

## Appendix 2

### CPRG - Clinton River WRRF Digestion Optimization Project Greenhouse Gas Emission (GHG) Reduction Calculations and Assumptions

**Overview:** This Appendix provides a detailed analysis of the GHG emissions analysis associated with the measures included in this project:

1. Measure 1: Food Waste (also referred to as high-strength organic waste, or HSOW) Diversion and More Local FOG Processing
2. Measure 2: Digester Optimization by Implementing Microbial Hydrolysis Process (MHP)

Table 1 provides the detailed analysis. The rest of the appendix provides a narrative of each of the parameters included in the table.

**Table 1. Detailed Analysis of GHG Emissions for Clinton River WRRF Digester Optimization Project**

No.	Parameter	Units	With CHP - Existing Conditions	With CHP - With Outside Food Waste	With CHP and MHP - With Outside Food
1	<b>Solids Loading and Biogas Available</b>				
2	Raw sludge (generated on-site from CRWRRF)	dt/d	15	15	15
3	Food Waste (imported)	dt/d	0	10	10
4	Raw sludge (generated on-site from CRWRRF)	lb/d	30,000	30,000	30,000
5	Food Waste (imported)	lb/d	0	20,000	20,000
6	Digested biosolids	dt/d	8	14	10
7	Digested biosolids	lb/d	16,400	27,400	20,800
8	Digester Biogas available	scfd	203,600	339,300	438,800
9	<b>Heat Requirements and Natural Gas Offset</b>				
10	THP	BTU/hr	870,600	1,451,000	1,451,000
11	MHP	BTU/hr	na	na	1,418,000
12	Total heat requirement	BTU/hr	870,600	1,451,000	2,869,000
13	Heat recovered from CHP	BTU/hr	1,736,800	2,894,700	4,277,800
14	Natural gas demand	BTU/hr	0	0	0
15	Natural gas demand offset	therms/yr	(211,300)	(352,200)	(520,500)
16	<b>Electricity Requirements and Offset</b>				
17	HSOW processing	kWh/year	na	66,200	66,200
18	Pre-Dewatering	kWh/year	8,400	14,100	14,100
19	THP	kWh/year	149,000	248,300	248,300
20	CHP & Biogas Treatment	kWh/year	64,100	64,100	64,100
21	MHP process	kWh/year	na	na	522,800
22	Total electricity demand	kWh/year	221,500	392,700	915,500
23	CHP electricity output offset	kWh/year	(4,839,800)	(8,066,400)	(10,430,700)
24	<b>Annual GHG Emissions</b>				
25	Natural Gas demand from treatment processes	tonne CO <sub>2</sub> e/y	-	-	-
26	Electricity demand from treatment processes	tonne CO <sub>2</sub> e/y	122	216	504
27	Biogas Combustion - CHP	tonne CO <sub>2</sub> e/y	7	12	15
28	Natural Gas Offset (heat produced from CHP)	tonne CO <sub>2</sub> e/y	(1,159)	(1,933)	(2,856)
29	Electricity Offset (electricity produced from CHP)	tonne CO <sub>2</sub> e/y	(2,667)	(4,445)	(5,747)
30	Landfill offset (for portion of waste previously going to LF)	tonne CO <sub>2</sub> e/y	na	(4,307)	(4,307)
31	Co-digestion offset (for portion of waste previously going to LF)	tonne CO <sub>2</sub> e/y	na	(1,192)	(1,192)
32	<b>Net GHG Emissions, tonne CO<sub>2</sub>eq/y</b>	tonne CO <sub>2</sub> e/y	(3,700)	(11,600)	(13,600)

Narrative of each parameter presented in Table A-1. (The number of each parameter relates to the number in the table)

1. **Solids Loading and Biogas Available.** The solids loading summary based on existing and future conditions, and biogas generated from the anaerobic digestion process.
2. **Raw sludge** (generated on-site from CRWRRF; dry ton/day) for the existing condition was derived from the plants historical data.
3. **HSOW** (imported; dt/d). The solids with HSOW (Measure 1) was estimated based on additional capacity available in the digesters. Therefore, the digesters can process an additional 10 dt/d of solids.
4. **Raw sludge** (lb/day) converts dry tons per day to lb/day.
5. **HSOW** (imported; lb/day) converts the dry tons HSOW per day to lb/day. The total increased solids is 20,000 lb/day.
6. **Digested biosolids** (dt/d) is calculated by subtracting the volatile solids that are destroyed during digestion (and converted to biogas). Volatile solids reduction (VSR) of 58% was used for the scenarios without MHP, whereas the scenario with MHP (Measure 2), VSR of 75% was used.
7. **Digested biosolids** (lb/day) convert dt/d to lb/day.
8. **Digester biogas available** is calculated based on the above mentioned VSR and a biogas production rate of 15 cf/lb VS destroyed.
9. **Heat Requirement.** Heat is required for the THP and MHP processes.
10. **THP heat requirement** is calculated based on the solids feed to THP and a THP heating demand of 162 MJ/m<sup>3</sup>.
11. **MHP heat requirement** is calculated based on heating the digested solids (wet) from 95 degree F to 167 degree F (MHP operating temperature). Cp value is 1 BTU/lb/°F.
12. **Total heat requirement** is the sum of the THP and MHP heat demand.
13. **Heat recovered from CHP** is calculated based on the energy content of biogas of 585 BTU/scf and CHP heat recovery efficiency of 35 percent. Heat recovered from CHP is adequate to meet the total heat requirements.
14. **Natural gas demand.** Since the “total heat recovered from CHP” is greater than the “total heat requirement”, no natural gas is needed for firing the boilers.
15. **Natural gas demand offset.** This value represents the equivalent amount of natural gas that would have been used if recovered heat from CHP was not available.
16. **Electricity Requirements:** Electricity is required to operate the HSOW and MHP systems, as documented below.
  17. **HSOW processing** electricity requirement is calculated based on 20 kWh/dt, from previous project experience.
  18. **Pre-dewatering** electricity requirement is calculated based on 1.7 kWh/m<sup>3</sup>, based on centrifuge equipment information.
  19. **THP** electricity requirement is calculated based on 30 kWh/dt feed, based on Cambi equipment information.
  20. **CHP** electricity requirement is estimated based on CHP engine manufacturer information noting the auxiliary equipment load to be 7.7 kW. It was assumed that the CHP was operating 95 percent of the year.
  21. **MHP** electricity requirement is calculated based on the estimate (80 hp) from the CRWRRF Electrical Improvement Report (2021).

22. **Total Electricity Demand** is the sum of the electricity requirements.
23. **CHP electricity output offset.** Electricity recovered from CHP was calculated based on the energy content of biogas of 585 BTU/scf and CHP electrical efficiency of 40 percent and CHP is in operation 95 percent of the year.
24. **Annual Greenhouse Gas Emissions**
25. **Natural Gas Demand from treatment processes.** No additional natural gas is needed for treatment processes.
26. **Electricity demand from treatment processes.** 1,214 lb/MWh (US EPA eGRID - RFCM)
27. **Biogas Consumption - CHP.** 3.4 gCO<sub>2</sub>eq/m<sup>3</sup> (IPCC Protocol)
28. **Natural Gas Offset** (heat produced from CHP): 0.05444 kg CO<sub>2</sub>eq/scf (US EPA GHG Emissions Factors Hub 2024)
29. **Electricity Offset** (electricity produced from CHP): 1,214 lb/MWh (US EPA eGRID - RFCM)
30. **Landfill offset** is estimated using Biosolids Emissions Assessment Model (BEAM\*2022; <https://www.biosolidsgghgs.org/>), assuming that 50 percent of the HSOW received at CRWRRF would have previously been going to a landfill for disposal.
31. **Co-digestion offset** is estimated using BEAM and assuming that 50 percent of the HSOW received at CRWRRF would have previously been going to a landfill is diverted to CRWRRF. This estimate includes:
- Anaerobic digestion – GHG reduction by electricity and heat recovery via CHP.
  - Post-dewatering – GHG emissions associated with electricity and polymer use.
  - Land application – GHG reduction by carbon sequestration and fertilizer offset credit.
32. **Net GHG Emissions** is the sum of the additional demands and offsets for natural gas and electricity.