**CPRG Carbon Emissions Calculation**

**Technical Appendix**

**Microgrid:**

For the microgrid GHG reduction calculations, we modeled an 800 kW Bloom fuel cell operating with 92% runtime = 6.45 million kWh generated annually. Although the carbon intensity of a fuel cell is comparable to grid emissions in terms of CO2e, SOx, NOx and other localized pollutants, the major benefit comes during peak shaving events where the baseline fuel cell generator participates in demand related events to help reduce grid reliance on more carbon intensive “peaker plants” such as oil and coal fired power plants (R2) (R3).

Natural gas emission factor = 0.000373 MT CO2e per kWh

Oil emissions factor = 0.000969 MT CO2e per kWh

Coal emissions factor = 0.001086 MT CO2e per kWh

We determined the frequency of these events and compared the carbon intensity of the fuel cell running during these hours to the average coal and oil plant. This is a good estimate at the GHG reduction of a fuel cell.

When paired in microgrid mode, however, there is even more uncaptured emissions reduction by reducing the need for standby generators which typically run on diesel fuel.

In addition to GHG reductions, this project has a major alternative benefit of localized resiliency for the community. The microgrid would be planned to incorporate an area of refuge, education and recreational facilities, grocery stores, gas stations and other potentially necessary amenities.

Although resilience is hard to put a value on, much like safety, it is a vital component of sustainability to any community.

**Rooftop Solar:**

By completing a rooftop solar project, the emissions reductions will be directly related to the solar array production and the grid emissions intensity of the avoided grid purchased power.

The production for each array was calculated using the PV Watts software, industry standard for calculating kWh production based on localized weather and solar radiation data.

50 Jenning and 40 Jennings will produce an estimated 80,800 and 40,390 kWh annually respectively based on the PV Watts model assuming a 5-degree panel tilt, 180-degree azimuth and 1.2 DC/AC inverter ratio.

The CT grid mix has been calculated to have a carbson intensity of 0.0001939 MT CO2e per kWh.

By multiplying this grid emissions factor by the estimated annual production, we can determine avoided grid emissions – solar is a zero-emission source.

**Fleet to hybrid**

We used the provided fleet replacement data to find the number of metric tons of CO2 emissions will be reduced. The year and model of each car were input to fueleconomy.gov (EPA Fuel Economy Information Website) where the amount of CO2 (in grams) emissions per mile are documented. The methodology for finding these emissions factors is provided directly from the fueleconomy.gov website.

Please find the description of the calculator used below:

A screenshot of a computer

Description automatically generated

A white text on a black background

Description automatically generated

Using the average annual miles driven of each car, the amount of CO2 emissions was calculated and thus converted to metric tons (1,000,000 grams = 1 Metric Ton). The same process was used to find out how much CO2 would be emitted if the new replacement vehicles drive the same annual distance. The difference from the old cars to the new replacement is the annual reduction of CO2 emissions in Metric Tons.

**Process for Finding Waste Truck GHG Emissions:**

Data for ten of the current waste trucks to be replaced was provided showing annual mileage, make, and model. From research, the best estimate for this truck’s fuel economy is 2.5-4.0 mpg (Diesel) (R11). 4.0 mpg was used as a conservative estimate. Using the provided truck mileage, the volume of diesel (gallons) used was calculated. Using the emissions factor for Diesel to Metric tons of CO2e equivalent (MTCO2e/Diesel gal = 10.18 x 10-3) and the eGrid factor for metric tons of CO2/gallon of gasoline (MTCO2/gas gal = 8.887 x 10-3) (R13), carbon emissions for the current truck were found.

To find the fuel economy of the newly proposed Compressed Natural Gas (CNG) truck, a Peterbilt 520 with ISX12N engine and LaBrie Automizer 33yd (27 + 6) HD Right Hand Arm, we were provided a fuel economy ‘quote’ by the president of a local retailer for these trucks. The quote they provided was 3 mpg (CNG). Using source (R12) and gasoline gallon equivalence (GGE = CNG gal @ 3600 psi x 0.287), carbon emissions were subsequently calculated. Industry standard psi of 3600 was assumed with conversion factors based on the pressure of the CNG. This is also the most conservative conversion factor for CNG listed. Listed below is a table showing the emissions calculations for each replaced waste truck. Using the eGrid factor for metric tons of CO2/gallon of gasoline (MTCO2/gas gal = 8.887 x 10-3) (R13), the emissions for the replacement trucks were found.

A screenshot of a chart

Description automatically generated

**EV Chargers**

To calculate the emissions for the level 2 chargers, the battery size of each vehicle is to be considered. The two replacement vehicles in question are the 2023 Toyota Prius and the 2023 Ford Escape Hybrid. The Prius has a battery capacity of 13.6 kWh (R15), while the Escape has a size of 14.4 kWh (R16). Assuming each car dispatches 95% of the battery capacity daily, the volume used will be refilled with the newly proposed level 2 chargers (Note: This also assumes each vehicle will recharge the full charge every night). By totaling the annual consumption of these vehicles, we can convert into metric tons of CO2e thus finding the total emissions reductions for each project. The number used for this conversion (0.0001939 MT CO2e / kWh) is based on the CT Grid Emissions Factors.

A screenshot of a spreadsheet

Description automatically generated

**Process for Traffic Signal Projects:**

To estimate the reduction most accurately from the traffic signal projects, assumptions on red light time length, frequency, and number of cars stopped must be considered.

A table was created which tabulates the total amount of cars stopped at any given intersection annually. The number of red lights per hour was set for a range of 10-61. Cars stopped at the intersection on average were set for a range of 1-25. This allows for a wide range of total cars that pass through the intersection per year.

The next variable to consider is the average duration of time of each red light. This number is originally set at 30 seconds but can be subject to change. Using the total annual number of cars passing through the intersection, the annual aggregate amount of time spent at red lights was found.

From a study conducted by Argonne National Laboratory (R7), the idling emissions for a midsized sedan (2011 Ford Fusion: 23 mpg city) were found. From their research, this average car burns approximately 0.279 cubic centimeters (CC) of fuel per second. Converting this to gallons burned per hour, the average car uses approximately 0.27 gal/hour while idling. A value of 0.2 gal was used as a conservative estimate. Combining this information with the aggregate amount of time spent at the intersection, the total annual gallons burned at an intersection was found.

To calculate emissions, the amount of CO2e in Metric Tons was estimated. The conversion factor used was 0.000878 Metric Tons (MT) of CO2e per gallon of gasoline burned. This, combined with the previously calculated annual gallons burned gives the total emissions (in MT CO2e) of cars stopped at red lights.

From recent studies conducted by Google, early numbers suggest that AI optimized traffic signals in cities will reduce the emissions at intersections by approximately 10% (R9). Using this information, combined with the calculated emissions allows for the total avoided emissions from these new projects to be calculated.

To find the correct emissions for each proposed intersection, traffic data was utilized (R6). Data for the average daily number of cars on the road is documented at each intersection. Using this information, along with the previously calculated emissions for various scenarios, the emissions for each specific intersection were found.

**Complete Streets:**

For the complete streets projects multiple assumptions and considerations were made to calculate and estimated GHG emissions reduction.

A table with numbers and text

Description automatically generatedFor most of the streets being addressed, CT DOT traffic monitoring data was captured (R6) to calculate traffic flow of each of the roads proposed for complete streets projects. It is recognized that most of the travel on a roadway in any city is transit travel, which would not be impacted by complete streets projects in terms of mode shift since the starting point or destination do not lie within proximity. It is estimated that 10% of vehicles traveling on a city roadway are localized enough to promote mode shift to walking or biking from motorized transportation.

A study conducted by the University of Maryland (R5) concludes that complete streets projects allow and motivate ~3.5% of travelers, who are local enough, to shift modes of transportation to non-motorized modes. This study was conducted throughout 25 cities throughout Maryland. We utilized 3.5% for our assumptions, however it should be recognized that factors specific to CT, such as more inclement winter weather, could reduce the impact on a seasonality basis.

Distance of the expanse of the road for each site was calculated utilizing GIS measurements.

Calculations assume an average MPG of 23 MPG traveling along roadways. (R7)

Using these estimates of impacted vehicles traveling and distance travel coupled with average fuel economy, the annual gallons reduction was calculated.

The EPA standard emissions factor for gasoline was used 0.008780 MTCO2e per gallon (R2) to calculate GHG reduction equivalent.

For the two complete streets projects which include tree plantings (Reimagine Main St. and North Main St.), the emissions reductions from the tree CO2 absorption were added. Carbon absorption values were determined from the EPA carbon sequestration metrics (R8). For these projects, calculations assume 1 year old, hardwood trees are planted with average carbon absorption properties. Long term calculations take into consideration the higher GHG absorption potential as trees age.

**Upgrades to municipal buildings:**

For these GHG calculations, we were provided kWh reduction estimates for each energy efficiency project from the city engineering and planning team.

Utilizing these reductions, we overlayed grid emissions intensity of 0.0001939 MT CO2e per kWh to determine carbon reduction on an annual basis (the carbon intensity decreases annually based on CT RPS – this was accounted for in all calculations.

**Grid Emissions Calcs:**

The below grid mix calculation can be found in the calculation’s workbook.

The grid mix is based on EPA eGrid data, coupled with CT state renewable portfolio standard, below.

The example grid mix is shown for 2024 – grid mix becomes less carbon intensive annually based on increasing RPS standards in CT on an annual basis. Emissions factors in terms of MTCO2e for each fuel source, were also gather from the EPA database.





**Sources:**

