APPENDIX C: GHG CALCULATIONS TECHNICAL

Impact of GHG reduction measures:

Through executing this project, GLWA greenhouse gas emissions will be impacted by physical process and operational changes. The complete incremental emissions impact is calculated by considering the net changes in various process areas. For this project, greenhouse gas emissions are directly related to energy uses, and therefore, the net greenhouse gas impact can be summarized by balancing the energy uses as follows:

$$\left(\frac{CO_2e}{yr}\right) = +\begin{pmatrix}Energy\ Demand\\ from\ New\ Processes\end{pmatrix} - \begin{pmatrix}Energy\ Saving\\ from\ Retired\ Processes\end{pmatrix} - \begin{pmatrix}Renewable\\ Energy\ Generated\end{pmatrix}$$

For GLWA, energy is primarily electricity and natural gas, but can include other energy sources such as gasoline, diesel, fuel oil, and propane. New processes add an energy demand while retired processes eliminate an existing energy demand. Energy reductions, and the associated GHG reductions, are more certain when the energy demand from retiring processes exceeds the energy demand from new processes as the inherent energy demand decreases. Additionally, processes that generate renewable energy are accounted for such that the net greenhouse emissions is negative and a net CO_2e reduction is achieved. For this project, new processes consist of thermal hydrolysis (THP), anaerobic digestion (AD), gas conditioning, dewatering, drying, and hauling (biosolids) while retired processes include incineration and hauling (ash). The processes project will also result in a decrease in loading to the dryers.

$$\frac{CO_2e}{yr} = THP + AD + Dewatering + Drying + Gas\ Conditioning + Hauling_{biosolids}$$
$$-Incineration - Hauling_{ash} - Drying - Digester\ Gas$$

For accounting purposes, greenhouse gas emissions are partitioned into Scope 1 (direct), Scope 2 (indirect), and Scope 3 (external) emissions.

Scope 1, direct emissions, are primarily related to the consumption of energy as natural gas and digester gas. It is assumed that new digester gas produced will be used to directly offset natural gas use. Natural gas is used for digester heating, drying, incineration, and building heat. A smaller but pertinent Scope 1 emission under current operations is the hauling of incinerator ash, which consumes diesel fuel and will be eliminated.

Scope 2, indirect emissions, are related to the consumption of electricity. For the purposes of this evaluation, it is assumed that the decrease in electrical consumption from the incineration process, approximately 2MW, will be offset by an equivalent amount from the new thermal hydrolysis, anaerobic digestion, dewatering, drying, and gas conditioning processes. The indirect emissions associated with the production and transportation of natural gas is assumed to be negligible due to the relatively small fraction of natural gas being offset with new digester gas production, estimated at approximately less than 0.15% of the State of Michigan natural gas consumption and less than 0.005% of US natural gas consumption.

Scope 3, external emissions, are quantified but not accounted for. Scope 3 emissions include the transportation of dried biosolids.

Therefore, the net greenhouse gas emissions impacts are directly related to energy use and can be simplified to:

$$\frac{CO2}{yr} = (Digester_{NG} + Drying_{NG}) - Incineration_{NG} - Drying - Digester_{DG} - Hauling_{Fuel}$$

The existing incineration process has an average CO2 emission rate of 37,660 metric tons CO2/yr with an associated average natural gas consumption rate of 709,800 MMBTU NG/yr based on the period spanning 2016 to 2022. The existing drying system consumes 645,000 MMBTU NG/yr and is projected to increase to 845,000 MMBTU/yr according to the Wastewater Master Plan.

The new digestion process with hydrolysis heating, sludge heating, and drying is estimated to add an average heating demand of 776,136 MMBTU/yr. Additionally, the new digestion process is estimated to produce digester gas at an average rate of 1,121,500 MMBTU DG/yr. Therefore, the net energy balance can be estimated as:

$$\frac{NG}{yr} = +776{,}136 - 709{,}800 - 845{,}000 - 1{,}121{,}500 = -1{,}900{,}164 \frac{MMBTU}{yr}$$

The energy balance confirms that the energy demands of new processes will be offset by retiring existing processes, the process improvements will reduce energy demand of drying, and new renewable energy will offset the energy use. Therefore, the use of digester gas as a natural gas offset is the primary greenhouse gas reduction mechanism. Although the new processes are estimated to consume less than existing, this evaluation will only take credit for the greenhouse gas reduction associated with new digester gas production. Natural gas and digester gas use is presented in Figure 1, as this evaluation assumes that the incineration process will be replaced with digestion during year 2029 and 2030, with full digester operation beginning in year 2031.

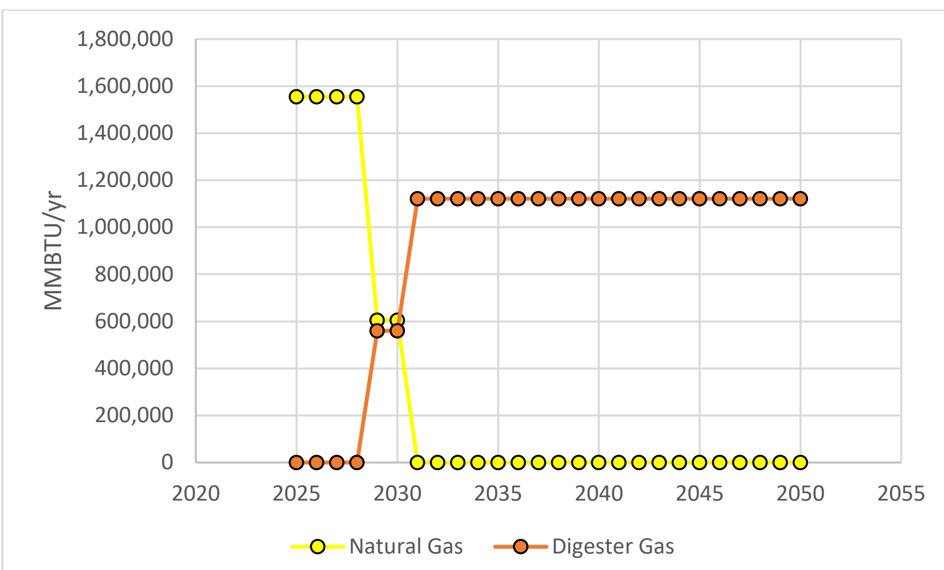

Figure 1. Projected natural gas and digester gas use

The associated cumulative CO2e emissions are presented in Figure 2. The transition from using natural gas to using digester gas creates a dramatic reduction in non-biogenic CO2e emissions, a 99.5% decrease on an annual basis resulting in avoiding 100,637 metric tons CO2e emissions by the year 2030 (20%), and 1,746,462 metric tons CO2e by the year 2050 when compared to the Baseline, an 80% reduction!

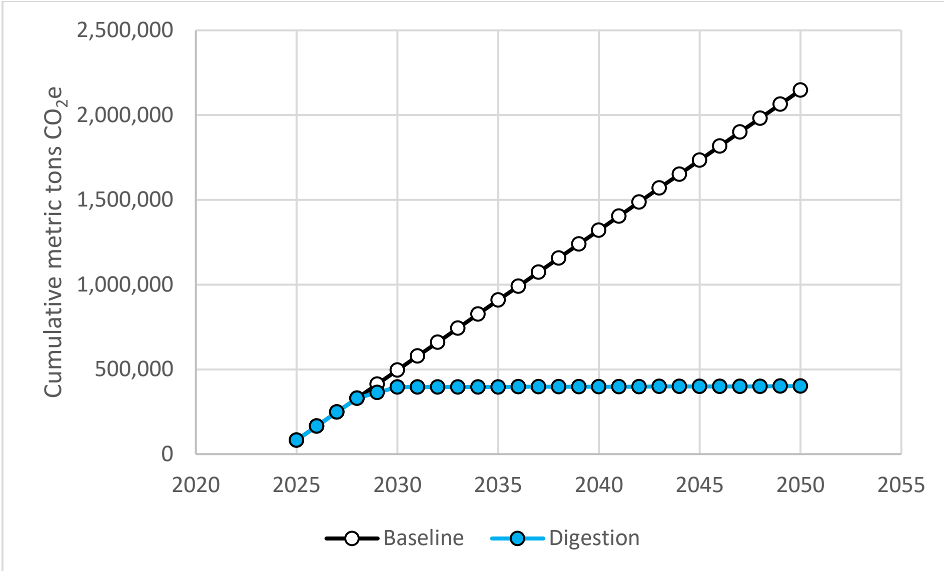

Figure 2. Projected cumulative non-biogenic CO_2e emissions

The replacement of incineration with digestion would produce enough digester gas to supplement the entire biosolids process, transitioning it to a 100% renewable process while reducing the inherent energy use of the system. The use of digester gas on site for drying processes reduces the complexity of the system, increasing the reliability and certainty that the digester gas will be used rather than flared. Additionally, implementing this project would eliminate 14,000 tons per year of landfilled ash, being replaced with a beneficially reused land applied biosolid.

Methodology

Assumptions:

Following Alternative 3a from the Wastewater Master Plan (WWMP). Primary sludge from PS1 bypasses mesophilic digestion to sludge storage. Primary sludge from PS2 and WAS through phosphorus recovery, thickening, thermal hydrolysis, and mesophilic digestion prior to sludge storage. Blended sludge (digested sludge and PS1 primary sludge) is dewatered via centrifuges and dried.

Primary sludge and waste activated sludge will be digested, reducing the volatile solids fraction by 50-65%, achieving a 35 to 51% total solids reduction. This process replaces incineration.

The electrical use of incineration would be eliminated entirely. New electrical use of anaerobic digestion, dewatering, drying, digester gas conditioning, and associated processes would be added at an assumed equivalent quantity.

The natural gas use of incineration would be eliminated entirely (~709,763 MMBTU/yr). Natural gas use at the dryers would be maintained dependent on the solids loading. The new natural gas would be offset by digester gas produced at the anaerobic digesters, a renewable fuel. (WWMP estimates +776,136 MMBTU/yr of future thermal demand)

Anaerobic digester sizing and digester gas production is calculated using industry best practices for a municipal anaerobic digester processing primary and waste activated sludge [by others].

Biosolids drying removes moisture content to less than 10% (greater than 90% solids).

- The digester gas production is converted to energy based on the methane content:

$$\frac{BTU\ DG}{t} = \frac{methane, cuft}{t} * \frac{1{,}038\ BTU}{cuft}$$

- Natural gas equivalents of digester gas is calculated by (NIST):

$$\frac{cuft\ NG}{t} = \frac{BTU\ DG}{t} * \frac{cuft}{923.70\ BTU\ NG}$$

- Gasoline equivalents of digester gas is calculated by (NIST):

$$\frac{GGE}{t} = \frac{cuft\ NG}{t} * \frac{0.04582\ lbs\ NG}{cuft\ NG} * \frac{1\ GGE}{5.66046\ lbs\ NG}$$

- Household heating equivalents of digester gas is calculated by (USEPA):

$$Households = \frac{Households - yr}{41590\ cuft\ NG} * \frac{cuft\ NG}{yr}$$

- Carbon dioxide emissions, not equivalents, of digester gas is calculated by (USEPA):

$$\frac{metric\ tons\ CO2}{yr} = \frac{0.005291\ metric\ tons\ CO2}{therm} * \frac{therms\ DG}{yr}$$

- Emission rates for natural gas were 53.06 kg CO_2/MMBTU, 0.001 kg CH_4/MMBTU, and 0.0001 kg N_2O/MMBTU.

- Emission rates for digester gas were 52.07 kg CO_2/MMBTU, 0.032 kg CH_4/MMBTU, and 0.00063 kg N_2O/MMBTU.

- Global warming potentials of were 28 for methane and 265 for nitrous oxide.

- Magnitude of GHG Reductions by year is calculated by comparing the baseline condition, incinerators, to digesters overtime. For years 2025 through 2030, the reductions are calculated by estimating the quantity of incinerators and digesters in service for a given year, use 50% incineration for 2029 and 2030, 0% incineration for 2031 and onward. For years 2030 and beyond, it is assumed that all incinerators are displaced by anaerobic digesters.

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Incineration Data

	CO_2 emitted (metric tons)	*CH_4 emitted (metric tons)*	*NO_2 emitted (metric tons)*
2016	41592	0.78	0.078
2017	40057.7	0.76	0.076
2018	42571.3	0.8	0.08
2019	32631.9	0.61	0.061
2020	31273.2	0.59	0.059
2021	34747.8	0.65	0.065
2022	40743.5	0.77	0.077
Average	37660	0.71	0.071

- Average gas production per year of 1,121,499 MMBTU/yr is calculated by assuming the following. WRRF generates 268 dry tons per day of blended sludge produced at 9.6% solids concentration. The blended sludge has a volatile solids percentage of 80% , of which 64% is destroyed by the AD. Based on a stoichiometry that 17.9 ft3 of biogas is generated per lb of volatile solids reduced, 4,933,526 ft3 per day of biogas is generated. Assuming a typical digester gas composition of 60:40 CH4:CO2, the methane produced is 1,121,499 MMBTU/yr.