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First Environment, Inc. (First Environment) has been contracted by Vermont Gas Systems (VGS) to provide an initial Carbon Intensity Model for the proposed District Energy Facility in Burlington, Vermont. This project entails diverting steam from the McNeil Generating Station over to University of Vermont Medical Center (UVM) located about 1.5 miles away.

Background

The Burlington Electric Department (BED) McNeil Generating Station uses renewable biomass (wood) for feedstock and is rated for 50 MW of electric power. The UVM has two natural gas fired boilers that provide steam for heat and other medical uses. VGS is part of a partnership with BED for the construction of the District Energy Facility. The District Energy Facility will have three main components:

1. Dedicated steam line (along with return condensate line) connected from McNeil over to the UVM Steam System. This steam would augment the UVM heating requirements and thus reduce UVM's natural gas usage.
2. 10 MW electric boiler to generate steam for UVM when the McNeil Generating Station is not operational or can't provide the steam necessary for UVM operations.
3. A heat recovery system utilizing flue gas from McNeil to improve overall operational performance.

GREET Model

First Environment utilized the Department of Energy Argonne National Laboratory GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) Carbon Intensity Model to evaluate the BED District Energy Facility. The GREET model has a number of inputs including feedstock material, the production process, energy use and the type of fuel that is being produced. The GREET1 2022 CI model was used.

The model converts all these inputs into a carbon intensity or CI Score which is the carbon dioxide equivalent (measured in grams) per unit of energy of the fuel consumed (measured in megajoules). Carbon dioxide equivalent sums up all the greenhouse gases being generated in the production/consumption of the fuel and converts the other gases into equivalent volume of carbon dioxide based on their GHG potential. For example, methane has a GHG potential 30 times carbon dioxide, so one gram of methane generated is equivalent to 30 grams of carbon dioxide.

The fuels that are modeled in GREET are used for transportation, while the benefit of the District Energy Facility will be the thermal displacement of natural gas at UVM. Despite this difference in final end-use, the GREET model provides a reasonable estimate of the carbon dioxide reduction for the District Energy Facility.

District Energy Facility and Operating Data

Figure 1 is a block diagram illustrating the McNeil Station and UVM Steam System with primary inputs for the GREET model. Data focused on the 1st and 4th quarters of 2021 and 2022. Using data from these quarters was a balance between available inputs and the maximum usage of the steam line. More detailed information on the model inputs is provided in Table 1 and include the following:

A. Feedstock & Operating information of the McNeil Generation Station.
B. Natural gas usage at the UVM Medical Center.
C. Design information on the District Energy Facility

Carbon Intensity Modeling

McNeil Generating Station Model

GREET has a Bio-electricity Generation model that was used to simulate the McNeil Generation Station. The proposed pathway assumes combustion of various woody biomass feedstocks (See Table xx). Transportation was assumed to be 35 miles by rail and 11 miles by truck on average. Notable sensitivities were shipping distance, adding 1.54 gCO2e/MJ per 25 miles of trucking for biomass shipping for typical model. See Table xx for all assumptions.

The following is a breakdown of the CI score for the various model outputs:

ARGONNE GREET MCNEIL OUTPUTS	CARBON INTENSITY SCORES
FUEL PROCESSING	7.26
FUEL TRANSPORT	1.24
POWER GENERATION	5.69
TOTAL	**14.19 g CO2e/MJ**

As a point of reference, this CI score is similar with renewable fuels like renewable diesel or biodiesel and well below average grid electricity which is about 100 g CO2e/MJ.

McNeil with District Energy Facility Model

GREET does not have a model simulating the combined heat and power (CHP) with a biomass feedstock that would replicate the planned District Energy Facility. To model this arrangement, fuel inputs to the McNeil Station were increased and all carbon offsets were associated with the steam line (See Figure 2).

McNeil was scaled to produce 54 MW of electricity. This equates to an an 8% increase in fuel usage, transportation, and power generation. The excess thermal energy is used for the District Energy Facility steam line at a rate of 35 MMBTU/hr. In turn, this steam usage will create natural gas (NG) avoidance at UVM. When excess steam from the biomass boilers is not available or can't meet UVM heating demand, an electric boiler is used to augment the steam line.

To model the NG avoidance at UVM, a small industrial boiler was modeled using the 35 MMBTU/hr steam rate. Data inputs and assumptions to the CHP model are in Table xx. The following is a breakdown of the CI score for the various model outputs:

ARGONNE GREET DISTRICT ENERGY FACILITY	MCNEIL ONLY	CHP (MCNEIL W/ IND. BOILER)
FUEL PROCESSING	7.26	7.84
FUEL TRANSPORT	1.24	1.34
POWER GENERATION	5.69	6.14
NG OFFSET	0.00	-11.57
TOTAL	**14.19**	**3.76 g CO2e/MJ**

As shown above, the NG offset from the small industrial boiler significantly reduces the overall CI score by 74% for the District Energy Facility. Another metric is the NG carbon offset equates to 5.5 g CO2e per MMBTU of steam diverted to the District Energy Facility.

At maximum offset, the steam line is capable of offsetting 854 mcf/day of natural gas. Historical hospital usage indicates a daily minimum usage of 450mcf and a maximum of 1300mcf during the 1st and 4th quarters of the year. The NG offset assumes full utilization of the steam line to directly offset the thermal energy created from a small industrial NG boiler. This is not representative of all usage conditions.

Notable items excluded from model are the extra power demand from auxiliary equipment for distribution, CHP systems and thermal distribution losses, and NG for plant startup.

District Energy Facility w/ Electric Boiler Model

As stated above, the District Energy Facility will have a 10 MW Electric Boiler that also will provide steam to UVM. While the wood-fired McNeil boilers will be the primary source of steam, the electric boiler will operate periodically when McNeil is out of operation or there is a high UVM heating demand and supplemental steam is needed.

ARGONNE GREET DISTRICT ENERGY FACILITY	MCNEIL ONLY	CHP (ELECTRIC BOILER)
FUEL PROCESSING	7.13	7.70
FUEL TRANSPORT	1.23	1.32
POWER GENERATION	5.69	6.14
NG OFFSET	0.00	-11.57
TOTAL	**14.05**	**3.60 g CO2e/MJ**

For this model run, the electric mix for this boiler was 100% renewable. This assumption gives similar results as the McNeil renewable biomass (wood) boilers. The electric backup boiler feeds the steam line at 0.039 gCO2e/MJ.

CA-GREET Model

The California Low Carbon Fuel Standard (LCFS) Program is used to incorporate renewable fuels into the California transportation fuel market. This program uses the CA-GREET model which is a modified version of the Argonne GREET.

The CA-GREET Pathway paralleled the Argonne-GREET model when possible; however, background data and calculations were not modified. Background data in the model may be older than 2015 and may not represent the true state of technology in 2023. A "Bio-electricity" worksheet is not available, as such the "electric" sheet was used. Transportation inputs varied by less than 5% and were not remodeled. Offset calculation inputs did not change between the models.

CA-GREET MODEL DISTRICT ENERGY FACILITY	**MCNEIL ONLY**	**CHP**
FUEL PROCESSING	9.53	10.29
FUEL TRANSPORT	1.24	1.34
POWER GENERATION	8.42	9.09
NG OFFSET	0.00	-11.57
TOTAL	**19.2**	**9.16 g CO2e/MJ**

While these CI scores were slightly higher than the Argonne GREET, they are in the same range and help prove out the initial results. Model defaults were used when project data is not available.