
Racine WWTP Renewable Projects

Scoping Memo

Presented to:



Submitted by:



A. General Information

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Project Name: City of Racine WWTP Renewable Projects Scoping
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B. Disclaimer

The intent of this Scoping Memo is to identify % renewable increases associated with Energy Efficiency Measures (EEMs). Appropriate detail is included in the following sections. However, this memo is not intended to serve as a detailed engineering design document. It should be noted that detailed design efforts may be required to implement the recommended upgrades.

While the calculations in this report have been reviewed for technical accuracy and are believed to be reasonably accurate, the findings are estimates and actual results may vary. As a result, Cascade Energy Inc. (Cascade Energy) is not liable if estimated % renewables or savings are not actually achieved. All calculations in the report are for informational purposes and are not to be construed as a design document or as guarantees.

The City of Racine (Racine) should independently evaluate any advice or direction provided in this report. In no event will Cascade Energy be liable for the failure to achieve a specified amount of % renewables or energy savings and any incidental or consequential damages of any kind in connection with this memo or the installation of identified EEMs.

C. Executive Summary

This memo summarizes the energy savings and potential % renewables increase from five identified EEMs, which were selected by Racine. The following table summarizes the findings of the analysis.

Table 1: Savings & % Renewables Summary

| Baseline Energy | | 99,796,249 | kBTU/yr |
|-----------------------|--|--------------------------------------|---|
| Baseline % Renewables | | 40.9% | |
| EEM No. | Description | Annual Site Energy Savings (kBTU/yr) | % Renewables = Plant Biogas Consumption / Total Plant Energy (Purch. Nat. Gas, Biogas, & Purch. Elec.) |
| 1 | Biogas Electric Generator & New Turbo Blower | 10,359,151 | 45.6% |
| 2 | Aeration control upgrades | 3,737,760 | 47.6% |
| 3 | Diffuser replacement | 2,773,934 | 49.2% |
| 4 | Digester Gas Conditioner | 9,716,998 | 55.7% |
| 5 | UV System Upgrade | 4,283,227 | 59.2% |
| TOTAL | | 30,871,070 | 59.2% |

Note the proposal identified 6 projects, but two projects (Turbo Blower Upgrade and Digester Gas Electric Generator) were combined for analysis simplification into EEM 1. For additional project descriptions, please see *C-22 efficiency.pdf*, titled *Blower and Engine/Generator Project Efficiency*, dated January 2023.

C. Analysis Details

Baseline

The baseline energy use was established from the most recent complete year of WWTP electrical use, biogas consumption, and natural gas consumption, which was 2020. Additionally, EEM 3 was completed in 2021, making 2020 a good baseline year. The % renewables (renewable energy) is defined as the biogas consumption divided by total baseline WWTP energy use, which included purchased electricity, biogas consumption, and natural gas consumption. The following table summarizes the baseline calculations and assumptions.

Table 2: 2022 Baseline Energy Summary

| Description | Value | Units | Source |
|-------------------------------|--------------|-----------|---|
| WWTP Electricity | 7,675,961 | kWh/yr | 2020 data, Copy of WW Electric.xlsx |
| Electricity converted kBTU | 26,190,379 | kBTU/yr | 3,412BTU/1 kWh, 1kBTU/1,000 BTU |
| Biogas (Digester Gas) | 64,742,016 | scf/yr | 2020 data, Copy of WW Electric.xlsx |
| Biogas converted kBTU | 40,787,470 | kBTU/yr | Assume 630 BTU/scf, 1kBTU/1,000 BTU per FOE Calcs |
| Natural Gas | 328,184 | Therms/yr | 2020 data |
| Natural Gas converted to kBTU | 32,818,400 | kBTU/yr | 100 kBTU/Therm |
| Total Purchased Energy | 59,008,779 | kBTU/yr | Electricity & Natural Gas |
| Baseline Energy | 99,796,249 | kBTU/yr | Electricity, Biogas, Natural Gas |
| Renewable % Energy | 40.9% | | Biogas divided by baseline energy |

EEM 1 - Biogas Electric Generator & New Turbo Blower

This project would install a new turbo blower to replace the existing biogas (digester gas) engine driven positive displacement blowers. Additionally, it would install a biogas engine generator to generate electricity for on-site use. The biogas engine generator is a combined heat and power (CHP) unit, so in addition to generating electricity, heat will be recovered for process heating. This will save energy because the new biogas engine generator and turbo blower are more efficient than the existing gas driven blowers. The increase in the system efficiency will allow better use of on-site generated biogas which will reduce purchased natural gas consumption. The analysis assumes the turbo blowers will be able to turn down at low airflow demand and not over-aerate the basins. Over aeration is indicated by a dissolved oxygen (DO) level higher than the DO setpoint. These electrical savings convert to less biogas usage for the aeration system and more biogas usage for the electricity generation. The heat recovery of the CHP will reduce digester and building heating loads, leading to natural gas savings. The following table summarizes the EEM 1 calculations and assumptions.

Table 3: EEM 1 Energy Calculations

| Description | Value | Units | Source |
|--|--------------|---------------------|---|
| Baseline | | | |
| % of Biogas used by existing engine blowers | 84.2% | | FOE Calcs, Oct 2021-Sep 2022 |
| % of Biogas used for digester heating (boilers) | 12.3% | | FOE Calcs, Oct 2021-Sep 2022 |
| % of Biogas flared | 0.5% | | FOE Calcs, Oct 2021-Sep 2022 |
| % Unaccounted | 3.0% | | FOE Calcs, Oct 2021-Sep 2022 |
| Existing engine blower biogas usage | 34,329,227 | kBTU/yr | Calculated |
| | | | |
| Avg Annual Combined Blower Air Flow (Engine & Elec.) | 14,480 | scfm | Aeration MLSS Flow analysis.xlsx, Oct 2021-Sep 2022 |
| % of air provided by engine blowers | 93.1% | | Calculated, EEM 2, new turbo energy/total blower energy Remaining 6.9% air comes from electric blowers |
| Avg Annual engine blower airflow | 13,478 | scfm | Calculated |
| Atmospheric pressure | 14.37 | psia | Racine @ 618 ft elevation |
| Blower inlet pressure | 14.12 | psia | assume 0.25 psia loss through filter |
| Blower outlet pressure | 6.8 | psig | Engine Blower pressure data provided by site |
| Blower outlet pressure, absolute | 21.1 | psia | Calculated |
| Ambient air temp | 46.6 | °F | Typical Meteorological Year 3 (TMY3) Milwaukee Int AP |
| Absolute air temp | 506.6 | °R | Calculated, °F + 460 |
| Universal gas constant R for air | 53.3 | ft-lb/(lb air x °R) | Known |
| k = 1.395 for air | 1.395 | | Known |
| n = (k-1)/k = 0.283 for air | 0.283 | | Known |
| Mass air flow | 16.8 | lbs/second | Calculated, SCFM x 0.075 lb/cu ft x min / 60 seconds |
| Annual engine biogas use converted to power | 1,539.8 | hp | Calculated, converted from engine blower kBTU to hp: kBTU/yr x 1 yr/8760 hr x 1 hp/2.545 kBTU |
| Hp conversion | 550 | ft-lbs/s/hp | Known |
| Engine Blower efficiency | 23.0% | | Calculated from blower bhp equation |
| % of heat recovered from existing engine blowers | 35.3% | | Calculated, Existing engine, [1,094 kBTU/hr heat recovery] / [3,103.5 kBTU/hr consumption] |
| Baseline combined elec. and thermal eff. | 58.2% | | Calculated, add above efficiencies |
| | | | |
| Upgrade | | | |
| Existing PD blower electric efficiency | 57.0% | | 95% motor eff. x 60% PD Blower eff., FOE Calcs |
| New 674 kW engine generator combined elec. and thermal eff (CHP) | 83.8% | | Racine Engine Generator - Technical Info.pdf |
| New Turbo Blower Combined Eff. (motor & Blower) | 76.0% | | 95% motor eff x 80% turbo blower eff., FOE Calcs |
| New Turbo Blower elec. and heating Energy | 17,886,130 | kBTU/yr | Calculated, includes thermal savings because used thermal efficiency |
| Electric and thermal Biogas savings | 16,443,096 | kBTU/yr | Calculated |
| Equivalent natural gas savings | 10,359,151 | kBTU/yr | Biogas savings x 630/1000, FOE Calcs, DG = 630 BTU/cf, NG = 1000 BTU/cf |
| | | | |
| Upgrade total energy used | 89,437,098 | kBTU/yr | Calculated, Baseline minus savings |
| Upgrade Renewable % Energy | 45.6% | | Calculated, Upgrade / Baseline |

EEM 2 - Aeration control upgrades

This project would upgrade controls to improve DO control and reduce aeration system oxygen provided, saving blower energy. Energy savings assumes a DO level reduction from an average of 4.22 mg/L to 1.75 mg/L. The following table summarizes the EEM 2 calculations and assumptions.

Table 4: EEM 2 Energy Calculations

| Description | Value | Units | Source |
|--|-------------------|----------------|--|
| Baseline | | | |
| New generator electric efficiency | 37.5% | | <i>Racine Engine Generator - Technical Info.pdf</i> |
| New Turbo Blower Electric Energy Use | 17,886,130 | kBTU/yr | <i>From above calculation</i> |
| New Turbo Blower Electricity (ref only) | 5,242,125 | kWh/yr | <i>Calculated, Turbo Blower & Heating energy x Elec. Eff. / Combined Elec. & Therm Eff.</i> |
| Blower #1 Energy Usage | 5,100 | kWh/yr | <i>FOE Calcs, 2021 Data, 58A, 4160V, 0.9 PF, 13.6 hr</i> |
| Blower #4 Energy Usage | 388,295 | kWh/yr | <i>FOE Calcs, 2021 Data, 33.3A, 4160V, 0.9 PF, 1798 hr</i> |
| Blower #1 & #4 converted to kBTU | 1,342,264 | kBTU/yr | <i>FOE Calcs, 1 kWh = 3.412 BTU</i> |
| Baseline Blower Energy | 19,228,395 | kBTU/yr | Calculated |
| Upgrade | | | |
| Baseline Average DO | 4.22 | mg/L | <i>Trend data, 8/1/21 - 12/15/21, Basins 1-5</i> |
| Upgrade Average DO | 1.75 | mg/L | <i>Assume Average of 1.5-2 mg/L</i> |
| % Savings | 29.6% | | <i>12% savings per 1 mg/L reduction, based on Saturated DO minus DO in basin = driving force for oxygen transfer</i> |
| Upgrade Turbo Blower Energy | 12,584,681 | kBTU/yr | <i>Calculated</i> |
| Upgrade Blower #1 & 4 Energy | 944,417 | kBTU/yr | |
| Biogas savings (Turbo Blower savings) | 5,301,449 | kBTU/yr | <i>Calculated</i> |
| Natural gas savings | 3,339,913 | kBTU/yr | <i>Biogas savings x 630/1000, FOE Calcs, DG = 630 BTU/cf, NG = 1000 BTU/cf</i> |
| Electrical Energy Savings (Blower #1 & #4) in kBTU | 397,847 | kBTU/yr | <i>Calculated</i> |
| Total energy savings | 3,737,760 | kBTU/yr | <i>Calculated</i> |
| Upgrade total energy used | 85,699,338 | kBTU/yr | <i>Calculated, Baseline minus savings</i> |
| Upgrade Renewable % Energy | 47.6% | | Calculated, Upgrade / Baseline |

EEM 3 - Diffuser Replacement

This project replaced the 1990's era diffusers with new diffusers, it was completed in 2021. Energy savings comes from reducing blower airflow by improving diffuser oxygen transfer efficiency (OTE). The analysis assumes an OTE improvement from 9.6% to 13.9%. The following table summarizes the EEM 3 calculations and assumptions.

Table 5: EEM 3 Energy Calculations

| Description | Value | Units | Source |
|--|--------------|---------|--|
| Baseline | | | |
| Turbo Blower Energy | 12,584,681 | kBTU/yr | <i>Calculations above</i> |
| Blower #1 & 4 Energy | 944,417 | kBTU/yr | <i>Calculations above</i> |
| Upgrade | | | |
| Baseline Old Ceramic Disc Diffuser OTE | 9.6% | | <i>Avg of Basin 3 & 5, 9.34% & 9.81% SOTepw per Offgas Analysis of AB's Report, Redmon Engr. Co, 2021.</i> |
| Upgrade New membrane disc diffuser OTE | 13.9% | | <i>Avg of Basin 1 SOTepw per Offgas Analysis of AB's Report, Redmon Engr. Co, 2021.</i> |
| % Savings | 31% | | <i>Calculated</i> |
| Upgrade Turbo Blower Energy | 8,650,275 | kBTU/yr | <i>Calculated</i> |
| Upgrade Blower #1 & 4 Energy | 649,160 | kBTU/yr | <i>Calculated</i> |
| Biogas savings (Turbo Blower savings) | 3,934,407 | kBTU/yr | <i>Calculated</i> |
| Natural gas savings | 2,478,676 | kBTU/yr | <i>Biogas savings x 630/1000, FOE Calcs, DG = 630 BTU/cf, NG = 1000 BTU/cf</i> |
| Electrical Energy Savings (Blower #1 & #4) in kBTU | 295,257 | kBTU/yr | <i>Calculated</i> |
| Total energy savings | 2,773,934 | kBTU/yr | <i>Calculated</i> |
| | | | |
| Upgrade total energy used | 82,925,405 | kBTU/yr | <i>Calculated, Baseline minus savings</i> |
| Upgrade Renewable % Energy | 49.2% | | <i>Calculated, Upgrade / Baseline</i> |

EEM 4 - Digester Gas Conditioner

This would install a gas conditioner so that digester gas can be better utilized on-site for electricity generation and heating. Analysis assumes the conditioner would increase the biogas heating value from 630 to 1,000 BTU/cf. This would allow more energy to be gleaned from the biogas thereby reducing natural gas usage. Additionally the analysis assumes that all of the flare gas can be recovered and used on-site, offsetting natural gas use. The following table summarizes the EEM 4 calculations and assumptions.

Table 6: EEM 4 Energy Calculations

| Description | Value | Units | Source |
|--|--------------|---------|---|
| Electric generator and blower baseline | 16,443,096 | kBTU/yr | Above (EEM 1 - Electric and thermal Biogas savings) |
| Electric generator and blower upgrade | 10,359,151 | kBTU/yr | Above (EEM 1 - Equivalent Natural Gas savings) |
| Electric generator and blower savings | 6,083,946 | kBTU/yr | Calculated |
| | | | |
| Aeration controls baseline | 5,301,449 | kBTU/yr | Above (EEM 2 - Turbo & CHP Biogas savings) |
| Aeration controls upgrade | 3,339,913 | kBTU/yr | Above (EEM 2 - Equivalent Natural Gas savings) |
| Aeration controls savings | 1,961,536 | kBTU/yr | Calculated |
| | | | |
| Diffuser baseline | 3,934,407 | kBTU/yr | Above (EEM 3 - Turbo Biogas savings) |
| Diffuser upgrade | 2,478,676 | kBTU/yr | Above (EEM 3 - Equivalent Natural Gas savings) |
| Diffuser savings | 1,455,731 | kBTU/yr | Calculated |
| | | | |
| Biogas Flared (wasted) Annually | 215,786 | kBTU/yr | Calculated, 0.5% (above) x baseline 2020 data |
| Total Natural Gas Savings | 9,716,998 | kBTU/yr | Biogas savings x 630/1000, FOE Calcs, DG = 630 BTU/cf, NG = 1000 BTU/cf |
| | | | |
| Upgrade total energy used | 73,208,406 | kBTU/yr | Calculated, Baseline minus savings |
| Upgrade Renewable % Energy | 55.7% | | Calculated, Upgrade / Baseline |

EEM 5 - UV System Upgrade

This project would upgrade the low pressure UV system with a more efficient Trojan Signa system, resulting in electrical energy savings. The analysis file *UV System Savings – FOE.xlsx* by Focus on Energy was reviewed and found to be reasonable. The electrical energy savings from this file was converted to kBTU/year to determine the resulting increase in % renewable energy. The following table summarizes the EEM 5 calculations and assumptions.

Table 7: EEM 5 Energy Calculations

| Description | Value | Units | Source |
|-----------------------------------|--------------|---------|--|
| Energy Savings | 1,255,342 | kWh/yr | <i>Focus On Energy (FOE) Calculations</i> |
| Energy Savings converted to kBTU | 4,283,227 | kBTU/yr | <i>FOE Calcs, 1 kWh = 3,412 BTU</i> |
| | | | |
| Upgrade total energy used | 68,925,179 | kBTU/yr | <i>Calculated, Baseline minus savings</i> |
| Upgrade Renewable % Energy | 59.2% | | <i>Calculated, Upgrade / Baseline</i> |

Additional Savings – On Site Electrical Generation from Natural Gas

In addition to the above measures, Racine plans to run the Cogen system at full capacity, which will use some additional natural gas above the biogas generation. This will reduce their need to purchase electricity, saving money. The table below estimates the amount of natural gas the site will be able to use for generation after all the biogas is used.

Table 8: Cogen Natural Gas Consumption

| | | | |
|---|------------|---------|---|
| Generator peak Natural Gas Consumption | 6,128 | kBTU/hr | <i>Racine Engine Generator - Technical Info.pdf</i> |
| Annual max generator Natural Gas Consumption | 53,681,280 | kBTU/yr | <i>Calculated</i> |
| Annual Biogas generation | 64,742,016 | kBTU/yr | <i>Above, but assume 1,000 BTU/scf because of Gas Conditioner</i> |
| Remaining generator Natural Gas consumption after using all of biogas | 11,060,736 | kBTU/yr | <i>Calculated</i> |