Technical Appendix- GHG emission reductions

Underlying Assumptions & Models Impacting Multiple Measures

Discussed in detail in each emissions reduction measure section below, the City of Boise used the same marginal electricity emissions forecast and natural gas emissions factors to ensure GHG reductions were estimated consistently across measures.

- Forecasted Marginal Electricity Emissions: The City used the National Renewable Energy Laboratory (NREL) modeled long-run marginal CO_2 emission rates from the 2023 Cambium data sets. https://data.nrel.gov/submissions/230 To incorporate anticipated change to the resource mix supplied by the electric utility, Idaho Power, we used the annual direct combustion GHG emissions from the "Mid-case" scenario for the NorthernGrid_East region. We adjusted the Cambium modeled marginal emissions factor based on Idaho Power's commitment to providing 100% clean electricity by 2045. Table 1 shows the annual marginal electricity factors used across the City's GHG emissions estimates. The City applied the marginal electricity factors for both avoided and increased electricity assumption. For proposed GHG measures resulting in changes in electricity consumption in 2025 – 2029, the 2025 emission factors were used. In 2030-2034, the 2030 emission factors were used. In 2035 – 2039, the 2035 emission factors were used. In 2040-2044, the 2040 emission factors were used. In 2045 – 2050, carbon-free electricity was assumed.

Table 1

	Adjusted Mid-case					
NorthernGrid_East	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
CO_2 from Direct Combustion (kg per MWh of end-use demand)	238.4	149.6	147.6	62.5	0	0
CH_4 from Direct Combustion (g per MWh of end-use demand)	21.3	10.1	9.7	3.9	0	0
N_2O from Direct Combustion (g per MWh of end-use demand)	3.04	1.4	1.35	0.54	0	0

Source: Cambium 23 LRMER GEA, adjusted for 0 emissions in 2045 Idaho Power

To develop a GHGe estimate for marginal electricity emissions, the City used the Global Warming Potential for CO_2 (1), CH_4 (29.8), and N_2O (273), published in Appendix B. of the CPRG NOFO. Table 2 shows the kg per MWH marginal emissions for each GHG and the combined kg per MWH GHGe for each year.

Table 2

NorthernGrid_East	CO2 kg/MWh	CH4 kg/MWH	N2O kg/MWH	GHGe kg/MWH
2025	238.4	0.0213	0.00304	239.8647
2030	149.6	0.0101	0.0014	150.2832
2035	147.6	0.0097	0.00135	148.2576
2040	62.5	0.0039	0.00054	62.76364
2045	0	0	0	0
2050	0	0	0	0

- Natural Gas Emissions:
  The City used the EPA published Emission Factors for Greenhouse Gas Inventories for stationary combustion of natural gas last modified September 12, 2023. https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf Table 3 shows the emissions per mmBtu of natural gas burned.

Table 3

GHG	Emissions	Unit
CO_2	53.0600	kg/ MMTBU
CH_4	1.00	g/MMBTU
N_20	0.10	g/MMBTU

We converted the values in Table 3 to kg per Therm emission factors for straightforward application to metered natural gas consumption in buildings, identified in Table 4.

Table 4

GHG	Emissions	Unit
CO_2	5.31	kg/Therm
CH_4	0.00010	kg/Therm
N_20	0.00001	kg/Therm

Applying the same Global Warming Potential for CO_2 (1), CH_4 (29.8), and N_2O (273), published in Appendix B. of the CPRG NOFO, we calculated the combined 5.3117 kg GHGe/Therm from stationary natural gas consumption.

GHG Emission Reduction Measure Calculations

1. **Municipal Building Electrification**
   Calculating estimated emissions reduction for the Municipal Building Electrification measure requires 3 general steps. First, in identifying the reference case scenario, the City used its own actual annual natural gas consumption data for 6 buildings. In total, the 6 identified facilities use 106,416 therms of natural gas annually. Second, annual gas use was converted into projected increase in electricity consumption after electrification, identifying the incremental electricity use needed to power heat pumps and other electric appliances to be installed. For 3 of the facilities this conversion was based on modeled electricity consumption post-electrification completed by external consultants. For the remaining 3 facilities a kWh/Therm conversion ratio was used based on the applicable building square footage (20 and 22 respectively). We estimated an additional 1,963,004 kWhs of electricity needed to power the facilities post-electrification retrofit annually. Third, the selected electrification projects were phased over the 2025 – 20230 implementation period, with high emissions reduction projects prioritized as soon as possible for the highest emissions reduction potential. Using the emissions factors for electricity consumption and natural gas explained above, we calculated the net GHGe savings, reduction in GHG emissions from not using natural gas and additional emissions

from electricity, in each year and cumulative GHGe savings in both 2025 – 2030 (Table 5) and 2025 - 2050.

Table 5

	2025	2026	2027	2028	2029	2030
Incremental Avoided Gas Therms	-13946	-79391	-5897	-6001	-1181	0
Incremental Increased kWh	245000	1,400,000.00	160000	132022	25982	0
Total Decreased NG Therms	-13946	-93337	-99234	-105235	-106416	-106416
Total Increased kWh	245000	1645000	1805000	1937022	1963004	1963004
Gas avoided emissions kg CO2e	-74077.11	-495779.08	-527102.23	-558977.80	-565250.93	-565250.93
Increased electricity emissions kg CO2e	58766.85	394577.37	432955.71	464623.12	470855.29	295006.48
Net kg CO2e reduction	15,310.27	101,201.71	94,146.52	94,354.68	94,395.64	270,244.45

Total emissions reduction 2025 – 2030: 669,653.266 kg/CO_2e = 669.65 MTCO_2e

From 2031 – 2050 the same annual avoided natural gas use, 106,415 therms and increased kWh consumption, 1,963,004, were used, assuming no new growth in electricity consumption due to the municipal building electrification measure. As the forecasted electricity grid gets cleaner and cleaner through time, the emissions reduction benefits of this measure increase.

Total emissions reduction 2025 – 2050: 8,723 MTCO_2e

2. **Geothermal Heating Expansion**
Similar to the Municipal Building Electrification measure, we estimated GHG emissions reduction for Geothermal Heating Expansion by comparing emissions associated with all-electric space and water heating to the post-geothermal conversion emissions in each year for 2025 – 2050. As the electricity grid gets cleaner, the magnitude of annual GHG reduction savings in this measure decreases. For the reference case scenario, we used forecasted electricity consumption for the identified 450 unit multi-family housing building that is planned to be connected to the geothermal system with CPRG funding. We estimated 6,000,000 kWhs of electricity for space and hot water heating could be avoided by connecting to the geothermal system. This estimate was derived multiplying the total annual modeled electricity use for the development by the share of energy used for space and water heating from the 2020 Residential Energy Consumption survey data. The geothermal system provides zero-emission energy, delivering natural geothermally heated water to buildings through a networked system of pipes in Boise.

Using the emissions factors for electricity consumption explained above, we calculated the GHGe reduction from not using electricity in each year and cumulative GHGe savings in both 2025 – 2030 (Table 6) and 2025 – 2050. We estimated emissions reduction benefits beginning in 2027 based on the City's knowledge of the specific project identified and time necessary to complete the geothermal line extension to the site.

Table 6

Measure	2025	2026	2027	2028	2029	2030
Incremental Avoided kWhs	0	0	6,000,000	0	0	0
Total Annual Avoided kWhs	0	0	6,000,000	6,000,000	6,000,000	6,000,000
kg CO2e emissions avoided	0	0	1,439,187.96	1,439,187.96	1,439,187.96	1,439,187.96
MT CO2e emissions avoided	0	0	1,439.19	1,439.19	1,439.19	1,439.19

Total emissions reduction 2025 -2030: 5,219.26 $MTCO_2e$

From 2031 – 2050, the same 6,000,000 kWhs avoided electricity consumption was used multiplied by the marginal electricity emissions factor applicable in that year. For 2045 – 2050, there are no associated emissions reduction benefits from this measure as electricity is also forecasted to be zero-emissions.

Total emissions reductions 2025 – 2050: 15,156.70 $MTCO_2e$

3. **Shade Tree Planting for Energy Savings**
Emission data for this project was gathered using the i-Tree Planting Tool (https://planting.itreetools.org/). This tool estimates the long-term environmental benefits from a tree planting project in terms of carbon dioxide, air pollution, stormwater impacts, energy savings, and canopy cover. The information entered into this tool include: tree species, size of tree at planting, condition of trees, number of trees in the group, and project lifetime years. The outputs are carbon dioxide sequestered, carbon dioxide avoided due to reduction in building energy use, energy conserved, air pollutants captured and avoided tree total biomass, and canopy cover. The 17 tree species selected were based on high success rates from previous plantings done by City of Boise and Treasure Valley Canopy Network (TVCN). Emission reduction results are reported in pounds, which were then converted to MT using the conversion factor 1 metric ton/2,204.6 lbs.

Example output for 2026 planting:

Location: Boise City, Idaho 83702
Total number of trees planted in this project: 417
Electricity Emissions Factor: 119.69 pounds CO2 equivalent/MWh
Fuel Emissions Factor: 96.23 pounds CO2 equivalent/MMBtu
Lifetime: 5 years
Annual Tree Mortality: 3%

Table 7

Tree type	Initial number of trees	DBH (in)	Height (ft)	Surviving trees	Basal Area (ft2)	Canopy Cover (ft2)	Biomass (lbs)
River Birch	18	3.2	26.1	16	0.88	1844.9	0.3
Serviceberry	33	2.8	18.1	29	1.2	2762.8	0.5

Table 8

Tree type	Initial number of trees	CO2 avoided (lbs)	CO2 sequestered (lbs)
River Birch	18	487.6	1300.4
Serviceberry	33	1492.4	1946.1

4. **Solar Energy Deployment**
The GHG reduction estimate from solar energy deployment was calculated based on the newly installed solar energy resources' output displacing marginal electricity emissions. We used the published capacity factor, 0.2000398732, from EPA's AVERT tool v4.2 in the Northwest Region for distributed solar energy resources. https://www.epa.gov/avert/download-avert For each year we calculated solar output by multiplying the installed kW capacity x 8760 hours x the solar capacity factor divided by 1,000 to get MWh output. The annual MWh output was multiplied by the applicable annual marginal electricity emission factor to get avoided GHG emissions. As with the geothermal heating expansion measure, the magnitude of emissions reduced decreases as marginal electricity grid emissions approach and eventually reach 0. We calculated the GHGe reduction from avoided grid electricity emissions in each year and cumulative GHGe savings in both 2025 – 2030 (Table 9) and 2025 – 2050 (Table 10).

Table 9

Measure	2025	2026	2027	2028	2029	2030	Total
Installed kW Capacity	50	100	100	100	100	100	550
Additional MWh output	87.77	175.55	175.55	175.55	175.55	175.55	N/A
Cumulative MWh output	87.77	263.32	438.87	614.42	789.97	965.52	3159.89
kg CO2e emissions avoided	21054.04	63162.11	105270.18	147378.25	189486.32	145101.58	671,452.46

Total emissions reduction 2025 -2030: 671.45 $MTCO_2e$

From 2031 – 2050, the same cumulative 965.52 MWhs of solar output was multiplied by the marginal electricity emissions factor applicable in that year. For 2045 – 2050, there are no associated emissions reduction benefits from this measure as electricity is also forecasted to be zero-emissions.

Total emissions reductions 2025 – 2050: 2,270.59 $MTCO_2e$

To identify the installed kW capacity of solar energy systems funded through CPRG, we identified solar potential on city facilities and looked at trends in residential solar adoption in Boise. Forecasting 550 total kW of solar installed over the 2025 – 2030 implementation period is reasonable with existing solar installer capacity and interest in our local market and will likely lead to more interest in solar than can be funded through CPRG. Cost per kW of solar installed, $3,200, is equal to the median small non-residential system cost from the 2023 Tracking the Sun report produced by Lawrence Berkely National Laboratory. https://emp.lbl.gov/tracking-sun-tool

5. **EV Municipal Fleet**
To calculate the estimated GHG emissions reduction from replacing gasoline fueled vehicles with electric vehicles in our municipal fleet we used actual fuel consumption for 32 fleet vehicles to establish the reference case. Actual annual gasoline consumption in total, 13,885 gallons, and per vehicle were multiplied by the gasoline emission factor for CO_2 published by EPA in the Greenhouse Gases Equivalencies Calculator - Calculations and References. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

8,887 grams of CO_2/gallon of gasoline = 8.887 × 10-3 metric tons CO_2/gallon of gasoline

The City also calculated CO, NOx, and $PM_{2.5}$ emissions using the following emissions factors published by the Department of Transportation's Bureau of Transportation Statistics Estimated U.S. Average Vehicle Emissions Rates per Vehicle Type:

MT CO emissions per gallon of gasoline: 0.0000797836

MT NOx emissions per gallon of gasoline: 0.0000041678

MT $PM_{2.5}$ per gallon of gasoline: 0.0000000687

https://www.bts.gov/content/estimated-national-average-vehicle-emissions-rates-vehicle-vehicle-type-using-gasoline-and

Applying the Global Warming Potential for CO_2 (1), CH_4 (29.8), and N_2O (273), published in Appendix B. of the CPRG NOFO, we calculated the combined 0.0100248 MT GHGe/gallon of gasoline consumption.

Consistent with the methodologies for Municipal Building Electrification, Geothermal Heating Expansion, and Solar Deployment, we calculated the net emissions reduction from avoided gasoline use and the increase electricity consumption needed to fuel the new electric vehicles. To estimate electricity needed we used a ratio of 33.7 kWh for every 1 gallon of gas replaced, consistent with EPA and DOE's published fuel economy conversion at https://www.fueleconomy.gov/feg/topten.jsp . Net emissions reduction was calculated annually from 2025 – 2030 with avoided gasoline reduction attributable to individual vehicles replaced in years 1 – 4 of grant implementation.

Table 10

	2025	2026	2027	2028	2029	2030
Vehicles Replaced	10	10.00	10.00	2.00	-	-
Incremental Fuel Avoided (gallons of gasoline)	6200.798	4012.009	3156.829	515.832	0	0
Incremental Fuel Emissions Avoided MTCO2e	62.16	40.22	31.65	5.17	-	-
Incremental Electricity Consumption	208,966.89	135,204.70	106,385.14	17,383.54	-	-
Cumulative Electricity Consumption kWh	208,966.89	344,171.60	450,556.73	467,940.27	467,940.27	467,940.27
Cumulative Electricity Emissions Increase MTCO2e	50.12	82.55	108.07	112.24	112.24	70.32
Cumulative Fuel Emissions Avoided	62.16	102.38	134.03	139.20	139.20	139.20
Net Emissions Reductions MTCO2e	12.04	19.83	25.96	26.96	26.96	68.88

Total emissions reduction 2025 -2030: 180.61 $MTCO_2e$

From 2031 – 2050 the same annual avoided gasoline use, 13,885 gallons and increased kWh consumption, 467,940.27, were used, assuming no new growth in electricity consumption due to the municipal building electrification measure. As the forecasted electricity grid gets cleaner and cleaner through time, the emissions reduction benefits of this measure increase.

Total emissions reduction 2025 – 2050: 2,189.67 $MTCO_2e$