# Technical Appendix - Accelerating Emissions Reduction at Delaware WWTPs

## Reduction Measure 1: Reducing methane leaking during anaerobic digestion at Wilmington WWTP

The Wilmington WWTP is located in Delaware's largest city with a wastewater operation serving customers within its municipal boundaries (approximately 70,000 customers) and one wholesale customer, New Castle County (approximately 550,000 customers in northern New Castle County and two townships in Southeast Pennsylvania). The WWTP is a conventional, activated sludge plant with a peak primary design capacity of 340 MGD and a peak secondary design capacity of 168 MGD. The WWTP includes five anaerobic digesters. Reduction Measure 1 consists of replacement of floating steel cover on Digester #4 with fixed steel cover and appurtenances, recoating and rehabilitation of the concrete structure. Both the aging floating, steel cover and aging concrete structure are sources of methane leakage which when rehabilitated, will more effectively trap gases for reuse in the Renewable Energy Biosolids Facility. Reducing methane leakage during anaerobic digestion processes at Wilmington WWTP will result in significant, durable GHG emissions reductions as outlined in the methodology described below.

Full calculations for the GHG Reduction Estimates described in this Technical Appendix can be found in the Attached File: GHGCalc_DNREC.xls.

*GHG Reduction Estimate Method*
The GHG Reduction Estimate Method used for Reduction Measure 1 uses a formula to estimate the volume of leaking CO2 and CH4 that will be captured via the new digester cover and rehabilitation of the concrete structure. This capture of GHG emissions from the digester is the basis of the reduction under Reduction Measure 1.

**Step 1: Estimate the reduction in pounds of CH4.**
The formula used is described below and the calculations are also detailed in the attached GHG Calculations spreadsheet.

$$GP*pCH_4*L = vCH_4$$

Where:
GP = Annual Total Gas Emissions from Digester 4 (in $f^3$)
$pCH_4$ = % of Gas Emissions from Digester 4 that are $CH_4$
L= % total gas leaking from Digester 4
$vCH_4$ = volume of $CH_4$ leakage from Digester 4 (in lbs)

**Step 2: Use EPA's Greenhouse Gas Equivalencies calculator to convert the methane reductions to $CO_2$e.**
EPA's Greenhouse Gas Equivalencies calculator uses IPCC's Fifth Assessment GWP values.
https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

**Step 3**: **Estimate the reduction in pounds of $CO_2$.**
The formula used is described below and the calculations are also detailed in the attached GHG Calculations spreadsheet.

$$GP*pCO_2*L = vCO_2$$

Where:
GP = Annual Total Gas Emissions from Digester 4 (in $f^3$)

$pCO_2$ = % of Gas Emissions from Digester 4 that are $CO_2$
L= % total gas leaking from Digester 4
$vCO_2$ = volume of $CO_2$ leakage from Digester 4 in lbs

**Step 4: Develop total GHG reduction estimate**
Estimate total GHG emissions reductions based on the sum of $CO_{2e}$ as calculated in Step 1 through Step 3.

*Models & Tools Used*
To develop the estimate of GHG emission reductions from Reduction Measure 1, the EPA Greenhouse Gas Equivalencies Calculator was used in the final step to convert the estimated GHG reductions from lbs of $CH_4$ to annual $CO_{2e}$ in $tCO_2$. EPA's Greenhouse Gas Equivalencies Calculator uses IPCC Fifth Assessment GWP values as noted in their reference page.

EPA's Greenhouse Gas Equivalencies Calculator was developed to allow users to convert greenhouse gas emission numbers into different types of equivalent units. The equivalencies in the calculator used for the Reduction Measure 1 are converted into $CO_2$ equivalents ($CO_{2e}$) and are calculated using global warming potentials (GWPs) from the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) which aligns with the requirements in the FOA for EPA's CPRG Implementation Grant Funding Opportunity.

*Measure Implementation Assumptions*
Wechselberger et al. (2023) conducted investigated 33 biogas plants in Austria, Germany, Sweden and Switzerland including mainly agricultural and biowaste treating facilities. The four measurement teams used a harmonized measurement procedure to systematically survey individual on-site emission sources and leakages. Leaks were detected using an optical gas imaging (OGI) camera and/or a portable methane analyzer were used to screen exposed biogas bearing plant components, ventilation grids of biogas processing rooms (CHP, biogas upgrading units [BUU], compressor stations) and air-outlets of air-inflated double membrane domes. A leakage was defined as an unintentional $CH_4$ loss (i.e. due to technical or human failure) when the $CH_4$ concentration exceeded 0.1 vol%.

The study found that digesters with concrete roofs exhibited the following range of $CH_4$ emissions via leakage:

*Table 1: Concrete Roof Digesters - Methane Emissions via Leakage*

| Min | Median | Max |
|---|---|---|
| .09% | 0.28% | 0.97% |

The estimate method for Reduction 1 assumes that once implemented, the fixed steel cover and rehabilitated digester will result in an CH4 emission factor equal to the median observed by Wechselberger et al. for digesters with concrete roofs (0.28%) which represents an approximate 90% in reduction from current leakage emissions (see additional detail on current leakage rate in *GHG Reduction Assumptions* below).

**Implementation Milestones**
It is assumed that achievement of the following implementation milestones will mark the start of the GHG reductions estimated for Reduction Measure 1.

- Construction and Installation
- System Integration and Testing
- Tentative In-Service-Date

Based on the implementation milestones, it is assumed that if an EPA CPRG award is issued by October 1, 2024, the project in-service date will occur approximately 16 months later (January 1, 2026).

**Reduction Measure Lifetime**

Based on market research the assumed minimum design life for the steel digester cover and rehabilitated digester tank is 30 years.

**Capital Cost Assumptions**

The capital costs assumed for Reduction Measure 1 are based on project scoping cost estimates developed in 2022 and adjusted to 2028 dollars (assuming a 3% annual inflation factor).

**Operation and maintenance cost assumptions**

There are no assumed operation and maintenance costs for Reduction Measure 1.

*GHG Reduction Assumptions*

Key assumptions for this GHG Reduction Estimate Method include the following:

**$pCH_4$ (Percentage of the Gas Emissions from Digester 4 that are $CH_4$)**

The value of 60% for $pCH_4$ is a key assumption and is based on the guidance provided in the *IPCC, 2000, Good Practice Guidance for Emissions from Wastewater Handling*. The IPCC Guidelines describe a single method for calculating $CH_4$ emissions from domestic wastewater handling. Emissions are a function of the amount of waste generated and an emission factor that characterizes the extent to which this waste generates $CH_4$. IPCC specifics that it is good practice to use a default value of 0.25 kg $CH_4$/kg Chemical Oxygen Demand (COD) or a default value of 0.6 kg $CH_4$/kg Biochemical Oxygen Demand (BOD)
This assumption of 60% is also used in *EPA's State Inventory Tool v. 2024.1 Wastewater Module January 2024*.

**L = (% of total gas leaking from Digester 4)**

Results Wechselberger et al. indicated the following technology specific $CH_4$ emission factor for digestate storage tanks utilized for biogas production that were not considered gas-tight:

*Table 2: CH4 Emission Factor for Digestate Storage Tanks Utilized for Biogas Production*

| Min | Median | Max |
|---|---|---|
| 0.06% | 2.83% | 5.62% |

The estimate method for Reduction 1 assumes that the current $CH_4$ emission factor is equal to the median observed by Wechselberger et al. for digesters that are not gas tight (2.83%)

*Reference Case Scenario*

The reference case scenario for Reduction Measure 1 is represented by the digester continuing operation with the existing cover and without any rehabilitation to the structure or the appurtenances from for the years 2025-2050 with an assumed rate of $CH_4$ emissions of 2.83% for all years.

*Measure Specific Activity Data*

DNREC recognizes that most robust measure specific activity data would include measuring the fugitive emissions of methane from the digester tanks at the Wilmington WWTP before and after retrofit. Best practice methods to measure emission reductions from Reduction Measure 1 include optical gas imaging, drone surveys, continuous measurement via a fixed system, or academic supported modeling. The specific measurement process used to track implementation of Reduction Measure 1 has not yet been specified and is not included in the application budget. If funding for this application is awarded DNREC is committed to using a quantifiable measurement technique to track the results of project implementation that is aligned with the best available technology option and utility resource availability.

*Uncertainties*

The primary uncertainties for Reduction Measure 1 include assumption that the pre-implementation and post implementation $CH_4$ leakage rates are equivalent to the results presented in the study by Wechselberger et al. Researchers from that study noted the following limitations should be considered:

- Uncertainties caused by the measurement method (e.g. sampling and instrument precision)
- Short averaging measuring times of the study (several minutes to one hour)

- Variability of $CH_4$ emissions due to changing operating states, weather and climate conditions

*GHG Emissions Reduced*

The GHG emission reductions for this reduction measure are presented in the tables below.

*Table 3: Reduction 1 GHG Emissions Reduced: Absolute and Cumulative from 2025-2030 (in tons of CO2e)*

| Year | Reduction (tCO2e) |
|---|---|
| 2025 | 0 |
| 2026 | 607 |
| 2027 | 607 |
| 2028 | 607 |
| 2029 | 607 |
| 2030 | 607 |
| **Cumulative Reduction 2025-2030** | 3037 |

*Table 4: Reduction 1 GHG Emissions Reduced: Absolute and Cumulative from 2025-2050 (in tons of CO2e)*

| Year | Reduction (tCO2e) |
|---|---|
| 2025 | 0 |
| 2026 | 607 |
| 2027 | 607 |
| 2028 | 607 |
| 2029 | 607 |
| 2030 | 607 |
| 2031 | 607 |
| 2032 | 607 |
| 2033 | 607 |
| 2034 | 607 |
| 2035 | 607 |
| 2036 | 607 |
| 2037 | 607 |
| 2038 | 607 |
| 2039 | 607 |
| 2040 | 607 |
| 2041 | 607 |
| 2042 | 607 |
| 2043 | 607 |
| 2044 | 607 |
| 2045 | 607 |
| 2046 | 607 |
| 2047 | 607 |
| 2048 | 607 |
| 2049 | 607 |
| 2050 | 607 |
| **Cumulative Reduction 2025-2050** | 15183 |

## Reduction Measure 2 – Reducing energy-related emissions at Wilmington WWTP

The Wilmington WWTP currently has 14 existing aeration blowers which provide air to the plant's secondary treatment aeration basins. Reduction Measure 2 proposes to replace all 14 of Wilmington WWTP's existing single-speed multi-stage centrifugal blowers with modern blowers and variable frequency drives (VFDs), including power supply, instrumentation and Supervisory Control and Data Acquisition (SCADA), and blower appurtenances.

The Industrial Assessment conducted by the University of Delaware recommended installation of VFDs on existing blowers. However, due to the condition and age, the engineers from the Wilmington WWTP plan to replace the blowers in their entirety concurrently with the VFD addition.

*<u>GHG Reduction Estimate Method</u>*

GHG Reduction Estimates for Reduction Measure 2 are based on the findings of the Industrial Assessment. The Industrial Assessment recommended that Wilmington WWTP replace the throttle control with variable speed drive control of the aeration blowers. The Assessment advised that this can be accomplished by opening the throttling valves to 100%, and then controlling the blower speed using Dissolved Oxygen (DO) control. The anticipated energy savings in kW as calculated by the Industrial Assessment is detailed below:

| blower | valve | HP | kW full load | kW at load | kW VFD | savings/year | |
|---|---|---|---|---|---|---|---|
| 7 | 1 | 300 | 235.6 | 235.6 | 235.6 | | |
| 8 | 0.68 | 300 | 235.6 | 197.9 | 74.1 | | |
| 9 | 1 | 300 | 235.6 | 235.6 | 235.6 | | |
| 10 | 0.7 | 300 | 235.6 | 200.2 | 80.8 | | |
| 11 | 0.95 | 300 | 235.6 | 229.7 | 202.0 | | |
| 15 | 0.55 | 400 | 314.1 | 243.4 | 52.3 | | |
| 17 | 0.68 | 400 | 314.1 | 263.8 | 98.8 | | |
| | | | **total kW:** | **1606.3** | **979.0** | | |
| | | | **total kWh/year** | **14080438** | **8582252** | **5498186** | $577,310 |

*Figure 1: Anticipated Energy Savings (in kW)*

*<u>Models & Tools Used</u>*

The Industrial Assessment determined in consultation with plant personnel that the aeration blowers each have a throttling valve that is controlled by a DO sensor, to maintain set point. Display readings for the blowers indicated that they have a roughly linear power vs. flow curve, with approximately 50% power at zero flow. The consumption of the blowers during the assessment (detailed in the table below) was used as a snapshot average to calculate total blowers consumption per year. The 14,080,000 kW of consumption accounted for 46.8% of energy consumption at the plant at the time of the Industrial Assessment

| blower | valve | HP | kW full load | kW at load |
|---|---|---|---|---|
| 7 | 1 | 300 | 235.6 | 235.6 |
| 8 | 0.68 | 300 | 235.6 | 197.9 |
| 9 | 1 | 300 | 235.6 | 235.6 |
| 10 | 0.7 | 300 | 235.6 | 200.2 |
| 11 | 0.95 | 300 | 235.6 | 229.7 |
| 15 | 0.55 | 400 | 314.1 | 243.4 |
| 17 | 0.68 | 400 | 314.1 | 263.8 |
| | | | **total kW:** | **1606.3** |
| | | | **total kWh/year** | **14080438** |

*Figure 2: Consumption of Blowers*

EPA's Greenhouse Gas Equivalencies Calculator was developed to allow users to convert greenhouse gas emission numbers into different types of equivalent units. The equivalencies in the calculator used for the Reduction Measure 2 are converted into $CO_2$ equivalents ($CO_{2e}$) and are calculated using global warming potentials (GWPs) from the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) which aligns with the requirements in the FOA for EPA's CPRG Implementation Grant Funding Opportunity

*<u>Measure Implementation Assumptions</u>*

During the Industrial Assessment (which Wilmington WWTP plant personnel described as an average day), seven blowers were operating. The authors of the Industrial Assessment used the consumption of the seven operating blowers as a snapshot average to calculate total blowers consumption per year. The GHG Emission Reduction calculations for Reduction Measure 2 rely on the Industrial Assessment conducted by the University of Delaware which calculated energy savings based on replacement of the WWTP's aeration blowers that currently utilize throttle control with variable speed drive control. The energy savings estimated by this upgrade is likely highly conservative for the current project which proposes to replace the entire single-speed multi-stage centrifugal blowers with modern blowers and VFDs, including power supply, instrumentation and SCADA, and blower appurtenances which will likely achieve efficiencies beyond the simple control replacement recommended by the Industrial Assessment.

**Implementation Milestones**

- Construction and Installation

- System Integration and Testing
- Tentative In-Service-Date

Based on the implementation milestones, it is assumed that if an EPA CPRG award is issued by October 1, 2024, the project in-service date will occur approximately 16 months later (January 1, 2026).

**Reduction Measure Lifetime**

Based on market research the assumed minimum design life for the upgraded blowers is 25 years[1].

**Capital Cost Assumptions**

Modern blowers have more sophisticated instrumentation (such as vibration monitoring) and SCADA controls (such as speed) and therefore some SCADA upgrades are also included in the project budget for Reduction Measure 2, in order to integrate the new equipment into existing SCADA. Existing blowers are powered from Motor Control Centers (MCC) and conductors installed in the 1960s and 1970s. Due to the age, many of the MCC components are no longer serviceable. Connecting new VFDs to the old MCC is discouraged, therefore replacement of MCC is included in the project.

**Operation and maintenance cost assumptions**

There are no operation and maintenance costs assumed for this project.

*GHG Reduction Assumptions*

GHG Reduction Estimates for Reduction Measure 2 are based on the energy efficiencies calculated by the Industrial Assessment. The estimates in the assessment assume the installation the speed drives referenced in the Industrial Assessment[2] (or functional equivalent).

*Reference Case Scenario*

The reference case scenario for Reduction Measure 2 is represented by the aeration blowers continuing operation without any modification or replacement from for the years 2025-2050 at the current energy consumption.

*Measure Specific Activity Data*

As mentioned previously, display readings for the current blowers indicated that they have a roughly linear power vs. flow curve, with approximately 50% power at zero flow. The consumption of the blowers during the assessment was used as a snapshot average to calculate total blowers consumption per year.

New Motor Control Centers (MCCs) have modern safety and monitoring equipment which will provide further measurement to quantify the energy savings from the implementation of this Reduction Measure.

*Uncertainties*

Reduction Measure 2 is still in the pre-scoping phase. As such, the blower vendor has not been identified and the exact design specifications and energy consumption of the equipment that will be installed for the Reduction Measure is unknown. While this is the primary uncertainty of the GHG Reduction Estimate, the estimate is almost certainly conservative as previously discussed (due to the fact that the entire blower is being replaced).

*GHG Emissions Reduced*

The GHG emission reductions for this reduction measure are presented in the tables below.

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[1] Examining Payback on New Generation High Speed Blowers | WaterWorld

[2] https://www.wolfautomation.com/lslv2500h100-4cofd-plus-vfd-400hp-250kw-380/
https://www.wolfautomation.com/odp-2-84400-3hf4n-mn-vfd-400hp-250kw-480-amp/
https://www.wolfautomation.com/vfd-400hp-460v-3-phase-50x21-1x16-8/

*Table 5: Reduction 2 GHG Emissions Reduced: Absolute and Cumulative from 2025-2030 (in tons of CO2e)*

| **Year** | **Reduction (tCO2e)** |
|---|---|
| 2025 | 0 |
| 2026 | 3841 |
| 2027 | 3841 |
| 2028 | 3841 |
| 2029 | 3841 |
| 2030 | 3841 |
| **Cumulative Reduction 2025-2030** | 19205 |

*Table 6: Reduction 2 GHG Emissions Reduced: Absolute and Cumulative from 2025-2050 (in tons of CO2e)*

| **Year** | **Reduction (tCO2e)** |
|---|---|
| 2025 | 0 |
| 2026 | 3841 |
| 2027 | 3841 |
| 2028 | 3841 |
| 2029 | 3841 |
| 2030 | 3841 |
| 2031 | 3841 |
| 2032 | 3841 |
| 2033 | 3841 |
| 2034 | 3841 |
| 2035 | 3841 |
| 2036 | 3841 |
| 2037 | 3841 |
| 2038 | 3841 |
| 2039 | 3841 |
| 2040 | 3841 |
| 2041 | 3841 |
| 2042 | 3841 |
| 2043 | 3841 |
| 2044 | 3841 |
| 2045 | 3841 |
| 2046 | 3841 |
| 2047 | 3841 |
| 2048 | 3841 |
| 2049 | 3841 |
| 2050 | 3841 |
| **Cumulative Reduction 2025-2050** | 96025 |

## Reduction Measure 3 – A statewide program to baseline and reduce energy-related emissions at wastewater treatment facilities throughout Delaware

Reduction Measure 3 is a replicable and scalable program modeled on the energy efficiency improvements achieved via the blower replacement at the Wilmington WWTP. Reduction Measure 3 will provide direct pass-through grants to wastewater utilities in Delaware and will initially focus on blower replacement projects.

Delaware's Water Pollution Control Revolving Fund (SRF) provides low interest loans to public wastewater systems to support water quality improvements, capacity building, and capital infrastructure projects. Currently, only ten percent of the annual federal funding must qualify as "Green Project Reserve" which are projects with short- and long-term goals aimed at water, energy efficiency, green infrastructure, and utilizing environmentally innovative technologies. Additional funding via direct pass-through grants via the CPRG (Reduction Measure 3) would accelerate energy efficiency upgrades and lead to increased short-term emissions reductions.

*<u>GHG Reduction Estimate Method</u>*

Estimates for GHG Reduction Measure 3 were calculated using the following Steps.

**Step 1: Calculate the Cost Effectiveness of Reduction Measure 2**

Reduction Measure 2 Cost Effectiveness = Reduction Measure 2 Cost/Reduction Measure 2 Cumulative GHG Reductions (2025-2030)

**Step 2: Determine Total Cost for Reduction Measure 3**

The Reduction Measure 3 cost was estimated for the statewide program by reviewing the improvement plans in the Delaware Wastewater Needs Assessment for each facility in the state. Cost estimates for all pump and blower replacement projects proposed in the 5-year plan were used to estimate the Reduction Measure 3 cost of $21,038,844.

**Step 3: Calculate Estimated Lifetime GHG Reductions for Reduction Measure 3**

It is assumed that on a per dollar basis, the new blowers will achieve an energy savings comparable to that at the Wilmington WWTP once installed,

Estimated Total Lifetime GHG Reductions for Reduction Measure 3 = Reduction Measure 3 Total Cost/Cost Effectiveness of GHG Reduction 2

**Step 4: Estimate Annual GHG Reductions Achieved when Reduction Measure 3 is 100% Implemented**

Estimated Annual GHG Reductions = Estimated Total Lifetime GHG Reductions for Reduction Measure 3/25 Years

**Step 5: Calculate Estimated GHG Reductions for 2025-2030 based on funding phases**

GHG Reduction Year 2025 = Cumulative % of funding spent 2025*Estimated Annual GHG Reductions (*Formula is repeated for Years 2026-2030*)

*<u>Models & Tools Used</u>*

GHG Reduction Estimates for Reduction Measure 3 are based on those calculated for Reduction Measure 2. There are no unique models or tools used in the calculations for Reduction Measure 3.

*<u>Measure Implementation Assumptions</u>*

**Implementation Milestones**

The grant funding provided under Reduction Measure 3 is planned to be spent in the following phases:

| Phasing of Funding (Year Funding Spent) | Cumulative Funding Spent Per Year | Cumulative % Spent Per Year |
|---|---|---|
| 2025 | $38,844.00 | 0.18% |
| 2026 | $1,928,844.00 | 9.17% |
| 2027 | $14,948,844.00 | 71.05% |
| 2028 | $20,618,844.00 | 98.00% |
| 2029 | $21,038,844.00 | 100.00% |

**Reduction Measure Lifetime**

Based on market research the assumed minimum design life for the upgraded blowers is 25 years[3].

**Capital Cost Assumptions**

[3] Examining Payback on New Generation High Speed Blowers | WaterWorld

The Reduction Measure 3 cost was estimated for the statewide program by reviewing the improvement plans in the Delaware Wastewater Needs Assessment for each facility in the state. Cost estimates for all pump and blower replacement projects proposed in the 5-year plan were used to estimate the Reduction Measure 3 cost of $21,038,844.

**Operation and Maintenance Cost Assumptions**

The Delaware Wastewater Needs Assessment was used as the basis for the cost estimate for Reduction Measure 3. The costs associated with blower needs included in that assessment are capital project costs and do not include ongoing operation and maintenance.

**GHG Reduction Assumptions**

It is assumed that on a per dollar basis Reduction Measure 3 will result in the same level of GHG Reductions as Reduction Measure 2.

**Reference Case Scenario**

The reference case scenario for Reduction Measure 3 is represented by the blower funding needs at other Delaware WWTPs going unmet and the aeration blowers at those facilities continuing operation without any modification or replacement from for the years 2025-2050 at the current energy consumption.

**Measure Specific Activity Data**

Implementation of the financial program will be measured via financial tracking and reporting from grant recipients. Similar to Reduction Measure 2, energy savings at each utility can be tracked and measured via the blower's MCC.

**Uncertainties**

Site specific conditions can impact the energy savings achieved at individual utilities. It is uncertain what the energy savings per dollar achieved at Wilmington WWTP will be equivalent to that achieved at other facilities.

<u>*GHG Emissions Reduced*</u>

*Table 7: Reduction 3 GHG Emissions Reduced: Absolute and Cumulative from 2025-2030 (in tons of $CO_2e$)*

| Year | Reduction (t$CO_2e$) |
|---|---|
| 2025 | 2 |
| 2026 | 120 |
| 2027 | 931 |
| 2028 | 1284 |
| 2029 | 1310 |
| 2030 | 1310 |
| **Cumulative Reduction 2025-2030** | 4957 |

*Table 8: Reduction 3 GHG Emissions Reduced: Absolute and Cumulative from 2025-2050 (in tons of $CO_2e$)*

| Year | Reduction |
|---|---|
| 2025 | 1310 |
| 2026 | 1310 |
| 2027 | 1310 |
| 2028 | 1310 |
| 2029 | 1310 |
| 2030 | 1310 |
| 2031 | 1310 |
| 2032 | 1310 |
| 2033 | 1310 |

| Year | Reduction |
|---|---|
| 2034 | 1310 |
| 2035 | 1310 |
| 2036 | 1310 |
| 2037 | 1310 |
| 2038 | 1310 |
| 2039 | 1310 |
| 2040 | 1310 |
| 2041 | 1310 |
| 2042 | 1310 |
| 2043 | 1310 |
| 2044 | 1310 |
| 2045 | 1310 |
| 2046 | 1310 |
| 2047 | 1310 |
| 2048 | 1310 |
| 2049 | 1310 |
| 2050 | 1310 |
| **Cumulative Reduction 2025-2050** | 34056 |

## Cost Effectiveness of GHG Reductions 2025-2030

Cost Effectiveness of GHG reductions = (Requested CPRG Funding)/Sum of Quantified GHG reductions from CPRG funding from 2025-2030

| | |
|---|---|
| Reduction Measures 1-3: Requested CPRG Funding | $38,960,532 |
| Reduction Measures 1-3: Cumulative Reduction 2025-2030 (in tons of CO2e) | 27,199 |
| Cost effectiveness of GHG reductions | $38,960,532/27,199 |
| Cost effectiveness of GHG reductions | $1,432 per ton of CO2e |

## Cost Effectiveness of GHG Reductions 2025-2050

Cost Effectiveness of GHG reductions = (Requested CPRG Funding)/Sum of Quantified GHG reductions from CPRG funding from 2025-2050

| | |
|---|---|
| Reduction Measures 1-3: Requested CPRG Funding | $38,960,532 |
| Reduction Measures 1-3: Cumulative Reduction 2025-2050 (in tons of CO2e) | 145,263 |
| Cost effectiveness of GHG reductions | $38,960,532/145,263 |
| Cost effectiveness of GHG reductions | $268 per ton of CO2e |

*References*

Wechselberger V, Reinelt T, Yngvesson J, Scharfy D, Scheutz C, Huber-Humer M, Hrad M. *Methane losses from different biogas plant technologies*. Waste Manag. 2023 Feb 15;157:110-120. doi: 10.1016/j.wasman.2022.12.012. Epub 2022 Dec 16. PMID: 36529031.

*EPA's State Inventory Tool v. 2024.1 Wastewater Module January 2024*. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool