[v] [vi]

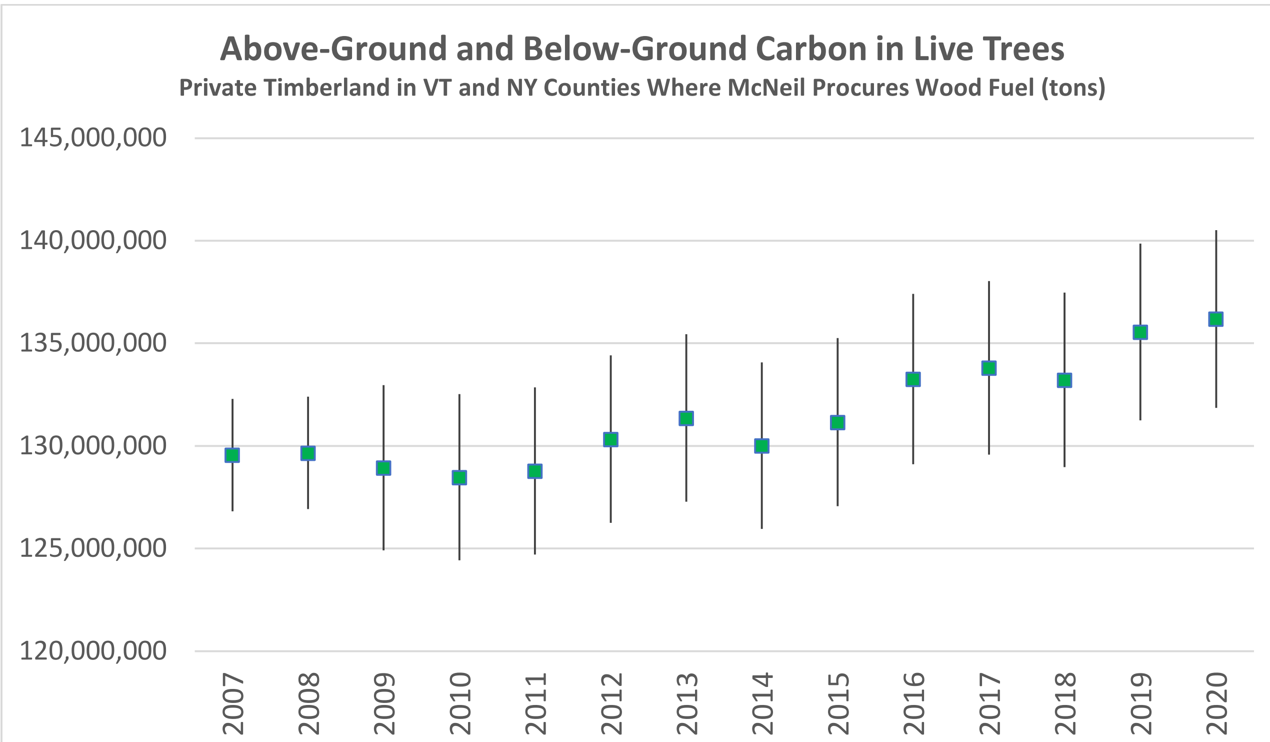

Figure 1. *Tree Carbon on Private Timberland in Vermont (Addison, Chittenden, Franklin, Lamoille, Orleans, Rutland, Washington, and Windsor) and New York (Clinton, Essex, Franklin, and Warren) Counties*

As shown above, the total forest carbon on private timberland in the counties McNeil Station purchases wood from was 129,556,074 tons in 2007[vii]; in 2020 this had grown to 136,186,750 tons of carbon[viii]. Given this information, the private timberland in the region added over 6.6 million green tons of carbon over this 13-year time period; over a half million tons per year or 1,397 tons of carbon per day.

Carbon is a component of carbon dioxide (CO_2), and CO_2 or its equivalent (CO2e) is the unit used when considering the climate impact of carbon. As such, it is important to convert carbon to CO_2e when comparing to CO_2 emission, using a factor of 3.67 tons of CO_2e for each ton of carbon[ix]. As described in a recent publication for New England woodland owners[x]:

> **"Confusing Carbon with CO_2:** You often read of "carbon storage," or "carbon sequestration," followed by numbers of tons. It can be hard to keep track of whether the writer is talking about carbon or CO_2. Obviously, carbon does not hang around in the atmosphere by itself – it only gets

there because organic material (or something) gets burned or oxidized to CO_2. Ecologists have spoken for decades about the "carbon cycle," and have measured ecosystem productivity in terms of carbon fixed per unit of area. This was an extremely important breakthrough in how ecosystems were perceived and understood. But gases forcing climate change are always discussed in terms of CO_2, or the equivalent.

The number to remember here is 3.67. High school chemistry told us that every carbon dioxide molecule consists of two oxygen atoms (atomic weight 16), attached to one carbon atom (atomic weight 12). So, two times sixteen plus one times 12 equals 44. For every ton of carbon atoms in wood cellulose, you'll have 44/12 (or 3.67) tons of CO_2."

Converting the forest carbon to CO_2 equivalent using a factor of 3.67, there are 24.3 million tons of additional forest CO_2 equivalent over the 13 year period from 2007 to 2020, or 1.87 million tons annually or 5,128 tons of CO_2 equivalent daily. Photosynthesis converts atmospheric CO2 to sequestered carbon and free oxygen as plants grow.

Importantly, this forest carbon growth in the regions that McNeil Station procures wood from is not claimed by the facility, but is provided for context and comparison when evaluating stack and other CO_2 emissions associated with the facility. This is consistent with biogenic carbon accounting methodologies used at state, national and international levels, as described above. This data clearly demonstrates that private timberland in the region McNeil Station procures wood from has been managed in a way that increases carbon stocking. This can be attributed, in some part, to McNeil Station's sustainable harvesting and forest management plan requirements and harvest limitations that require timber harvesting operations to protect residual trees and ensure rapid and adequate regeneration, discussed in more detail below.

McNeil Station Fuel Types

It is important when discussing McNeil fuel supply to understand that when used in forest management, the term "whole tree chip" does not necessarily mean that the entire tree was chipped, but that the wood fuel was produced using a whole tree harvesting system. Whole tree harvesting results in a wide range of products, including sawlogs (for lumber), pulpwood (for paper making), firewood, and chips to be used as a renewable fuel. As described in an article for the Society for the Protection of New Hampshire Forests[xi]:

"Whole-tree harvesting is the practice of cutting the entire above-ground portion of a tree and removing it from the forest. The different parts of the tree are used for different purposes – the trunk is often sawn into dimensional lumber, *while the tree top and limbs can be chipped and sold to a biomass energy plant.* This harvest method can be contrasted with "conventional harvesting", which uses the tree trunk in the same way, but leaves tree tops on site to decompose.

"The advantage of whole-tree harvesting is that it provides another forest product and income source for landowners. *It also produces electricity by using a renewable product (tree tops and limbs) that can be harvested locally. Biomass chips are not very valuable (one or two dollars a ton usually), but they can provide a financial incentive to cut unhealthy, low-value trees that may* *not otherwise have a use. By increasing the utilization of the trees that are cut, a harvest designed to improve the health and vigor of a forest may be more economically feasible*."

In 2022, McNeil Station used a little over 350 thousand greens tons of biomass fuel to generate nearly 230 thousand MWh of electricity. The vast majority of this fuel (88%) was from whole-tree chips, with most of the remainder being made up of sawmill residuals and waste wood. Fuel, purchased in the form of roundwood from low-value trees, to be chipped during periods of supply disruption (e.g., mud season), was 882 tons in 2022, or 0.3% of the total fuel purchased.[xii]

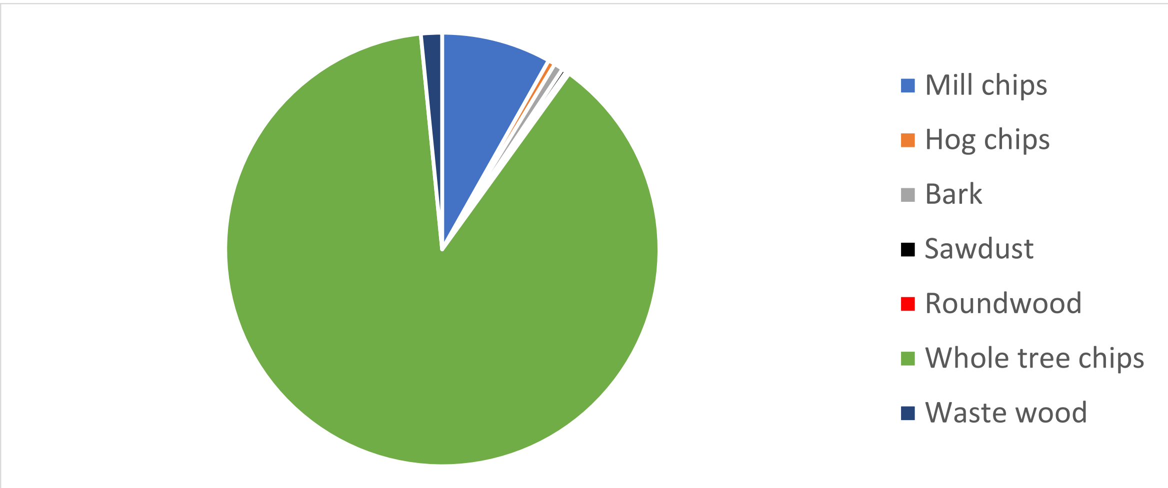

Figure 2. *Wood Fuel by Type (green tons), 2022*

In the Vermont counties where McNeil station procures wood fuel[xiii], total wood harvest in 2021[xiv] was 1,148,210 green tons[xv] [xvi]. Of this, 182,640 green tons– or 16 percent – were whole tree chips. In this region of Vermont, the overwhelming majority of timber harvested was roundwood, primarily as sawlogs, pulpwood, or firewood.

Figure 3. *Total Harvest in Select Vermont Counties (green tons), 2021*

This whole-tree chip to roundwood ratio suggests that most of the volume of the chips procured by McNeil in these Vermont counties are produced by chipping tops and branches of trees felled for other purposes (e.g., sawlogs, pulpwood, or firewood) based on the following information. Logging residues (tops and branches) constitute approximately 22% of total growing stock harvest for pine and 31% for hardwood[xvii]; another analysis suggests that "reasonable estimates of 'logging residues' generated would be about 22%, on average, for sawtimber harvests and 35% for pulpwood.[xviii]" Given that whole tree chips represent 16% of the harvest volume in these counties, it is fair to assume that much of this volume is from logging residues, and not from the stem of healthy trees with more valuable markets.

Carbon accounting for biomass is complex and not well understood, with some disagreement about how to account for the near-term release of carbon from combustion compared to the role that forests play in capturing and storing carbon and the time over which that occurs. As noted above, the U.S. Energy Information Agency assumes that the "release of carbon from biomass combustion is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net emissions over some period of time.[xix]" Others have suggested a "debt-then-dividend" accounting framework for biomass carbon emissions, where the biomass combustion is weighed against future forest growth. Under this scenario, the use of logging residues (and mill residues) provides a favorable fuel type:

> "The harvest and use of tops and limbs for biomass can have an important influence on carbon recovery times and profiles: tops and limbs decay quickly if left in the forest and so their use comes with little carbon 'cost" which tends to shorten carbon recovery times.[xx]"
>
> "It is interesting to consider the 'harvest' and use of just tops and limbs…The results in this case indicate rapid recovery, with nearly 70% of the carbon losses "recovered" in one decade. Thus, all bioenergy technologies—even biomass electric power compared to natural gas electric—look favorable when biomass 'wastewood' is compared to fossil fuel alternatives.[xxi]"

Given the fact that whole tree chips represent such a small portion (16%) of total roundwood harvest in the Vermont counties where McNeil Station procures fuel, it is fair to assume that most of the "whole-tree chips" purchases are tops and branches, and thus a carbon-favored fuel source under the debt-then-dividend biomass accounting framework.

Forest Management on Lands Supplying McNeil Station

"Wood-fueled electrical plants located in Vermont are required to obtain fuels from contractors that adhere to harvesting standards imposed by the Vermont Public Service Board.[xxii]" McNeil Station has significant timber harvesting guidelines for wood fuel that it purchases[xxiii].

These guidelines note that:

> "The landowner or land manager and/or the harvesting contractor will confer with a professional forester representing Burlington Electric Department in developing a harvesting procedure which meets the forester's approval. In all cases, harvesting will incorporate, to the extent reasonably possible, the protection of residual trees, minimization of waste and assurance of rapid and adequate regeneration. Every effort will be made to put harvested products to their most valuable use."

Given that sawlogs are always, and pulpwood is usually a higher valued use of wood (from booth a stumpage and delivered price perspective) than biomass chips, the policy again favors the utilization of roundwood for other uses, and the utilization of logging residues (e.g., tops and branches) for biomass fuel.

Further, the types of forest management that McNeil purchases from are designed to incorporate regeneration, including but not limited to:

- *The Selection System* – A silvicultural system involving the removal of trees of all sizes singly or in groups, at regular intervals resulting in an uneven-aged stand. This system involves a continuous forest cover and favors shade-tolerant species.
- *The Seed Tree System* – A silvicultural system involving the retention of a very light stocking of selected trees after an initial cut. The role of the residual trees is to furnish seed for the next crop. This system results in an even-aged stand.
- *The Shelterwood System* – A silvicultural system that involves the removal of the overstory in several stages. The partial overstory removal provides favorable conditions for the establishment of regeneration. The residual overstory is removed after the new stand is well-established. Shelterwood cutting also results in an even-aged stand.
- *The Clearcutting System* – A silvicultural system that involves the harvesting in one cut of all trees larger than 2 inches in diameter on an area and results in an even-aged stand. The size and configuration of the cut area is variable (even to as small as a fraction of an acre). Clearcutting is recognized to be useful in certain silvicultural and wildlife management situations. However, due to public sensitivity, only modified forms of clearcutting will be allowed by BED (narrow progressive strips and small blocks up to 25 acres in size).
- *Improvement Cut* – An improvement cut is an intermediate cut which can be prescribed by a forester as part of either of the previously mentioned silvicultural systems and can be carried out at various times during the rotation (in even-aged stands) or as part of the regeneration cut. The objective of an improvement cut is the reduction of low value stand components through the removal of poorly formed stems and less valuable species.
- *Thinning* – Thinning is an intermediate cut prescribed by a forester to reduce the level of tree stocking to a recommended level in order to concentrate tree growth on fewer but selected stems.

Each of these forest management systems is designed to meet particular landowner objectives while assuring future forest growth. These are all responsible/sustainable silvicultural techniques, employed throughout Northern New England. Importantly, while Burlington Electric Department procures only wood fuel from these timber harvests, these same timber harvests can produce sawlogs, pulpwood, and firewood.

Value of Avoided Emissions from Electric Generation

If the 228,981 MWh that McNeil Station generated in 2022 did not come from the facility, they would need to be procured from other generators in ISO-New England. The regional grid has a time-weighted marginal average carbon dioxide (CO_2) emission rate of 706 pounds per MWh, or 0.353 tons per MWh[xxiv] [xxv]. This means that using biomass at McNeil Station kept 80,830 tons of carbon dioxide emissions from occurring at alternative electricity generation facilities, predicated on the carbon neutrality of the facility (see below).

At a value of $141 per ton for carbon emissions[xxvi] (N.B. – this is a placeholder value; there is not currently a mandated market for carbon emissions), this means the avoided carbon cost of generating electricity with biomass at McNeil Station is $11.4 million annually using the grid time-weighted marginal average emissions for CO_2, assuming that McNeil is carbon neutral.

McNeil Station Emission – Stack and Operations

As noted above, the combustion of biomass for electricity production does have emissions, though these are balanced by forest growth in the region. In 2022, McNeil station emitted 375,540 tons of CO_2. Additionally, plant operations used 7,935 gallons of gasoline and 41,003 gallons of diesel in 2022, resulting in an additional 537 tons of CO_2 emissions. As a result, the facility is responsible for 376,077 tons of CO_2 annually.

As demonstrated in Figure 1, the total forest carbon on private timberland in the counties McNeil Station purchases wood from was 129,556,074 tons in 2007; in 2020 this had grown to 136,186,750 tons of carbon. Given this information, the private timberland in the region added over 6.6 million green tons of carbon over this 13-year time period; a half million tons per year or 1,397 tons of carbon per day.

Converting this to CO_2 equivalent, this represents 24.3 million tons of additional forest CO_2 equivalent over the 13-year period from 2007 to 2020; 1.87 million tons annually or 5,128 tons of CO_2 equivalent daily.

Given the 376,077 tons of CO_2 that McNeil Station is responsible for, this represents 73 days of carbon additions on private timberlands in the region, or 20% of annual additions.

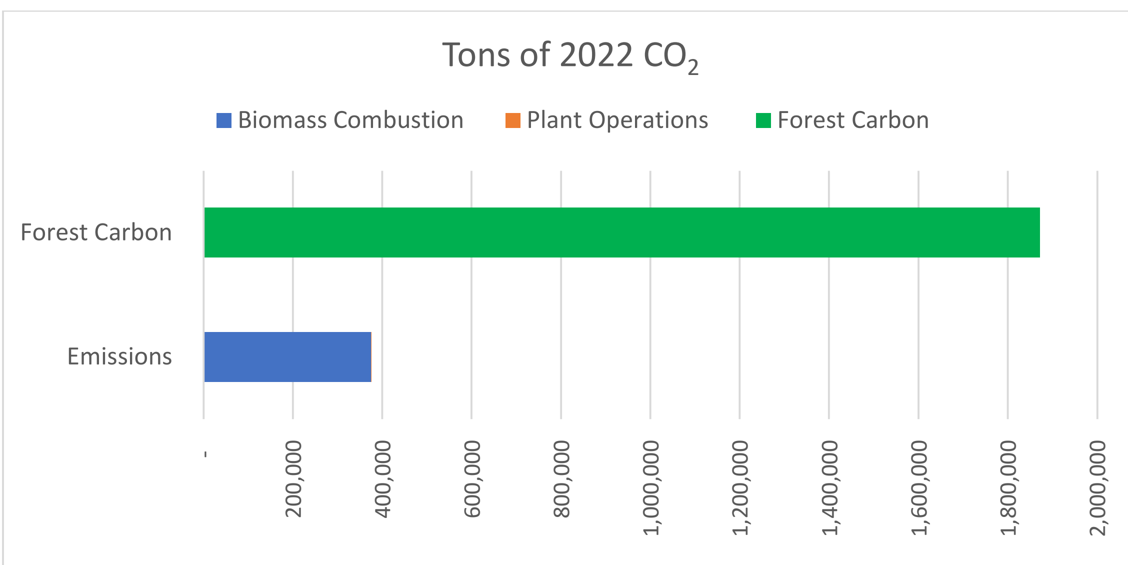

***Figure 4**. Annual forest carbon CO_2e additions in the supply area, and McNeil emissions, 2022*

In the period 2007 through 2020 (the time period that we have forest inventory carbon data for), McNeil Station recorded annual CO_2 emissions correlated with electricity production. The following figure shows annual CO_2 emissions from the facility, with the annualized forest carbon additions (all 1.87 million tons of CO_2e).

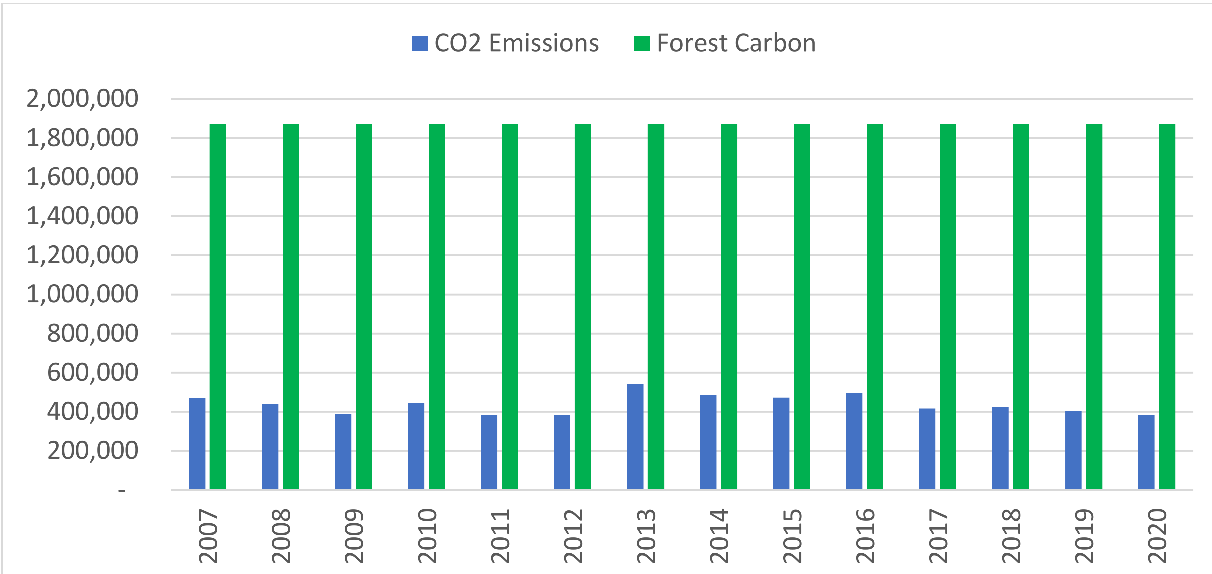

Figure 5*. Forest carbon CO_2e additions (annualized) in the supply area, and McNeil emissions, 2007 - 2020*

Assessment by Eric Kingsley, Innovative Natural Resource Solutions LLC, kingsley@inrsllc.com, June 12, 2023.

Endnotes

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[i] US Energy Information Agency. *Biomass explained - Biomass and the environment*. November 7, 2022. https://www.eia.gov/energyexplained/biomass/biomass-and-the-environment.php#:~:text=Burning%20either%20fossil%20fuels%20or,a%20carbon%2Dneutral%20energy%20source

[ii] See Note 2: Accounting for carbon dioxide emissions from biomass energy combustion in the Environment section note of the Monthly Energy Review. March 2023.
https://www.eia.gov/totalenergy/data/monthly/pdf/sec11_n.pdf

[iii] Vermont Department of Environmental Conservation, Agency of Natural Resources. *Vermont Greenhouse Gas Emissions Inventory and Forecast: Methodologies.* April 2023.

[iv] Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, X. Zhang, 2007: Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://archive.ipcc.ch/publications_and_data/ar4/wg3/en/ch9s9-es.html

[v] Data from USDA Forest Service, Forest Inventory and Analysis Program. Forest Inventory EVALIDator web-application Version 2.0.6. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: https://apps.fs.usda.gov/fiadb-api/evalidator]. Data analysis by Innovative Natural Resource Solutions LLC.

[vi] The Forest Inventory & Analysis program conducts their sampling over multiple (5 or 6) year periods. The year reported is the last date of that survey cycle. The data is shown with sampling error, reflecting that this data is based on a sample, and not a full inventory of all timberlands in the region.

[vii] The 2007 data, collected by the USDA Forest Service between 2003 and 2007, has been updated from previous reports to reflect a correction.

[viii] The Forest Inventory and Analysis collects information over several years; these dates represent the last year in each panel.

[ix] U.S. Environmental Protection Agency. Greenhouse Gas Equivalencies Calculator. Last Updates on April 4, 2023. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#:~:text=To%20convert%20a%20quantity%20of,carbon%20dioxide%2C%20multiply%20by%203.67.

[x] Jennifer Hicks. *Carbon in Wood Products – Translated to Plain English*. Writing for the Maine Woodland Owners Association. February 3, 2020. https://www.mainewoodlandowners.org/articles/carbon-in-wood-products-translated-to-plain-english

[xi] Roxbury, Gabe. *Forestry Research: Whole-tree Harvesting*. February 2, 2015. https://forestsociety.org/blog-post/forestry-research-whole-tree-harvesting (emphasis added)

[xii] Personal communication, Burlington Electric Department staff

[xiii] Addison, Chittenden, Franklin, Lamoille, Orleans, Rutland, Washington, and Windsor Counties in Vermont

[xiv] The latest year for which data is available

[xv] Data from Vermont Agency of Natural Resources – Department of Forests, Parks, and Recreation. VERMONT *FOREST RESOURCE HARVEST SUMMARY - 2021.*
https://fpr.vermont.gov/sites/fpr/files/doc_library/2021%20Harvest%20Report.pdf

[xvi] Data analysis by Innovative Natural Resource Solutions LLC, using conversion factors in Maine Forest Service. *2020 Wood Processor Report*. December 28, 2022. https://www.maine.gov/dacf/mfs/publications/index.html

[xvii] Robert C. Abt, PhD., Professor - Forestry and Environmental Resources, North Carolina State University. Testimony on Behalf of Virginia Forest Watch before the Virginia Corporation Commission Docket Case No. PUE-2011-00073. November 23, 2011.

[xviii] Manomet Center for Conservation Sciences. 2010. *Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources*. Walker, T. (Ed.). Contributors: Cardellichio, P., Colnes, A., Gunn, J., Kittler, B., Perschel, R., Recchia, C., Saah, D., and Walker, T. Natural Capital Initiative Report NCI-2010-03. Brunswick, Maine. https://www.manomet.org/wp-content/uploads/2018/03/Manomet_Biomass_Report_Full_June2010.pdf

[xix] See Note 2: Accounting for carbon dioxide emissions from biomass energy combustion in the Environment section note of the Monthly Energy Review. March 2023. https://www.eia.gov/totalenergy/data/monthly/pdf/sec11_n.pdf

[xx] Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources. See page 109.

[xxi] Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources. See page 110.

[xxii] Vermont Agency of Natural Resources – Department of Forests, Parks, and Recreation. *Timber Harvesting in Vermont: A Resource Guide.* https://fpr.vermont.gov/sites/fpr/files/About_the_Department/Rules_and_Regulations/Library/Timber_Harvest_2012Web.pdf

[xxiii] Burlington Electric Department. *Harvesting Policy for Whole Tree Chipping Operations in Vermont.*

[xxiv] 2020 ISO New England Electric Generator Air Emissions Report. April 2022. https://www.iso-ne.com/static-assets/documents/2022/05/2020_air_emissions_report.pdf

[xxv] The most recent data for grid emissions is from 2020. It is probable that this has changed; INRS used the latest available data.

[xxvi] Personal communication, Burlington Electric Department staff