Technical Appendix

Project GHG Impact & Scenarios

The combined heat and power system, also known as cogeneration, is an efficient, clean, and reliable method of converting biogas (a byproduct of the anaerobic digestion process) to electrical power and thermal energy needed for the treatment process.

The existing Salt Lake City Water Reclamation Facility is being upgraded in order to comply with new water quality standards and support forecasted population growth in the region. The existing treatment process is being replaced with a new biological nutrient removal (BNR) process. Salt Lake City is currently flaring off the biogas produced through the anaerobic digestion process rather than converting it to electrical power and thermal energy. The proposed Salt Lake City Combined Heat and Power project will reduce greenhouse gas emissions and reduce the amount of electricity that the Salt Lake City Water Reclamation Facility needs to pull from the power grid. This will be accomplished by utilizing the inexhaustible renewable biogas generated from the anaerobic digestion process to produce approximately one megawatt per hour (MWh) of electrical power and heat that will also contribute toward energy security and independence. Utilization of the inexhaustible renewable biogas source with the new combined heat and power system will emit less carbon dioxide compared to conventional power sources. The electrical power and thermal energy produced from the combined heat and power system will be utilized onsite at the Salt Lake City Water Reclamation Facility offsetting the need to import electrical and thermal power for the treatment process.

Description of GHG Reduction Measures

Baseline Scenario

Currently all digester gas (methane) produced through the treatment process is being flared (burned off). This is an inefficient use of the methane gas that is a renewable resource that could serve as an alternative energy source for Salt Lake City. Electrical power is currently purchased from Rocky Mountain Power to meet the full energy needs for the wastewater treatment process. The electrical power and thermal energy that will be produced from the combined heat and power project will be used to offset a portion of the electrical power that need to be purchased from Rocky Mountain Power for the new treatment process.

The emissions modeled in the baseline scenario include those from the combustion of digester gas in the flare, very minor fugitive release of methane in the unburned digester gas, and the production of electricity at the power plant.

The emissions from combustion of digester gas in the flare versus the new CHP system was also considered in the modeling of the baseline and CHP scenarios. The resulting GHG emissions from each is estimated to be equivalent and therefore did not have a reduction impact in GHG emissions. However, there is a beneficial air quality impact in the reduction in CAPs and HAPs.

Proposed New Scenario

In alignment with the Priority Climate Action Plan, the Project will contribute to the Salt Lake City goal to achieve 100% of the City's municipal electricity from renewable sources by 2030.

The electricity produced by the digester gas used in the new system will reduce the power demand provided by Rocky Mountain Power grid electricity system. It is assumed that one engine will operate full time (24/7/365) through 2030 and then two engines operate full time at 60% capacity after 2030. The power output of each of the two engines is 847 kW, after 2030, the two engines combined would produce 1,016 kW to fully utilize the methane gas available. The new heat and power system will replace the need for flaring but will have GHG emissions equivalent to that of the existing flare combustion. Electricity produced by the new system will offset the amount of electricity needed to be purchased from Rocky Mountain Power, thereby substantially reducing emissions. Additionally, there would be a reduction of other air pollutant emissions, as discussed in section 3.

Benefits

This project will allow for the beneficial use of digester gas to produce electricity and heat, as compared to the current situation where that energy is wasted, and the gas is destroyed in a flare. Mitigation of climate change, and achievement of the 1.5°C or even a WB2°C scenario, will require the employment of all available options to avoid and remove GHG from the atmosphere. Naturally conservation and efficient use of resources should be accomplished before considering new generation of low-carbon electricity or implementation of other technical options. This project will thus reduce the generation of grid-supplied electricity by 3rd parties, and therefore make new renewable generation options available to other consumers. In addition, the combined heat and power process will be a cleaner burning system as compared to the flares, thus reducing emissions of criteria and toxic air emissions, and improving air quality in the degraded Salt Lake City airshed.

The proposed project will result in a reduction in emissions of criteria air pollutants such as nitrogen oxides (NOX), volatile organic compounds (VOC), particulate matter (PM10, PM2.5) and carbon monoxide (CO) as shown in Table 1 below.

Table 1: Pollutants and Projected Reduction in Emissions for 2027 and Beyond

Pollutant	Projected Reduction in Emissions for 2027 and Beyond
NOX (tpy)	Note 1
CO (tpy)	~43%
VOC (tpy)	~58%
PM/PM10/PM2.5 (tpy)	~79%

Note: 1 Actual emissions as a result of the Combined Heat and Power Project implementation of are anticipated to be much lower than the guarantee of 0.6 g/BHP-hr provided by the vendor. A net reduction in NOX emissions compared to combustion in flares is expected due to higher efficiency for the latest cogeneration equipment.

Methodology

The 134.3 standard cubic feet of methane gas produced at the Salt Lake City Water Reclamation Facility through 2026 is based on the actual gas volume measured for 2023. The volume of methane gas is projected to remain relatively constant at the current production rate through 2027 when the Salt Lake City Water Reclamation Facility Nutrient Project is completed. Following completion of the Nutrient Project the volume of methane gas produced is expected to increase over time attributed to greater sludge production from implementation of the new treatment process and population growth projections. The heat and power output to be generated by the combined heat and power project is based on the manufacturer information presented in Table 2 below.

Table 2: Maximum Gas Use and Power Output When Operating at 100 Percent Load

Engine	kW Output	MBTU/hr Energy Input (LHV)	Digester Gas Volume (scf)
J316 D825	847	7,507	134.3
J316 D828	847	7,711	134.3

It is assumed that one engine will operate full time (24/7/365) through 2030 and then two engines operate full time at 60% capacity after 2030.

Guidance was obtained primarily from the Greenhouse Gas Protocol and the United States Environmental Protection Agency (USEPA) Center for Corporate Climate Leadership. Guidance and supporting document references for inventory methodology and emission factors are provided in Table 1.

Relevant greenhouse gases covered by the Kyoto Protocol included in the calculations include Carbon dioxide, CO_2, Methane, CH_4, and Nitrous oxide, N_2O. GHGs have different warming potentials. The Global Warming Potential (GWP) index[1] was developed to compare different GHGs on a common reporting basis of CO_2 equivalents (CO_2 e). GWP values used to calculate CO_2e emissions are based on the IPCC Fifth Assessment Report, 2014.

1. [1] 100-year GWP estimates, from the Intergovernmental Panel on Climate Change's *Fifth Assessment Report* (2014).

The GWP factors are used to convert CH_4 and N_2O emissions to units of CO_2 equivalent. The CO_2 equivalents for each gas are then summed to determine the total emissions. See the example below.

$$\boldsymbol{CH_4\ emissions\ (tonnes\ CO_2e) = CH_4\ emissions\ (tonnes)} \times\ (GWP_{CH4})$$

$$\boldsymbol{N_2O\ emissions\ (tonnes\ CO_2e) = N_2O\ emissions\ (tonnes)} \times\ (GWP_{N2O})$$

$$Total\ Emissions\ (tonnes\ CO_2e) = CO_2\ (tonnes) + CH_4\ emissions\ (tonnes\ CO_2e) + N_2O\ \text{emissions}\ (tonnes\ CO_2e)$$

Biogenic Emissions

Following established international GHG management principles (covered in Chapter 10 of the CARB, CCAR, and ICLEI, September 2008, Local Government Operations Protocol: For the Quantification and Reporting of Greenhouse Gas Emissions Inventories, Version 1.0.), emissions of CO2 from combustion of digester gas are calculated but not included in the summary totals used for comparative analysis because the carbon is of biogenic origin and would have otherwise been emitted to the atmosphere through the natural process of decay.*[2] CO2 released from digester gas combustion is being calculated separately as biogenic emissions in accordance with IPCC Guidelines for National Greenhouse Gas Inventories.

Table 3: Biogenic C02 Emissions in Metric Tonnes

Biogenic CO2 Emissions[a] (metric tonnes)	
Baseline Flaring	**New CHP**
2,057	2,057

The distinction of emissions from digester gas combustion applies only to CO2 and not to CH4 and N2O, which are also emitted from digester gas combustion and water reclamation processes. Unlike CO2 emissions, CH4 and N2O emitted from digester gas combustion, and N2O emitted from water reclamation processes are not considered to be of biogenic origin under current guidance because they are the result of man-made processes. Therefore, CH4 and N2O emissions from digester gas combustion and water reclamation processes are included in the summary emissions totals and comparative analysis.

Stationary Combustion of Digester Gas – Flare and CHP System

Default stationary combustion emission factors, based upon fuel type, from the USEPA Center for Climate Leadership GHG Emission Factors Hub were applied to the volume of digester gas produced annually to calculate the resulting annual GHG emissions.

To determine CO2 emissions from stationary combustion sources, the digester gas volume was multiplied by the CO2 emission factor and converted to metric tonnes. To determine CH4 and N2O emissions, the digester gas volume was multiplied by the emission factor and then by the appropriate GWP to calculate CO2e.

Water Reclamation Process Emissions – Incomplete Combustion of Flare or CHP

Water reclamation process emissions include CH4 emissions from incomplete combustion of digester gas. Operation of the anaerobic digesters produces CH4, which is combusted in the flare or CHP. Because of small but inherent inefficiencies, the incomplete combustion of digester gas is a source of CH4 emissions. The CH4 emissions are calculated in accordance with Chapter 10 of the CARB, CCAR, and ICLEI Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories, Version 1.0 (September 2008). The estimate of

[2] IPCC. 2006. Guidelines for National Greenhouse Gas Inventories

CH4 emissions also uses measured digester gas generation rates and the measured fraction of CH4 in the digester gas in the equation

$$CH_4\left[\frac{metric\ tons}{year}\right] \equiv Digester\ Gas\left[\frac{ft^3}{yr}\right] \times F_{CH_4} \times \rho\left(_{CH_4}\right)\left[\frac{g}{m^3}\right] \times (1-DE) \times 0.0283\left[\frac{m^3}{ft^3}\right] \times 10^{-6}\left[\frac{metric\ ton}{g}\right]$$

Where:

Table 4: Water Reclamation Process Emissions

Term	Description	Value	Source of Data
CH_4 incomplete combustion of digester gas	= CH_4 emissions from incomplete combustion of digester gas [metric ton CH_4/year]	**13**	
Digester Gas	= measured standard cubic feet of digester gas produced per day [ft^3/year]	134,300,000	Salt Lake City Public Utilities
F_{CH4}	= measured fraction of CH_4 in biogas	0.5	Salt Lake City Public Utilities
$\rho(CH_4)$	= density of methane at standard conditions [g/m^3]	662.00	Protocol default value
DE	= CH_4 destruction efficiency from flaring or burning in engine	0.99	Protocol default value
0.0283	= conversion from ft^3 to m^3 [m^3/ft^3]	0.0283	Conversion factor
10^{-6}	= conversion from g to metric ton [metric ton/g]	1.E-06	Conversion factor

Indirect Purchased Grid Electricity Emissions

Under the baseline scenario, SLC Public Utilities purchases grid electricity from Rocky Mountain Power. The indirect emissions are those associated with the generation of electricity that is purchased.

Regional location-based emission factors for purchased electricity are sourced from the USEPA's Emissions and Generation Resource Integrated Database (e-GRID2022) database for the WECC Northwest (NWPP) subregion. Non-baseload factors are chosen in alignment with the EPA's eGRID Technical Guide, "as an estimate to determine the emissions that could be avoided through projects that displace marginal fossil fuel generation."

In alignment with the GHG Protocol, market-based (supplier-specific) electricity emission factors were considered but not available for Rocky Mountain Power. Potential market-based emission factor sources reviewed included the following:

- Edison Electric Institute: Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers (June 2023)
- TCR's 2023 Default Emission Factors, Utility Specific Emission Factors Reported to TCR
- Rocky Mountain Power Website

To determine GHG emissions from purchased electricity, the amount of electricity consumed is multiplied by the appropriate emission factor and then multiplied by the GWP and converted to metric tonnes. This calculation is repeated for each pollutant and then summed to determine total CO_2e.

Upstream Fuel- and Energy-Related Activities from Grid Purchased Electricity

Emission factors for well to pump emissions for fuel and electricity are not available from USEPA or the WRI GHG Protocol. Therefore, Well to Tank (WTT) CO2e emission factors for electricity from the DEFRA Conversion Factors have been applied. The WTT emission factors are applied to the electricity totals used in determining Scope 1 and 2 emissions. As of 2022, DEFRA no longer provides the WTT data for overseas electricity use or emissions factors for the Scope 2. Therefore, the 2021 DEFRA oversees United States electricity value was used. Since the emission factors are CO2e, no GWP conversion is necessary.

Electricity losses from transmission and distribution are determined by dividing the utility electricity consumption total by one minus the average US grid gross loss factor. The grid gross loss factor is sourced from EPA's eGRID2021 Technical Guide. Emissions from electricity losses are then calculated by applying the eGRID NWPP emissions factors for CO2, CH4 and N2O as used for the Scope 2 purchased electricity calculations. GWP values are then applied to convert to CO2e.

Total fuel and energy related emissions are then calculated as the sum of well to tank and transmission and distribution emissions.

Increased Renewables in Grid Electricity Over Time

Projected reductions in electricity grid intensity ("greening of the grid" over time through modernization and clean energy development) were incorporated in the cumulative total GHG emissions impact from avoided electricity through the CHP scenario. After an exhaustive review for a credible source of future grid GHG intensity projections for the Salt Lake City area through 2050, the following two were considered.

United States Energy Information Agency (EIA)

The U.S. EIA's Annual Energy Outlook 2023 discusses the inherent uncertainty and complexity around forecasting the rate at which increased renewables will decarbonize the electricity grid. Influencing factors include economic growth, oil price, oil and gas supply, zero-carbon technology costs, and Inflation Reduction Act incentives. The U.S. Energy Information Administration - EIA - Independent Statistics and Analysis Table 18. Energy-Related Carbon Dioxide Emissions by Sector and Source provides annual projections in grid electricity emissions through 2050 by region. Overall, the EIA has predicted a total 60% reduction in grid electricity emissions for the Total Electric Power sector for the Mountain Region (which contains Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) from 2025 to 2050.

Salt Lake City Public Commitments and Progress Reports

Salt Lake City has made aggressive commitments to renewable electricity in their Climate Plan including 100% renewable energy for community electricity supply by 2030.

However, they have faced challenges that have impeded their progress. The Elektron Solar Project was expected to increase the percent of electricity from renewable sources for City Operations by 35-95% sometime in early 2023. Due to three unexpected challenges to date, the project is now expected to be operational by July 2024.

Average Approach

Therefore, to estimate the GHG reduction from the CHP project, an average between the EIA forecast and SLC commitment was applied as a reasonable assumption for year-over-year grid electricity reduction for SLC Public Utilities. This average year-over-year percent change was applied to the eGRID2022 non-baseload emission factors through 2030. After 2030, only the EIA year-over-year percent change was applied because the Salt Lake City change becomes zero percent assuming the percent renewables stays at 100% through 2050. Using this approach, it is forecasted that the fraction of zero-carbon electricity in the avoided grid electricity will increase to 96% by 2030 and reach 99% by 2050.

Scenario Comparative Analysis

GHG emissions from stationary combustion of the digester gas in the flare and the new CHP were calculated and included in the cumulative reporting periods of 2025-2030 and 2025-2050 but the resulting emissions were equivalent and therefore resulted in a net GHG emissions reduction of zero (no impact). Therefore the reduction in GHG emissions is from the avoided grid electricity with the new CHP system.

The 2025-2030 and 2025-2050 cumulative emissions reported in the workplan were calculated with the following equation for each year:

Sum of MWh (year 20XX) x forecasted emission factor (year 20XX)

Summary of GHG Emissions

Table 5 below summarizes the emissions results for each individual GHG.

Table 5: Emissions Results for Each Individual GHG

GHG Reductions	Baseline CO2e Emissions[a] (metric tonnes)			New CO2e Emissions[a] (metric tonnes)			CO2e Emissions Reduction (metric tonnes)
	Purchased Electricity	Digester Gas Flaring[b]	Total	Purchased Electricity	CHP Digester Gas Stationary Combustion[b]	Total	
Cumulative 2025 to 2030	2,698	1,873	4,571	0	1,873	1,873	**2,698**
Cumulative 2025 to 2050	5,975	9,365	15,340	0	9,365	9,365	**5,975**

[a] CO_2 emissions from wastewater treatment biogas are considered biogenic and following guidance not included in the reduction totals

[b] Includes methane from incomplete combustion of digester gas

GHG Reductions	Baseline CO2 Emissions[a] (metric tonnes)			New CO2 Emissions[a] (metric tonnes)			CO2 Emissions Reduction (metric tonnes)
	Purchased Electricity	Flaring	Total	Purchased Electricity	CHP	Total	
Cumulative 2025 to 2030	2,565	0	2,565	0	0	0	**2,565**
Cumulative 2025 to 2050	5,576	0	5,576	0	0	0	**5,576**

[a] CO_2 emissions from wastewater treatment biogas are considered biogenic and following guidance not included in the reduction totals

GHG Reductions	Baseline CH4 Emissions (metric tonnes)			New CH4 Emissions (metric tonnes)			CH4 Emissions Reduction[a] (metric tonnes)
	Purchased Electricity	Flaring[b]	Total	Purchased Electricity	CHP[b]	Total	
Cumulative 2025 to 2030	0.20	64	64	0	64	64	**0.2**
Cumulative 2025 to 2050	0.41	321	322	0	321	321	**0.4**

[a] CH4 emissions from Upstream Fuel and Energy-related Activities from electricity not included in the reduction total due to the available emission factor only in CO2e.

[b] Includes methane from incomplete combustion of digester gas

GHG Reductions	Baseline N2O Emissions (metric tonnes)			New N2O Emissions (metric tonnes)			N2O Emissions Reduction[a] (metric tonnes)
	Purchased Electricity	Flaring	Total	Purchased Electricity	CHP	Total	
Cumulative 2025 to 2030	0.09	0.27	0.37	0	0.27	0.27	**0.09**
Cumulative 2025 to 2050	0.12	1.37	1.49	0	1.37	1.37	**0.12**

[a] N2O emissions from Upstream Fuel and Energy-related Activities from electricity not included in the reduction total due to the available emission factor only in CO2e.

Table 6: Factor Reference Sources

Emission Source	Reference
Stationary Combustion – Digester Gas	USEPA Center for Climate Leadership GHG Emission Factors Hub (February 2024), Table 1 "Other Biomass Gases"
WRF - Incomplete Combustion of Digester Gas	Local Government Operation Protocol, Chapter 10
Grid Electricity Production	USEPA Center for Climate Leadership GHG Emission Factors Hub (February 2024), Table 6 Electricity
Grid Electricity – Upstream Fuel & Other Related Activities	UK Government Department of Environment, Food and Rural Affairs 2023 Conversion Factors (June 2023)
Grid Intensity Projections	U.S. Energy Information Administration Annual Energy Outlook 2023, Table 18. Energy Related Carbon Dioxide Emissions by Sector and Source (Mountain Region)
Grid Intensity Projections	Salt Lake City (SLC.gov) Sustainability Website (March 2024)