

Appendix C. Required Technical Appendix and Optional GHG Emission Reduction Calculations Spreadsheet - Included

F. Technical Appendix

CITY OF MILWAUKEE CPRG TECHNICAL APPENDIX

GHG Calculations and Accounting

Accounting for a community's greenhouse gas emissions depends in part on which emissions are counted. The City of Milwaukee follows international reporting protocol and works with experts to refine how emissions are estimated. Greenhouse gas emissions are categorized by scope for reporting purposes, which allows for the collection of activity data without double counting when reporting. We will customize one of the modeling software platforms to collect, analyze and report GHG emission reductions from Our 3 Measures 1 - Public EV Charger Installations, 2 - Building Standards Adoption and Building Energy Efficiency and 3 - Utility Scale Solar Arrays. Thanks to the Expert Match Program at NREL, we have been able to model the EV Charging Measure and Solar Array Measure. We are working with NREL on Building Energy Efficiency to employ the ComStock Model. That model is undergoing a scheduled update and we will be working with them to finalize the calculations and ComStock Milwaukee model.

The GHG Analysis models adopted by the City of Milwaukee CPRG each include Scope 1, 2 and 3 emissions information from baseline onward. We worked with 2 of the Federally Funded Research and Development Centers: National Renewable Energy Labs (NREL) and Argonne Labs. Three distinct models were chosen after considering several other options: AFLEET, ComStock and Re-OPT. National Renewable Energy Labs (NREL) has assisted the ECO team and partners to analyze existing energy models for the implementation measures that the City and SEWRPC have identified in their Priority Climate Action Plan. Through Exact match and also direct work with the NREL CPRG team, we identified 3 models that were most promising and presented the best results possible. The models all have weaknesses, as any metric-based model attempting to replicate the real-world will confront. The models chosen: AFLEET, ComStock and Re-Opt each integrate multiple data sources and are being tweaked by the FFRDC and Agencies regularly.

CPRG MEASURE 1: Electronic Vehicle (EV) Charging Networks

Greenhouse gasses (GHGs) are emitted from the tailpipes of cars and trucks that combust fuel. Once GHGs are released, they can stay in the atmosphere for 100 years or more. GHGs act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm. Emissions produced during a vehicle's production, operation, and disposal are often collectively called "lifecycle emissions." These include emissions produced during the vehicle manufacturing process and the transport of the vehicle to its first point of sale.

Electric-powered vehicles (battery-only electric vehicles—EVs) produce lower to zero tailpipe emissions than conventional fossil-fuel vehicles. However, tailpipe emissions are only one factor in considering a vehicle's lifecycle emissions; electricity and gasoline fuel pathways have upstream emissions to consider, including extracting, refining, producing, and transporting the fuel. Therefore, estimating cradle-to-grave emissions must account for both fuel-cycle emissions and vehicle-cycle emissions. The combined emissions from vehicle and fuel production through vehicle decommissioning (i.e., recycling or scrapping) are called life cycle or cradle-to-grave emissions (US DOE, n.d.). According to the EPA (2019), when considering all factors and associated GHG emissions, EVs reduce GHG emissions by

approximately 70 percent compared to internal combustion engines (ICE) greenhouse gas emissions. The cost of EV charging per vehicle mile traveled is significantly lower, with some EV estimates at \$2.00 per “gallon” of charge if computed in comparison to gasoline costs. The total GHG emissions from 100% Electric Vehicles approaches zero GHG emissions if the power is generated by renewable sources.

Calculating Emissions Associated with the EV Charging Scenario

According to a 2016 report by the National Renewable Energy Laboratory, the level of emissions associated with various charging scenarios is based on the carbon intensity of the electricity grid at the specific time of day the vehicles are charged, the emissions associated with burning gasoline, the ratio of electric-to-gasoline miles driven, and the efficiencies of the vehicles. To calculate emissions for electric miles driven, each electricity generation fuel source was assigned an emission factor (lbs CO₂/kWh), and the methodology developed by Brinkman (2015) was employed.

Project Specific Measure:

The City of Milwaukee CPRG project will procure, purchase, install, commission and maintain thirty (30), new Level 3 EV Charging Stations in locations in Milwaukee and Wauwatosa, WI. The EV Charging Stations will be procured based on City and Federal Requirements and 40% of the installed Public EV Charging Stations will be installed in Disadvantaged Communities as indicated on the EPA CJEST Maps and underlying data.



Level 3 Charging Station (Indicative Image Only)

Inclusion of charging infrastructure for public use holds multiple benefits. The first is lowering market barriers to EVs. Access to the lower operating cost EVs is ineffective without charging stations that are nearby. Figure 1 shows how few publicly available charging units are available on a typical day. This initiative involves the deployment of charging infrastructure at key locations throughout our selected region, including urban centers, residential areas particularly nearby multi housing units, and major transportation corridors. By expanding the availability of charging points, the proposal aims to alleviate range anxiety, a common concern for potential EV adopters, and encourage the widespread adoption of electric vehicles. Coupled with an incentive program augmenting existing state and federal tax incentives the displacement of ICE vehicles on the road will lead to overall GHG reductions.

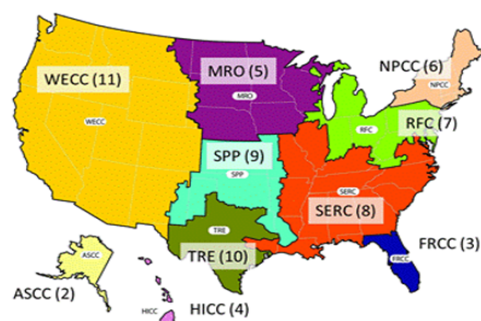
GHG Model for Calculations - DOE AFLEET Model.

The Department of Energy's Technology Integration Program has enlisted the expertise of Argonne to develop a tool to examine both the environmental and economic costs and benefits of alternative fuel and advanced vehicles (AFVs). Argonne developed the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool to help stakeholders estimate petroleum use, greenhouse gas (GHG) emissions, air pollutant emissions, and cost of ownership of light-duty and heavy-duty vehicles.

The AFLEET Charging and Fueling Infrastructure (CFI) Emissions Tool estimates well-to-wheel greenhouse gas emissions and vehicle operation air pollutant emissions for proposals to the Federal Highway Administration's (FHWA) Charging and Fueling Infrastructure Discretionary Grant Program (CFI Program). The CFI Program covers electric vehicle charging, as well as hydrogen, propane, and natural gas fueling infrastructure. This tool was developed with the support of the Joint Office of Energy and Transportation. The AFLEET Tool uses emissions data from both the EPA's MOVES and Argonne's GREET models.

Measures Implementation Assumptions

The Defined Regional Map



Level 2 EV Charging Stations (30) Installed and Distributed Evenly Low, Medium and High Station Utilization

Low	Med.	High	Low Util.	Moderate Util	High Util.
10 EV2	10 EV2	10 EV2	3,000kWh	6,000 kWh	10,000 kWh

Annual Fuel Consumption Based on Fuel Unit

Low: 3,000 kWh

Mod.: 6,000 kWh

High: 10,000 kWh

Light-Duty Vehicles represent 100% of Users

For gas vehicles:

- Tailpipe-CO₂ Emissions from a gallon of gasoline = 8,887 grams CO₂/ gallon
- Upstream-Tailpipe CO₂ emissions are multiplied by a national average factor of 1.25 to account for emissions associated with gasoline production, e.g., drilling, refining, and transportation, etc.
- For a “typical” electric vehicle: the Model Year 2023 median energy consumption is 36 kWh/100 miles (combined city/hwy) using the national average electricity CO₂ emission factor from [eGRID 2020](#).

User-Defined Electric Generation Mix Assumptions:

Residual Oil	.03%
Natural Gas	36.5%
Coal	23.8%
Nuclear Power	19.6%
Biomass	.03%
Others (Wind, Solar)	19.5%

Fuel Production Assumptions:

CNG Feedstock Source	North American Fossil Natural Gas	1
LNG Feedstock Source	North American Natural Gas	1
Source of Electricity for EVSEs and Hydrogen (Electrolysis)	Hydrogen	7
Hydrogen Production Process	Natural Gas SMR	1

Measure-Specific Activity Estimate Data

AFLEET Annual CFI Tool Calculations of GHG Reductions	150.4 Short Tons (US)
Fuel Dispensed to EV2 Chargers and Vehicles	190,000 kWh

The calculations produced here are the results of the AFLEET Model. Additional calculations and process information is available inside of the AFLEET Technical Notes and User Guide.

GHG Emissions Reduced Annually 150.4 Tons Years 2025-2030: 752 Tons

Years 2030-2050 3,760 Tons

CPRG MEASURE 2: Building Energy Efficiency and Building Energy Standards

Commercial Building Energy Efficiency (BEE) works to enable high-performing, energy-efficient and demand-flexible commercial buildings, in support of an equitable transition to a decarbonized energy system by 2050. Buildings and manufacturing plants account for about two-thirds of carbon dioxide emissions in the United States. The adoption of aggressive building energy codes and standards by cities and states in America has a deep impact on GHG reduction through building assessments and energy efficiency measures.

Project Specific Measures

The City of Milwaukee and municipal partners will establish a GHG Reduction **Sustainability Resource Center** in Milwaukee. The Sustainability Resource Centers will be supervised by a full-time Community Sustainability Manager (CSM) who is part of the CPRG project team and reports to the Project Manager. The Sustainability Resource Centers are responsible for community outreach, engagement and marketing of measures that reduce GHG emissions; that save energy and money; that can be financed with grants, incentives, tax credits and loans. The CSM works with owners and operators of municipal sector and private sector commercial buildings to assess current energy use, evaluate existing building systems and create an Energy Plan for every structure. This plan outlines specific measures that will reduce GHG emissions, improve building performance and energy optimization. The CSM has a financial tool-kit that owners can use to access financing and capital for building energy efficiency upgrades.

We are working with NREL utilizing the ComStock Model to understand the impacts on GHG of the implementation measures proposed. The Department of Energy NREL's ComStock Analysis Tool is a reliable tool for Commercial Building Energy Efficiency Modeling. The platform has rich commercial building characteristics from the DOE Prototype Model and Commercial Reference Building data sets. Unlike many other building stock models, ComStock combines these with a variety of additional public- and private-sector datasets. Collectively, this information provides high-fidelity building stock representation with a realistic diversity of building characteristics. ComStock's most notable capability is being able to tailor the results to the question at hand. Model results are available at multiple levels:

- Spatial: U.S., census division, climate zone, state, county, and Public Use Microdata Areas geographic resolutions
- Temporal: Annual aggregations to 15-minute simulation intervals
- Sectoral: 14 (and counting) building types

ComStock data includes End-use Load Profiles (EULP) which are critically important to understanding the time-sensitive value of energy efficiency, demand response, and other distributed energy resources.

Electricity from numerous electric generators is dispatched onto a “grid” that immediately responds to changes in demand for power from residential, commercial, and industrial customers throughout a broad geographic area. Reducing consumption through EE/RE programs makes some fossil fuel generation unnecessary. Electric generating units (EGUs) that are not required to generate electricity are not “dispatched” as often, so some of their emissions are avoided. A full dataset of individual building/dwelling unit load profiles is available at data.openei.org. See the README.md file for details. The raw dataset is a group of several hundred thousand files, each containing the outputs of an individual building energy model, totaling 17 terabytes

Measures Implementation Assumptions

ComStock Building models calibrated through 70+ model updates, supported by data from:

- Electric load data from 11 utilities and 2.3 million meters
- 15 end-use metering datasets

ComStock methodology was a hybrid of meter information and utilizes a wide range of empirical data to inform updates to detailed physics-simulation building stock models—produced EULPs covering all major commercial and residential building types and end uses, for all locations of the contiguous United States. More importantly, the calibrated building models enable what-if scenario analysis. ComStock is the first EULP dataset containing calibrated and validated 15-minute resolution load profiles for all major residential and commercial building types and end uses, for all locations of the contiguous United States. **ComStock calculates the greenhouse gas emissions from the building stock and savings from measures using both historical and projected emissions data.**

Electrification Measure Documentation:

All measures have been developed through the End Use Savings Shape project, specifically the 2023 Release 1 and 2 efforts. ComStock is: ComStock Energy Assumptions are Higher on stock electric heating energy and lower on stock gas heating energy.

Building Energy Efficiency Measures

Roof Top Unit (RTU) Heat Pump (HP)	Replace RTUs with HP-RTU.	45%
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Roof Ventilator + HP Split System	Replace RTUs with HP Split	11%
Air to Water HP Boiler Retrofit	Replace gas boilers with heat pumps	18%
LED Lighting Upgrade	All lighting to LED.	65%
Exterior Wall Insulation	Add exterior wall insulation panels.	98%
Secondary Windows	Add secondary windows.	>99%
Window Replacement	Replace windows.	>99%
Window Film	Add window film to windows.	>99%
Roof Insulation	Add roof insulation.	>99%

<u>Electricity Grid Scenario</u>	<u>Start</u>	<u>Data Sources:</u>
LRMER HighRECost	2022	15 years NREL Cambium
LRMER LowRECost	2022	15 years NREL Cambium
eGRID	2021	N/A EPA eGRID

Measure-Specific Activity Estimates by Commercial Building Implementation Measure in Metric Tons from ComStock Model - NREL The model was run on March 27, 2024

Window Film	4.28059372
Baseline	4.22898839
Secondary Windows	4.199063684
LED Lighting	4.158999579
New Windows	4.155878594
DCV	4.153183484
Roof Insulation	4.142300248
Wall Insulation	4.141958829
DOAS HP Mini Splits	4.037874414
HP RTU G Backup	4.036580711
HP RTU E Backup	4.019268333
Package 1: Envelope	3.986730555
HP Boiler G Backup	3.813896701
HP Boiler E Backup	3.81178583

Energy Recovery	3.80198483
VRF with DOAS	3.763348762
Package 2: LED + Heat Pumps	3.510280079
Package 3: Envelope + LED + Heat Pumps	3.347516197
<u>Totals</u>	71.59 Metric Tons

GHG Emissions Reduced Annually **71.59 Metric Tons**

<u>Years 2025-2030</u>	357.95 Metric Tons	<u>Years 2030-2050</u>	1,431.8 Metric Tons
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CPRG MEASURE 3: Large Solar Arrays

Solar cells, also called photovoltaic (PV) cells, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage). A PV system is made up of modules (groups of PV cells) – called PV panels, an inverter for a utility grid-connected system, wiring and mounting hardware. A properly designed, installed and maintained PV system operates for more than 20 years. The basic PV module (interconnected, enclosed panel of PV cells) has no moving parts and can last more than 30 years. A typical PV system rated at 2 kilowatts produces around 2,450 kilowatt-hours a year in Wisconsin (We Energies, 2/2023). We Energies currently manages over 100 solar installations in the State of Wisconsin.

Installation of large solar arrays greater than 20 Megawatts provide a renewable source for electricity generation and combined with battery storage can meet daytime and nighttime energy needs. Solar power reduces GHG compared to coal-fired or natural gas-generated electricity. Through a partnership with jurisdictions in 3 counties, we expect to install up to 150 MW of solar power generation that will have a significant impact on our region’s GHG emissions and lessen reliance on fossil fuels. ECO will utilize AVERT only to assess EE/RE impacts. AVERT uses data based on historical dispatch patterns and cannot credibly estimate emissions reductions resulting from changes to the overall pattern of dispatch. AVERT is driven entirely by historical, publicly available data reported to EPA. It uses statistically driven “behavior simulation” to estimate near-term future emissions displacement based on the recorded historical behavior of EGUs in the recent past.

The City of Milwaukee ECO has partnered with WE Energies on the installation of large solar arrays with 5-11 MW capacity over the past several years. Annual Electricity Production Breakdown: **PV Total Electricity Produced (kWh) 122,638,610.**

Project Specific Measures

Large Solar Installations in the following communities will be implemented under EPA CPRG funding. The WE Energies Solar program is the vehicle for implementation. The arrays will be located in participating communities like Milwaukee and Wauwatosa with a focus on site locations for at least 40% of all deployment in disadvantaged communities and featuring specific community benefits beyond solar fields. The CPRG Measure will install 78 total MW of solar arrays in Waukesha and Milwaukee, including at least 40% of those installations in EPA CJEST Disadvantaged Census Tracts and Communities.

Solar Array System Properties:
Minimum new PV size (kW-DC)
Array type

78084.119
Ground Mount, 1-Axis

Tracking Array Azimuth	180 degrees
Array Tilt	20 Degrees
DC to AC size ratio	1.28
System Loss	14%

GHG Model for Calculations

Re-Opt is the model utilized for understanding avoided GHG emissions for the quantity of solar generation of gigawatt hours. NREL assisted our team with orient

The emissions modeling in Renewable Energy Integration and Optimization - Re-Opt replaces a former NREL model called Cambium that integrates modeling of the evolution of the energy grid through 2025. The Cambium data was imported to Re-Opt and the data utilized in Re-Opt is hourly. Long-range marginal emissions rates are tied to specific, geographical generators with higher average emissions rates than the stack on average. Re-Opt is also capable of providing health-related impacts.

EV Charging Station Implementation impact was analyzed with AFLEET developed by Argonne Labs with the Department of Energy Technology Integration Program. The model was built for an EV Charging Program at DOE and is designed specifically for the purposes of the Level 2 Charging Station installations.

Additional Assumptions on Vehicle Charging Profile - Low: 50 EVs per year - High of 167 EVs per year. Planned Installation of 30 EV Charging Stations distributed equally 10-10-10 between low, medium and high-utilization. Please note that a metric ton is 1.102 US Tons.

Measures Implementation Assumptions

The model assumption utilized a 25-year life-cycle for the equipment, customized .01 kWh cost of Electricity, a \$1kWh per month demand charge, a 1.7% annual cost of electricity escalator, and 6.38% Host Discount Rate. The load information is calculated as 24/7 and up to 1,000,000 annual kWh. Inputs to generate levelized climate emissions factors from Cambium data, GSA Regions - Upper Midwest, Metric of LRMR CO₂e, a Mid-Case Grid Scenario and Averaged Emissions over 2024-2028. The US EPA AVERT default Midwest Region was used with Projected annual percent decrease in grid health emissions factors of 2.163%. Re-Opt Photovoltaic system capital costs of \$1,790 yielded an optimization of the installation of 78084 kW-DC.

This measurement analysis run is for a PV system that produces an average of 122,638,611 kWh of electricity annually in Milwaukee. The (current) avoided emissions calculations assume REopt default values for climate and health emissions rates of grid-purchased electricity, as described below:

The default grid climate emissions factors in REopt are hourly, long-run marginal emissions rates (LRMERs) from NREL's Cambium 2022 database for CO₂e averaged over the analysis period at a resolution of "generation and emission assessment (GEA) regions." CO₂e values are calculated using 100-year (AR6) global warming potential values (GWP) from the IPCC's Sixth Assessment Report (2023), with GWP values for CO₂, CH₄, and N₂O of 1, 29.8, and 273, respectively. The default emissions rates include pre combustion and combustion emissions and T&D losses.

Default grid health-related emissions factors (SO₂, NO_x, and PM_{2.5}) in REopt are obtained from the EPA's AVOIDed Emissions and geneRation Tool (AVERT). The default health-related emissions data are

hourly marginal emissions factors for the EPA AVERT region corresponding to the site's location and accounting for T&D losses.

Measure-Specific Activity Estimates

Modeled Combined Totals GHG Reductions: PM2.5, SO2, NOx, CO2e

<u>Annual Emissions</u>	<u>Emissions 2025-2050</u>	<u>BAU Annual/25 years</u>	
(24,745)	(618,377)	834	8,096

These results show emissions outcomes for the business as usual and optimized cases. If marginal grid emissions rates are utilized (the default inputs), users should focus on avoided emissions, rather than emissions totals. Note for all emissions outputs, "t" (as in, "t CO2e") represents metric tons (tonnes)

GHG Emissions Reduced Annually 24,720 Metric Tonnes

Years 2025-2030 **123,600 Metric Tonnes**

Years 2030-2050 **494,400 Metric Tonnes**

<u>CPRG Measure</u>	<u>Amount</u>	<u>Disadvantaged Impact/Notes</u>
EV Public Charging Stations Total	\$2,000,000.00	40% of All Installations in EPA CJEST Disadvantaged Tracts
Cluster 1 - Wauwatosa	\$500,000.00	
Cluster 3 - Milwaukee	\$1,500,000.00	
Building Energy Efficiency Retrofits	\$2,250,000.00	40% of All Installations in EPA CJEST Disadvantaged Tracts
Cluster 1 - Wauwatosa	\$1,125,000.00	
Cluster 3 - Milwaukee	\$1,125,000.00	
Solar Arrays	\$2,604,840.00	40% of All Installations in EPA CJEST Disadvantaged Tracts and Union Labor PLA
WE Solar Partnership	\$2,604,840.00	Utility Provided Contracted Installations of panels totalling 78MW

The subawards will be based on EPA Budget Cost line items with the sub-awardees providing administrative support. CPRG Project Manager Erick Shamberger will supervise the staff team.

