Summary Memorandum

To: Darren Springer, Betsy Lesnikoski, Paul Pikna, and James Gibbons

From: Damon Lane and Adam Sherman

Date: April 29th, 2022

RE: Assessment of lifecycle GHG emissions from Joseph C. McNeil Generation Station

Introduction

VEIC is a mission driven non-profit sustainable energy organization. VEIC was hired by Burlington Electric Department (BED) to conduct a high-level GHG assessment of the Joseph C. McNeil Generation Station and this memorandum lays out our findings.

The Joseph C. McNeil Generating station is a 50 MW wood chip fired electric power plant located in Burlington, Vermont and is owned by a partnership of electric utilities. The McNeil station has been operating since 1984 and consumes approximately 400,000 tons of wood chips to produce 248,700 MWh of electricity in an average year.

Methods

GHG and Metrics

This assessment examined a range of standard GHG emissions (specifically CO_2, CH_4, and N_2O) from the McNeil Station and these GHG emissions are reported in this memorandum in equivalent units of CO_2 or CO_2e. For consistency, emissions are reported in metric tons of CO_2e per year (metric tons CO_2e/year) or per amount of generation (metric tons CO_2e/MWh).

Accounting Boundary

To conduct a life-cycle carbon assessment, accounting framework boundaries must first be determined. This operational assessment focused on the McNeil Station and did not allocate emissions based on the percentages of ownership to the multiple entities that jointly own and control the power station.

Included in GHG inventory

- Scope 1 direct (non-biogenic) emissions from combusting the wood fuel and other on-site fossil fuel use like natural gas for startup and diesel for bucket loaders.
- Scope 2 indirect fossil fuel derived emissions from the upstream activities associated with extracting, processing, and transporting wood fuels to the McNeil Station.

Excluded in GHG inventory

- Scope 3 emissions of the removal of bottom and fly ash.
- Emissions from the construction of the station, the manufacture of the bucket loaders, etc.
- Site-specific forest inventory change over time from harvest jobs from which wood fuel was procured[1].

Treatment of Biogenic & Fossil Fuel Derived Carbon Emissions

For this assessment, an accounting framework that distinguishes between biogenic and fossil fuel-based emissions was used. This framework follows GHG Protocol's Corporate Standard[2] and U.S. Environmental Protection Agency carbon accounting guidance[3]. Biogenic carbon emissions are those carbon emissions that are from the combustion of materials that are already part of the natural carbon cycle. Forests are both a carbon sink and source – they continually absorb ***and emit*** carbon over time. As part of the natural carbon cycle, "biogenic" carbon is continually cycled between forests and the earth's atmosphere over time. Earth's forests have been absorbing and emitting carbon with no net increase to atmospheric CO_2 levels for thousands of years[4]. Since the mid1800s global levels of CO_2 in the atmosphere have been rising due to human activities – primarily use of fossil fuels and land-clearing for agriculture and development. Using wood fuel from well-managed forests simply mimics the natural carbon cycle. See Figure 1 for simplified illustration.

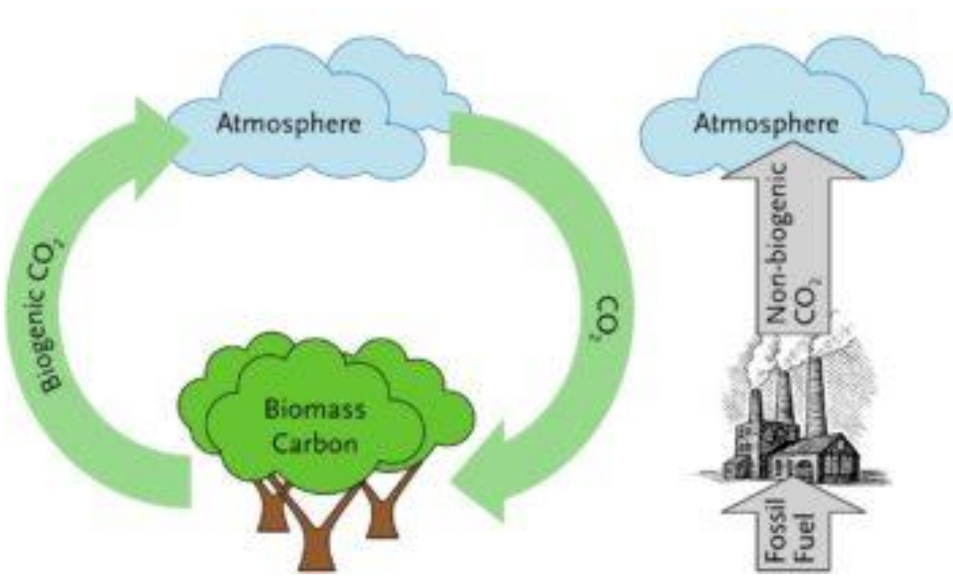

Figure 1 - Biogenic carbon cycle and the one-way path of geologic carbon into the atmosphere.

[1] This is because McNeil does not own, manage, or directly control the forest management activities of the forestland from which the fuel is sourced.
[2] **https://ghgprotocol.org/corporate-standard**
[3] **https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance**
[4] Citation

While harvesting a live, growing tree and using it for fuel, immediately emits carbon and shortens the amount of time before the stored carbon in wood is released back to the atmosphere when the tree dies and decomposes, wood fuel harvested as part of sustainable management causes little or no long-term net increase in CO_2 levels in the atmosphere[5] and is therefore excluded from carbon emission inventories.

National and international agencies widely recognize the important distinction between fossil fuel derived carbon emissions and those from biogenic sources. The US Environmental Protection Agency (EPA), the IPCC, and WRI's GHG Protocol all use frameworks to account for and distinguish between these two types of emissions. Below is language from the EPA Greenhouse Gas Inventory Guidance document:[6]

> *"…CO_2 emissions from biomass combustion at stationary sources are reported as biomass CO_2 emissions (in terms of total amount of biogenic CO_2 emitted) and are tracked separately from fossil CO_2 emissions.* ***Biomass CO_2 emissions are not included in the overall CO_2 -equivalent emissions inventory for organizations following this guidance. CH_4 and N_2O emissions from biomass are included in the overall CO_2 -equivalent emissions inventory****."*

While biogenic carbon emissions do not yield long-term net increases in atmospheric CO_2 levels, it is imperative that forests are managed sustainably and are able to grow more new wood than is harvested annually. McNeil sources over 90 percent of its wood fuel from managed forests in Vermont and Northern New York and follows detailed sustainability requirements enforced by the State of Vermont. At the landscape level, Vermont's forests grow more new wood each year than is harvested by a 2 to 1 ratio. Based on a 2019 study conducted for the State of Vermont's Department of Forests, Parks and Recreation, analysis that examined FIA data on forest inventory, growth, mortality, and wood harvesting levels, Vermont and Northern New York's forests have been adding forest inventory (and stored carbon) consistently for decades.[7]

GHG Protocol Corporate Standard[8] further articulates how sourcing wood from well-managed forests creates carbon mitigation benefits:

> *"During photosynthesis, plants remove carbon (as CO_2) from the atmosphere and store it in plant tissue. Until this carbon is cycled back into the atmosphere, it resides in one of a number of "carbon pools." These pools include (a) above ground biomass (e.g., vegetation) in forests, farmland, and other terrestrial environments, (b) below ground biomass (e.g., roots), and (c) biomass-based products (e.g., wood products) both while in use and when stored in a landfill. Carbon can remain in some of these pools for long periods of time, sometimes for centuries.*

[5] Miner et al., 2014 - **https://www.fs.usda.gov/treesearch/pubs/48712**

[6] **Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources (epa.gov)**

[7] **https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Wood_Biomass_Energy/Library/2018%20VWFSS%20Final%20Report%20with%20Letter.pdf**

[8] **https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf**

An increase in the stock of sequestered carbon stored in these pools represents a net removal of carbon from the atmosphere; a decrease in the stock represents a net addition of carbon to the atmosphere."

Based on McNeil wood fuel procurement records, less than 10 percent of wood fuels sourced by McNeil, come from land clearing activities – either for agriculture or development. It is important to note that land clearing activities are driven by factors outside the control or influence of the McNeil Station. If the McNeil station did not exist, these land clearing activities would still happen and the resulting wood would either be burned in open piles (releasing carbon without any energy capture) or shipped to another biomass energy facility further away -- burning more fossil fuels in transport.

Emission Factors Used

McNeil Station's Emissions

For this assessment, we examined annual emissions that represent current conditions using 100-year life-cycle emissions factors.

For the consumption of fuel oil and natural gas in McNeil's operations:

- ***Direct Emissions from Stationary Combustion Sources*** published by the US EPA was used for the emission factors for fossil fuels.[9]

For the wood fuels consumed:

- ***Life Cycle Analysis of Renewable Fuel Standard Implementation for Thermal Pathways for Wood Pellets and Chips***, Unnasch. S. and L. Buchan (2021)[10] was used for different emission factors for various wood chip sources. Wood chips will have varying levels of embedded emissions depending on the source and the amount of upstream processing and handling that is needed. This analysis aligned McNeil wood fuel procurement records with the categories of wood fuel in Table 18 of the Unnasch and Buchan paper. Emissions factors for forest products mill waste, forest residue, and urban wood waste were all used as is. However, for pulpwood, the emissions factor was reduced by 1.01 from the total of 7.00 grams per MJ to account for the fact that pulpwood in this region is not typically derived from plantation forestry, but from naturally regenerating forests.

[9] EPA, "Emissions Factors for Greenhouse Gas Inventories" September 2021

[10] Unnasch. S. and L. Buchan (2021) - **https://www.biomassthermal.org/wp-content/uploads/2021/06/LCA_TTC-Wood-Pellets-Chips-GHG-FINAL.pdf**

Table 18. GHG Emissions of Wood Chips

GHG (g CO_2e/MJ)	Forest Products Mill Waste	Forest Residue	Urban Wood Waste	Fire Hazard Reduction[a]	Pulp Wood Planted Trees
Collection & Transportation					
Farming	0	0	0	0	1.01
Collection	0	1.59	0.68	0.97	2.45
Transportation	0	0	0	0	0
Chipping Plant					
Diesel	0.26	0.32	0.27	0.19	0.33
Transportation to Market	1.00	1.22	1.05	0.74	1.26
Burning Emissions	1.96	1.96	1.96	1.96	1.96
Total	3.22	5.09	3.96	3.86	7.00
100% Avoided Fate	Compost	Burning	Compost	Burning	N/A
Total Drying	-26.71	-12.34	-23.86	-12.05	

[a]Refers to Fire Hazard Reduction/Insect-Killed Standing Dead Trees Bioenergy Scenario.

Figure 2 – Emissions factor table used for this study

Electricity Generation Avoided Emissions

BED representatives analyzed the ISO-New England Fuel Mix reports from 2017 to February 2022 to determine what type of power plant was marginal during the same time periods McNeil was running. This serves as a proxy for determining which type/source of power generation would be running more if McNeil were not running. Whether using a capacity-weighted average when more than one fuel was listed as marginal or considering only time periods in which only one marginal fuel was listed, the result is that natural gas was marginal 92-98% of the time McNeil is running. BED's results are shown in Table 1.

Table 1 - Marginal fuels on ISO-New England grid during hours McNeil was running 2017 - Feb. 2022

Fuel	Marginal MWh %	Marginal % (when only 1 fuel marginal)
Coal	0%	1%
Hydro	1%	4%
Landfill Gas	0%	0%
Natural Gas	98%	92%
Oil	1%	2%
Other	0%	0%
Refuse	0%	0%
Wind	0%	1%
Wood	0%	1%

ISO-New England's most recent Air Emissions Report, from 2019, shows that natural gas was marginal 96% of that year. Since this agrees well with BED's analysis over a longer time period, VEIC was confident using an emissions factor from the ISO-NE Air Emissions Report. As shown in Table 2 below, the report offers four versions of the emissions rate: all Locational Marginal Units (LMUs) vs emitting LMUs, and a time-weighted average vs. a load-weighted average.

Table 2 - Electricity Emissions Factors in ISO-New England[11]

LMU Marginal Emissions			
	2019 Time-Weighted Annual Rate	2019 Load-Weighted Annual Rate	2019 Load-Weighted vs. 2019 Time-Weighted
	(lbs/MWh)	(lbs/MWh)	(%)
All LMUs			
NO_x	0.101	0.108	6.9
SO_2	0.021	0.028	33.3
CO_2	648	719	11.0
Emitting LMUs			
NO_x	0.155	0.145	-6.5
SO_2	0.039	0.039	0.0
CO_2	970	943	-2.8

Since McNeil is a dispatchable power plant that runs when loads require, VEIC used the load-weighted average for emitting LMUs. A non-emitting LMU could not be dispatched instead of McNeil. Therefore, VEIC used the emissions factor of 943 lbs. CO_2 per MWh from the table, along with the corresponding values for NO_x and SO_2. When combined into a carbon dioxide equivalent using Global Warming Potential factors from the IPCC,[12] these values result in an emissions factor of 429 kg CO_2e per MWh. As discussed above, natural gas provides more than 90% of the energy this average represents. It is important to note that this emissions factor for natural gas is likely conservative because it does not account for the potentially significant amounts of methane leakage. Methane is a primary component of natural gas. In the past decade, several studies have found previously unaccounted for levels of methane leakage at extraction sites and throughout the natural gas distribution network. Recent studies suggest methane leakage are 60% greater than official estimates[13] but the issue is not sufficiently settled to update the natural gas emissions factor.

[11] ISO-New England, "2019 ISO New England Electric Generator Air Emissions Report," Table 5-7, March 2021. **https://www.iso-ne.com/static-assets/documents/2021/03/2019_air_emissions_report.pdf**
[12] IPCC, "AR5 Synthesis Report," **https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf**.
[13] Nature News, "Methane leaks from US gas fields dwarf government estimates," June 2018. **https://www.nature.com/articles/d41586-018-05517-y**.

District Heating Avoided Emissions

The proposed district heating system would provide heat to University of Vermont Medical Center (UVMMC), the University of Vermont (UVM) campus, and the Intervale Center. UVMMC would be by far the largest heat customer and is the near-term proposal, so this scenario only included their usage and factored the avoided emissions of natural gas.

Results

McNeil GHG Direct and Indirect Emissions

The following tables illustrate the analysis steps from the physical amount of wood consumed, to the energy content of it, and finally the emissions. All values are 3-year[14] averages. The tables include traditional US units for fuel and energy as well as the international standard metric units.

Table 3 - Average Annual Wood Fuel Consumption			
	US Short Tons	**Metric tons**	**Mean % moisture**
Harvested Top & Limb Wood Fuel	327,994	297,550	45%
Harvested Roundwood Fuel	3,509	3,183	45%
Sawmill Residues	31,021	28,141	30%
Recycled Wood Waste	10,700	9,706	25%
TOTAL	**373,223**	**338,581**	

Table 4 - Net Energy Value of Wood Fuel		
	Million Btu/US Short Ton	**Gigajoules/Metric Ton**
Harvested Top & Limb Wood Fuel	9.1	9.6
Harvested Roundwood Fuel	9.1	9.6
Sawmill Residues	11.6	12.3
Recycled Wood Waste	12.5	13.1

Table 5 - Wood Fuel GHG Emissions Factors			
	Grams/Megajoule	**Metric Tons/Gigajoule**	**Annual Metric Tons**
Harvested Top & Limb Wood	5.09	0.00509	14,589
Harvested Roundwood	5.99	0.00599	184
Sawmill Residues	3.22	0.00322	1,111
Recycled Wood Waste	3.96	0.00396	505
TOTAL			**16,388**

As illustrated in Table 5 above, McNeil's use of wood fuel causes 16,388 metric tons of non-biogenic CO_2e emissions each year. The emissions factors used in this analysis account for all the upstream fossil fuel used to fell, forward, process, and transport the chips to the McNeil Station as well as the non-biogenic carbon emissions when the fuel is combusted.

Table 6 combines the emissions associated with wood fuel with the emissions from fossil fuels consumed at the McNeil Station. Seventy-four percent of these onsite emissions are from oil burned by the loaders.

[14] The three years chosen were 2018, 2019, and 2021 to avoid the most significant pandemic impact.

Table 6 - GHG Emissions from Other Fuels and Total		Annual kg CO_2e	Annual Metric Tons CO_2e
Wood Fuel	Main Boiler	**16,388,000**	**16,388**
Oil (#2)	Main Boiler	139	0.1
	Misc.	171	0.2
	McNeil Loaders	3,141	3.1
	Waste Wood Loader	124	0.1
	NO_x Control System	-	0.1
	Oil Total	**3,575**	**3.6**
Natural Gas	NO_x Control System	2	0.0
	Other Gas	688	0.7
	Gas Total	**691**	**0.7**
Total		**16,393,000**	**16,393**

Figure 3 below presents the net annual electrical output of McNeil Station over the last nine years.

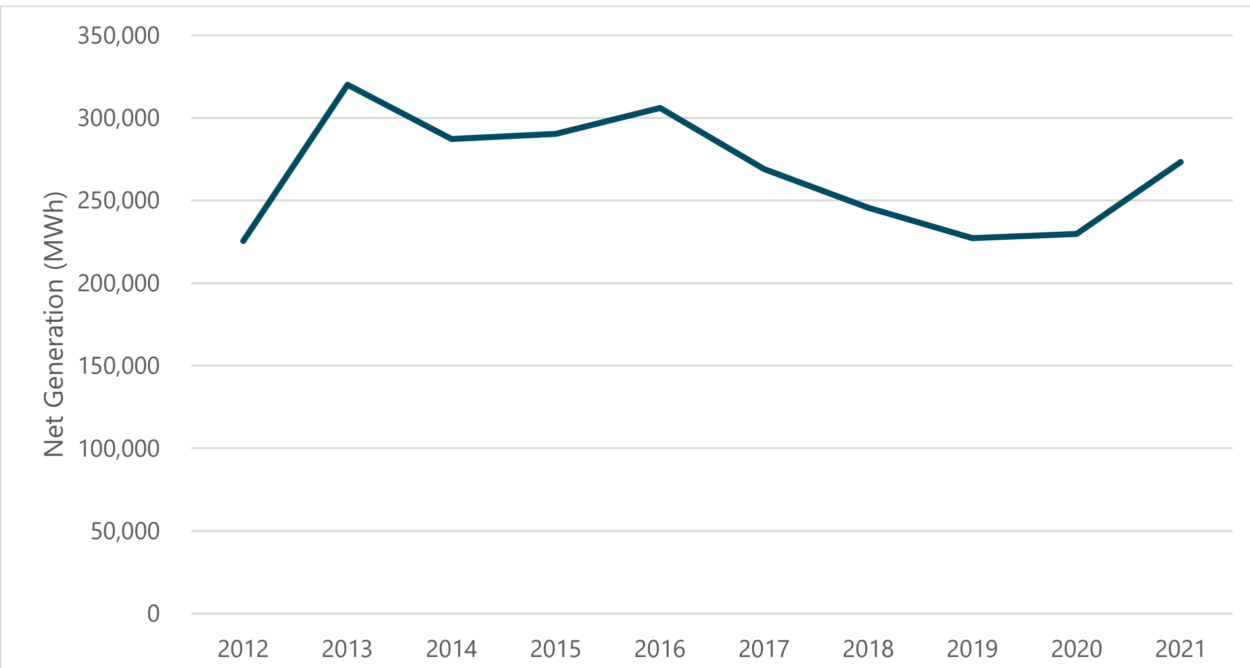

Figure 3 - McNeil's net generation by year

McNeil Station is responsible for an annual average of 16,393 metric tons of non-biogenic CO_2e while generating an average of 248,700 MWh of power. This gives an average GHG rate of 0.07 metric tons per MWh. In the absence of the McNeil Station and the energy it produces, VEIC assumed the average ISO-New England grid mix to be its replacement source of electricity -- providing the same amount of electricity at the same times of day and year. As discussed in the

Electricity Generation Avoided Emissions section above, the relevant grid average emissions factor is 429 kg CO_2e per MWh.[15]

Table 7 directly compares the GHG emissions rate for McNeil Station and the ISO-New England average. Per amount of generation, McNeil's fossil emissions are less than one-sixth of the ISO-New England average.

Table 7 - Comparison of McNeil and ISO-New England average emissions per MWh generation	Metric tons CO2e/MWh	kg CO2e per MWh
McNeil Station total emissions	0.07	65.9
ISO-New England average emissions	0.43	428

Figure 4 shows the average annual emissions from McNeil's production of electricity compared to the ISO New England alternative sourcing scenario.

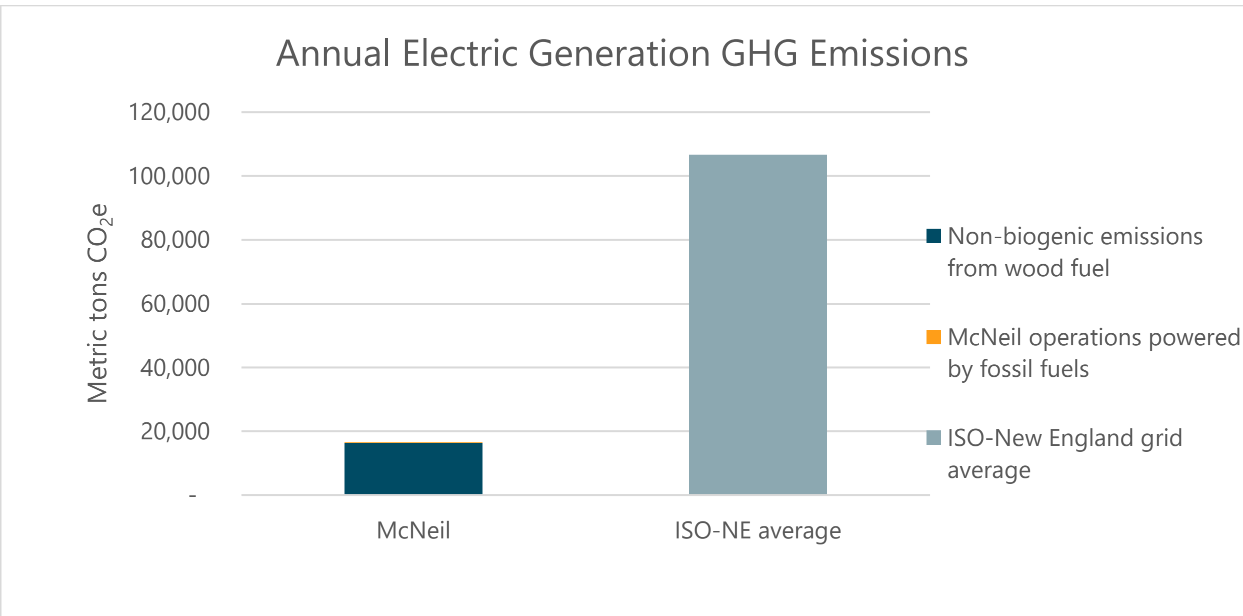

Figure 4 - Annual GHG emissions of the McNeil Station compared to an alternative source an equal amount of energy

The difference between these two scenarios is over 90,000 tons of CO_2e emissions per year that would otherwise be emitted. This comparison is hypothetical because the ISO-New England grid may not be able to supply additional natural gas fired electricity for all the times McNeil generates, particularly in the winter when natural gas pipelines are at capacity.

[15] This does not account for the additional line losses from increased transmission distances to Burlington, Vermont

Future District Heat Scenario

It is also important to examine the GHG emissions of the McNeil Station if the planned district heating project comes to fruition in the next few years. The VEIC team worked with BED staff and representatives of Ever-Green Energy to characterize the likely parameters of the district energy system. The following assumptions were used:

- The DES would provide steam to serve the loads of UVM Medical Center, a small portion of the buildings on UVM campus, and the Intervale Center.
- Input energy sources would include:
    - The McNeil Station would need to burn another 15,000 US short tons of wood, assumed to be the same composition as the wood in the base scenario.
    - The McNeil Station would burn an additional 4,200 million Btu worth of natural gas
    - The remainder of the heat provided to DES customers would be recovered waste heat from McNeil's current energy production
- The DES would reduce its customers' natural gas consumption by 130,000 million Btu.
- The heat capture and use would boost the overall energy efficiency of the McNeil Station ~26% efficiency to ~29% efficiency

Figure 5 shows the incremental emissions from McNeil to provide the input district heat, and the emissions from using natural gas for heating at potential DES customers. Using steam from McNeil instead of onsite combustion of fossil fuel provides a similar emissions reduction percentage to McNeil's electricity generation, although the scale of the initial DES is small compared to the electricity generation.

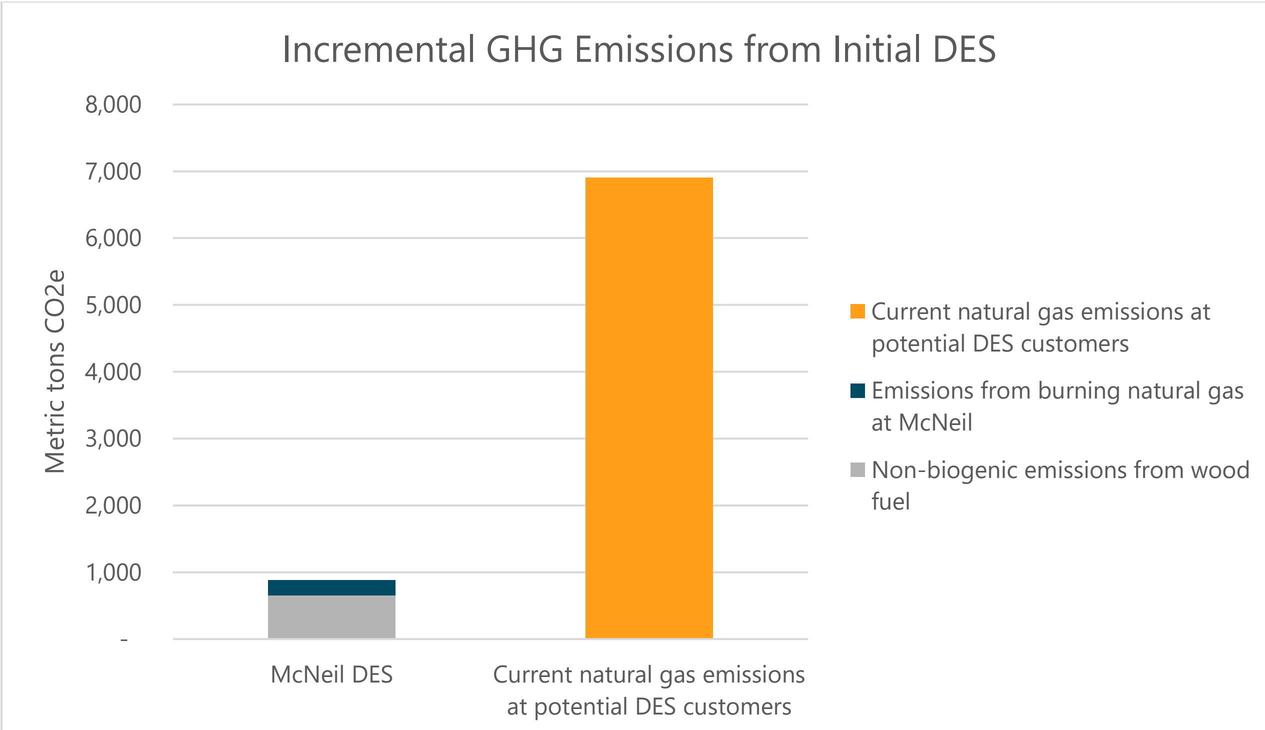

Figure 5 - Incremental emissions impact from initial DES

The difference between these two scenarios in Figure 5 is over 6,000 tons of CO_2e emissions per year that would be avoided.

Adding the incremental DES emission results to the electricity emissions numbers, Figure 6 shows the total emission in a DES scenario.

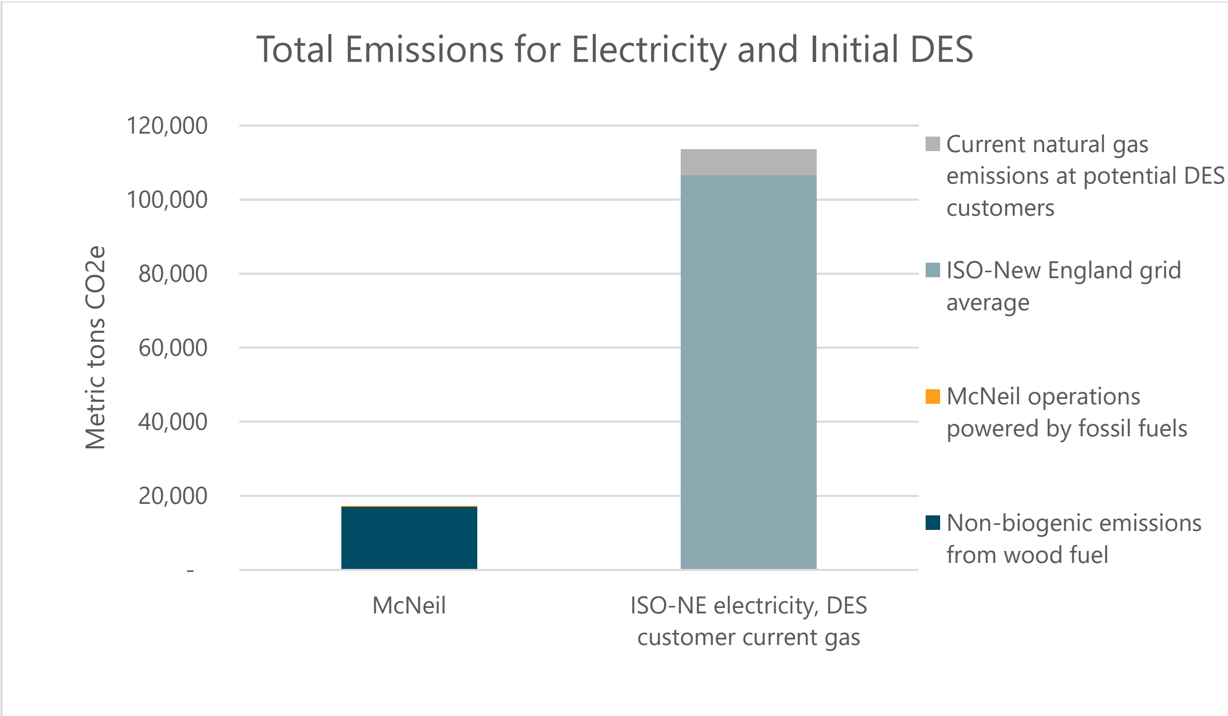

Figure 6 - Annual GHG emissions of the McNeil Station providing heat to DES compared to an alternative source an equal amount of electricity and heat

The difference between these two scenarios is over 96,000 tons of CO_2e emissions per year that would otherwise be emitted.

Discussion

The data and methods used in this assessment conform with national and international carbon inventory methods by differentiating between biogenic and non-biogenic CO_2, and intentionally err on the side of being conservative in how the GHG emissions from wood fuels are compared to those of natural gas. Two examples of this conservative approach are the choice to include all the upstream emissions from sourcing wood fuels, while excluding the potential methane leakage that occurs upstream from the use of natural gas. Additionally, the McNeil Station is located extremely close to the load it serves (i.e. the City of Burlington) which drastically reduces transmission line losses. An alternative scenario with ISO-NE regional power plants would likely have higher line losses that would impact the carbon emissions attributed to that energy.

As presented in the results section, the McNeil Station currently directly contributes to reducing regional GHG emissions by over 90,000 tons of CO_2e per year. If the DES project is built and brought online, there would be an additional 6,000 metric tons of CO_2e avoided.

In addition to this direct carbon emission mitigation benefit, McNeil Station indirectly creates additional carbon emission mitigation benefits.

- **Keeping forests as forests** – without healthy local markets for low-grade wood (which allows foresters and landowners to not cut as many higher-quality trees), private forestland owners often struggle to cover the costs of owning and properly managing forests. Markets for low-grade wood help foresters conduct timber stand improvement (TSI) thinnings, prevent high-grading of forests when only harvesting the highest quality trees, and ultimately avoid forest fragmentation, parcelization, and land clearing for development. [16] Keeping in-tact forests as forests is widely regarded as one of the most critical strategies for mitigating global climate change.
- **Supporting the durable wood products market** – thinning stands to enhance the growth of high-quality timber helps sawmills and producers of dimensional lumber. When these products are used in building construction, it stores carbon dioxide for longer periods of time and displaces other carbon-intense building materials like steel, concrete, and plastics.
- **Anchoring market for woodchip heating in Vermont** – large consumers of woodchip fuel like McNeil Station are vital for logging and chipping contractors to sell enough volume while also selling relatively small amounts of wood chip fuel to the numerous schools, hospitals, and colleges that heat with woodchips. Without a viable supply of wood chip fuel, these facilities would be burning millions of gallons of heating oil each year.

Conclusions

The Joseph McNeil Station produces approximately 250,000 MWh of electricity a year and is responsible for an average of 16,400 metric tons of non-biogenic CO_2e emissions annually using widely recognized carbon emission inventory methods. This gives an average GHG emissions rate of 0.07 metric tons of CO_2e per MWh.

By comparison, the regional power plants supplying the power grid at the same time as McNeil, produce an average of 0.43 metric tons CO_2e per MWh – a 6x increase. This estimate may be slightly conservative because it is based on emissions factors that do not include possible methane leakage and other upstream impacts from extracting and transporting fossil fuels nor line loses from transmissions and distribution.

Continuing to source electricity from the McNeil Station reduces GHG emissions 85% compared to the most probable option of buying power from the ISO-NE grid. If the planned District Energy System were added, there would be a similar percent reduction of GHG emissions applied to additional energy services, heating at UVM Medical Center. This would yield 6,000 metric tons more GHG reduction.

[16] https://vnrc.org/healthy-forests-wildlife/forest-fragmentation/