

Appendix B: Technical Appendix

Project Background

The City of Fargo has over 15,000 street lights that operate on a nightly basis. As of March 2024, approximately 70% of these street lights have been converted from HPS lighting to LED lighting. This has taken time to implement due to budget constraints. The remaining 3,889 street lights are over twelve years old and still utilize HPS bulbs, which generally consume about 50% more electricity compared to LED lighting. With additional funding, the City of Fargo would be able to purchase more LEDs and enhance the replacement schedule to be able to replace the remaining 3,889 HPS bulbs in just two years with more efficient LED lighting. The two-year implementation will be performed by an electrical contractor hired by the City, and progress will be monitored by the City's Engineering Services Division. A successful project funded under the CPRG would guarantee decreased energy consumption faster and more robustly than the speed at which the City can act with current funding and would result in greater, permanent GHG emissions reductions over time.

Summary

In summary, replacing the 3,889 HPS bulbs with LED bulbs will decrease the bulbs' annual energy use by 64% - a savings of 1,383.3 MWh/yr for all 3,889 HPS bulbs replaced. Under a successful project funded through the CPRG, this energy efficiency will be monitored closely by the City's Facilities Management Department using Energy Star. The data reported from the Energy Star program will play a crucial role in monitoring changes in energy consumption. With these energy savings; the cumulative GHG emissions reductions are as follows:

- 2025 through 2030: 1,322 MT CO₂e
- 2025 through 2050: 1,359 MT CO₂e

Cost effectiveness of the project is determined by dividing the CPRG funding request (\$2,640,331) by the cumulative reductions in GHG emissions:

- 2025 through 2030: \$1,998 per MT CO₂e
- 2025 through 2050: \$1,943 per MT CO₂e

As a result of the expedited project schedule enabled by CPRG funding, additional cost effectiveness is achieved through reducing annual energy consumption, saving the City \$125,000 annually on energy costs..

Analysis Methodology

This analysis closely follows the methods used in the preparation of the ND PCAP, however as the project understanding increased and more information became available, some aspects of the analysis have been modified to present a more accurate estimation of GHG reductions.

To quantify the GHG reductions from the LED lighting upgrades, annual electricity savings were first determined by calculating the amount of electricity used by the HPS bulbs compared to new, more efficient LED based on information about the products from the City of Fargo. The 3,889 HPS bulbs needing

replacement range in wattage from 100 to 400 watts.¹ According to the City’s past upgrade operations, the replacement LED bulbs for each street light fixture would range from 35 to 160 watts, shown in Table 1 below. The City provided estimates of the quantity of each bulb type needing replacement.

Table 1. Current and Replacement Fixture Wattages

Current HPS Fixture Wattage	Replacement LED Fixture Wattage	Estimated Quantity to be Replaced
400-watt	216-watt	25
250-watt	160-watt or 120-watt	375
150-watt	90-watt	1287
100-watt	70-watt	2202

To determine how much electricity each bulb uses annually, the City provided an estimate that each street light operates 11.4 hours per day each day of a year. Based on these assumptions, the average annual electricity usage and savings for each bulb type is shown in Table 2.

Table 2. Estimated Electricity Consumption Savings

Bulb Type		Estimated Electricity Savings per Bulb Replacement (MWh/bulb/yr)	Bulbs Replaced	Estimated Electricity Savings (MWh/yr)		
HPS	400-watt	LED	160-watt	-0.999	25	-25.0
	250-watt		105-watt	-0.604	375	-226.4
	150-watt		50-watt	-0.416	1,287	-535.9
	100-watt		35-watt	-0.271	2,202	-596.0
Total (3,889 bulbs)					-1383.3	
Average electricity savings per bulb					-0.356	

With the annual electricity savings per LED bulb replacement calculated, savings per year can then be calculated based on how many bulbs are replaced each year. At this point in the project schedule, there are no anticipated priorities in which bulb types are to be replaced first; a weighted average annual electricity savings per bulb (0.356 MWh/yr) was calculated based on the quantities of each bulb type in the City. With additional funding, the City of Fargo plans to complete the transition of the remaining 3,889 HPS bulbs to LEDs over 2 years, replacing around 1,950 bulbs each year over the project term:

Year 1 (2025): 0.356 MWh per bulb savings x 1,950 LEDs = 694.2 MWh saved

Year 2 (2026): 0.356 MWh per bulb savings x 3,886 LEDs = 1383.3 MWh saved

For a baseline to compare to, it was assumed that without additional funding, the City of Fargo may be able to set aside enough budget to replace 500 HPS bulbs with LEDs in a given year for 178 MWh saved per year. This baseline “business as usual” projection does not include the effect of non-CPRG federal incentives through programs or legislation such as IRA, BIL, and/or CHIPS. The City has not historically used these

¹ City of Fargo. “City Efforts at Climate Resiliency, Renewable Energy, Emissions Reductions, Energy Efficiency and Environmental Stewardship.” Accessed March 2024. Retrieved from: https://download.fargond.gov/0/src_white_paper.pdf

federal incentives to fund its LED upgrades. The baseline projection supports a replacement frequency covered exclusively by City funds.

It was assumed that each LED street light supported directly by CPRG funding would last approximately 14 years before requiring replacement.² This expected lifespan extends past the 8-year baseline implementation schedule; the cumulative GHG reduction estimate was not impacted by the 14-year bulb lifespan.

Total electricity usage savings per year due to additional funding was determined by subtracting the estimated cumulative baseline electricity usage savings (500 bulbs upgraded per year) from the estimated cumulative electricity savings with enhanced bulb replacement enabled by dedicated funding (around 1,950 bulbs per year).

To determine annual GHG reductions from the annual electricity savings, first change over time of the GHG emissions rate for associated electricity generation was estimated. There is uncertainty in projections specific to the City of Fargo's electricity supply at this time. For simplicity and based on transparent, available data, projections of North Dakota's statewide average electricity grid mix were estimated. These estimates were then used to inform an average grid GHG emission rate applied to the electricity savings from lighting replacement over time.

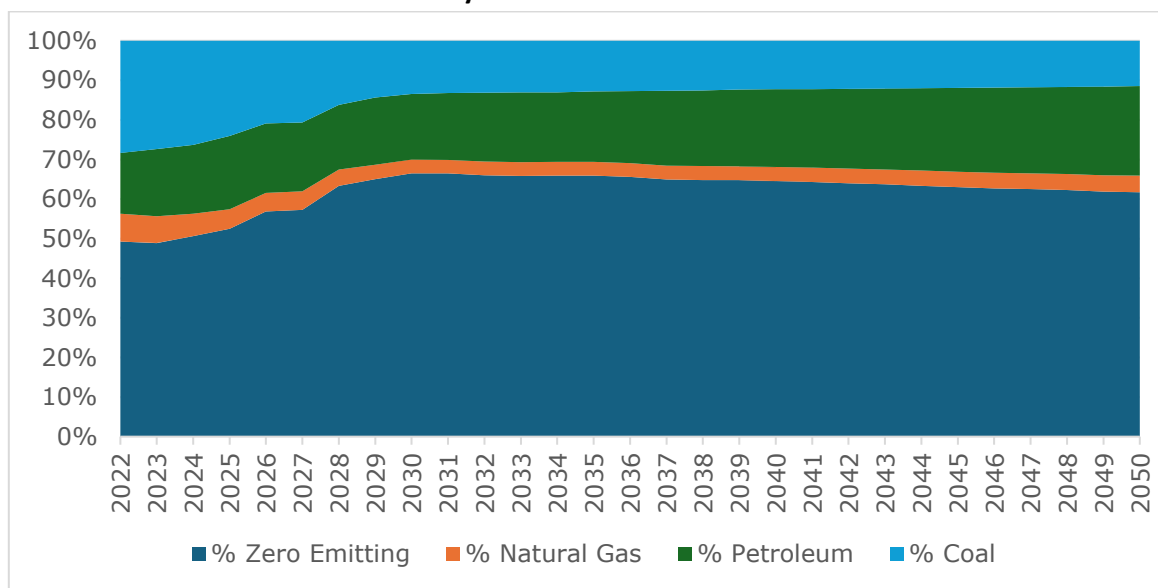
EIA's Annual Energy Outlook (AEO) 2023 Reference Case was used to inform the projected state grid mix.³ EIA provides electric power projections by Electricity Market Module Regions in Tables 54.01 to 54.25. These regions broadly do not align with state boundaries.⁴ The electricity generation by resource type projections for the regions in which North Dakota is located were used to inform an estimate of the state's projected grid mix. A weighting of 95% was given to the projected grid mix of the Southwest Power Pool/North (SPPN) Region as this covers the vast majority of the state. The remainder weights the projected grid mix of the Midcontinent ISO/West (MISW). The resulting estimated grid mix for the state of North Dakota informed by EIA AEO2023 is shown below in Figure 1, depicting a significant increase in zero-emitting resources over the next decade with a decline in fossil fuel-fired generation. This is in-line with broad findings from EIA, driven by increasing clean energy investments due to incentives from the Inflation Reduction Act of 2022 as well as accounting for planned changes, such as energy utility commitment to coal retirements and wind expansion across the central U.S.

² Shenzhen EXC-LED Technology Co. 17 May 2022. "How Long do LED Street Lights Last?" Accessed March 2024. Retrieved from: <https://www.exc-streetlight.com/news/lighting-blogs/lifespan-about-led-street-lights.html>

³ US Energy Information Administration (EIA). 16 March 2023. "Annual Energy Outlook 2023." Accessed March 2024. Retrieved from: https://www.eia.gov/outlooks/aeo/tables_ref.php

⁴ US EIA. "Electricity Market Module Regions." Accessed March 2024. Retrieved from: https://www.eia.gov/outlooks/aeo/pdf/nerc_map.pdf

Figure 1. North Dakota Estimated Electricity Grid Mix



An average electricity grid emission rate was calculated for each year based on the above electricity generation mix and average emission factors for end use of natural gas, coal, petroleum, and zero-emitting electricity. Zero-emitting electricity generation sources do not have any GHG emissions associated with end use. Average U.S. natural gas combined cycle facility and coal-fired electricity generation emission factors for CO₂, CH₄, and N₂O were estimated from GREET, a life cycle analysis model created by the Department of Energy's Argonne National Laboratory.⁵ Average petroleum electricity generation emission factors were estimated via the EPA's "Emission Factors for Greenhouse Gas Inventories."⁶ For the GHG emission rate for each fuel in grams of CO₂e per kilowatt hour (kWh), global warming potentials for the 100-year time horizon from IPCC 5th Assessment Report were used.⁷ The emission factors used by resource type are shown below in Table 3.

Table 3. Emission Rates for Electricity Generation

Electricity Generating Resource Type	Emission Rates (grams of pollutant per kWh)			
	CO ₂	CH ₄	N ₂ O	CO ₂ e
Zero-Emitting	0	0	0	0
Natural Gas	450	0.89	0.01	478
Coal	1,050	1.70	0.02	1,103
Petroleum	636	0.03	0.01	640

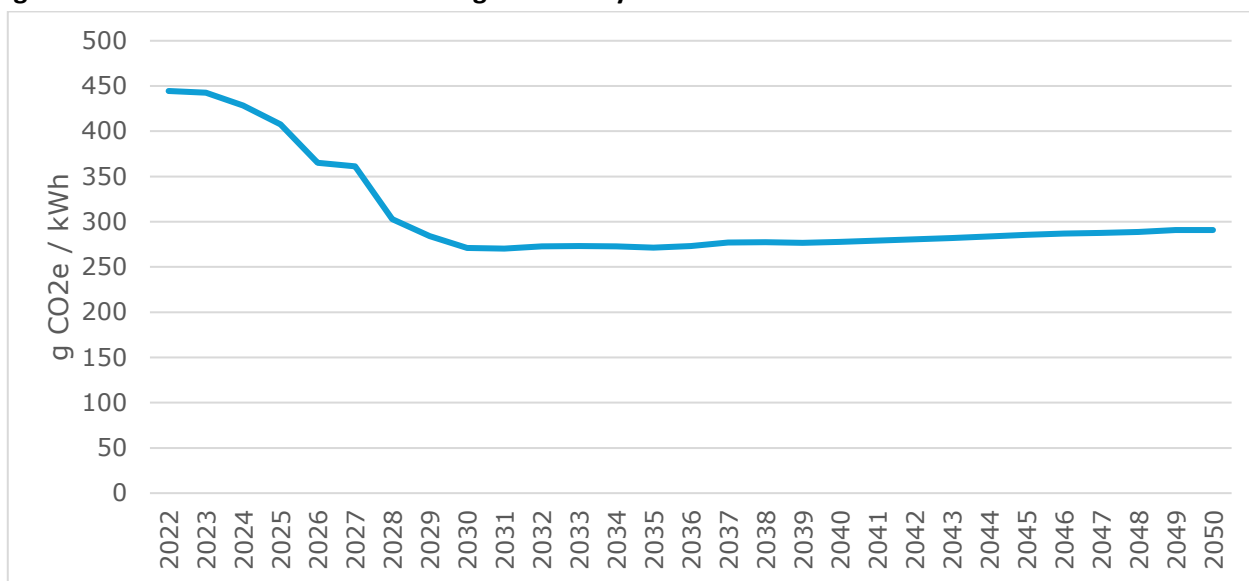
These resulting GHG emission rates in grams of CO₂e per kWh were applied to the associated resource type's estimated share of electricity generation for a given year to estimate the state average electricity grid GHG emission rate, as shown in Figure 2.

⁵ US Department of Energy, Office of Energy Efficiency & Renewable Energy. "GREET." Accessed March 2024. Retrieved from: <https://www.energy.gov/eere/greet>

⁶ US Environmental Protection Agency. "Emission Factors for Greenhouse Gas Inventories." Accessed March 2024. Retrieved from: https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

⁷ Intergovernmental Panel on Climate Change. 2016. "Global Warming Potential Values." Accessed March 2024. Retrieved from: https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Figure 2. North Dakota Estimated Average Electricity Grid GHG Emission Rate



The above emission rate was then multiplied by the electricity savings (after removing baseline savings) for a given year to calculate the GHG emissions reductions due to more efficient LED street lighting. Standard conversion factors were used to align units from grams to metric tons and kWh to MWh. The GHG emissions reductions were calculated annually for each year from 2025 through 2050, as shown in Table 4. Once all 3,889 street lights are replaced after the second year of implementation, annual GHG reductions decline due to decarbonization of the average state electricity grid mix over time. After 2031, the baseline replacement rate of 500 bulbs/year will have accounted for all bulb upgrades, so annual net reductions are zero. As shown in Table 4 below, the total cumulative amount of GHG emissions reductions for the project is 1359 MT CO₂e.

Table 4. Annual and Cumulative GHG Emissions Reductions (MT CO₂e)

Year	Annual Reductions (MT CO ₂ e)	Cumulative Reductions (MT CO ₂ e)
2025	210	210
2026	375	585
2027	307	892
2028	203	1096
2029	140	1236
2030	86	1322
2031	37	1359
2032	-	1359
2033	-	1359
2034	-	1359
2035	-	1359
2036	-	1359
2037	-	1359
2038	-	1359
2039	-	1359

2040	-	1359
2041	-	1359
2042	-	1359
2043	-	1359
2044	-	1359
2045	-	1359
2046	-	1359
2047	-	1359
2048	-	1359
2049	-	1359
2050	-	1359

Cost-Effectiveness of GHG Emissions Reductions

Table 5 below includes information regarding the cost-effectiveness of the program's GHG reductions. These dollar per MT CO₂e values were calculated based on the CPRG funds requested divided by the cumulative GHG emissions reduced from 2025-2030 (1,322 MT CO₂e) and 2025-2050 (1,359 MT CO₂e).

Table 5. Cost Effectiveness

Funds Requested	\$/MT CO₂e for GHG Reductions 2025-2030	\$/MT CO₂e for GHG Reductions 2025-2050
Program Total (\$2,640,331)	\$1,998	\$1,943

In addition, under the baseline "business as usual" scenario, the City expects that operating its 3,889 HPS bulbs costs roughly \$125,000 more per year compared to the scenario where all the HPS bulbs are replaced with more efficient LED bulbs. This cost savings calculation was informed by the estimated energy price (per the City) of \$0.09/kWh. As described earlier in this technical report, the annual energy savings of replacing all HPS bulbs with LED bulbs is 1,383.3 MWh/yr. Multiplying this total annual energy savings by the estimated cost of energy gives the annual energy cost savings between all-HPS and all-LED scenarios. The City's operational energy budget is not anticipated to change as a result of these LED upgrades, so due to the increased energy efficiency, the City expects \$125,000 in annual savings that will be directed to the Community Resilience Fund.