**Technical Appendix**

## Measure 1-GHG emission reduction through the production of power through solar PV systems for three microgrids. Data on electricity use for 2020 was collected for each governmental building for 2020. The top ten buildings were looked at for solar PV systems with battery storage to reduce ghg emission. Out of the top ten consumers, a grouping was done for buildings in proximity. Three microgrids are proposed for measure 1.

## Table1 Buildings served by proposed microgrid:



**Table 2 Buildings served by the second microgrid**:



**Table 3** Buildings served by third microgrid:



**Table 4 Cloud cover entered**

The size of each solar PV system was chosen by using NREL’s PV Watts calculator[[1]](#footnote-2). I first entered the address of the Tribal Center and proceeded to enter in the degree of tilt at 47 degrees and chose bifacial panels and further choose a percentage of cloud covering for each month based upon location in Baraga County, MI.

The size of the system was changed through a trial and error until the AC system Output was close to producing 100% offset of electricity usage. The system size chosed was 2500 kW, which is equivalent to 2.5 MW. This was done with Dr. Ana Dyreson, Assistant Professor, Mechanical Engineering-Engineering Mechanics, Michigan Technological University. The same process was done for the Natural Resources department complex and Police/Pines Gas Station complex through trial and error until there was an AC system output close to 100% offset of electricity usage. An assumption of a new building with a 75000 kwh expected usage was used in the process. The Tribe recently received news that the building is for sure being funded. The system size chosen for the Natural Resources Department and the Police/Pines Gas Station complexes were each 300 kW.

**Tabel 5 Microgrid annual kwh**

A report is produced for each of the Solar PV systems that describes the output of energy.

The Casino Complex is expected to produce a total of 2529593 kwh of electricity for one year. The EPA’s Greenhouse Gas equivalency calculator[[2]](#footnote-3) was used to calculate the GHG reduction by entering 2529593 kwh of electricity avoided. The result was 1,767 MT CO2 reduction.

**Table 6 NRD Microgrid annual kwh** **Table 7 Police Microgrid Annual kwh**



The NRD Complex is expected to produce a total of 306999.4 kwh of electricity for one year. The EPA’s Greenhouse Gas equivalency calculator[[3]](#footnote-4) was used to calculate the GHG reduction by entering 30699.4 kwh of electricity avoided. The result was 214 MT CO2 equivalent reduction. The Police/Pines Gas Station is expected to produce 295576.9 kwh of electricity avoided which equates to 206 MT CO2 equivalent reduction. Total for 1 year =1767 +214+206=2187 MT CO2 equivalent reduction by 2030, as it is expected that completion of the microgrids will be complete by that time and be in operation. The total reduction by 2050 would be 2187 x 30 years =43,740 MT CO2 equivalent reduction.

**Measure 2- Install 4 kW Solar PV at 700 homes.**

According to the Keweenaw Bay Indian Community enrollment office, there are 1,130 members located in Baraga County. There are 8,158 residents in Baraga County and 5052 housing units.[[4]](#footnote-5) Using this information, a calculation was done to arrive at an estimated number of Tribal member homes located in Baraga County.

**Table 8 Residential Annual kwh**

1,130 ÷8158 x 5052 = 700 Tribal member homes located in Baraga County. Using NREL PV Watts Calculator and the same assumption of cloud cover with a 4-kW system and an address of 123 Michigan Ave., Baraga, MI 49908, the following output was obtained for electricity use avoided. 3842.149 kwh avoided/home x 700 homes = 2689504 kwh avoided which is equivalent to 1,879 MT CO2 equivalent reduction by 2030. The total reduction by 2050 would be 1879 x 20 years = 37,580 MT CO2 equivalent.

**Measure 3-Increase building energy efficiency for commercial buildings.**

There are 51 Tribal government buildings. Commercial weatherization, NREL SLOPE data on annual electricity[[5]](#footnote-6) and fuel savings[[6]](#footnote-7) from each upgrade was sourced for the state of Michigan. It is assumed that the Tribe will complete 100% of its buildings. By adding window film =1.9% savings, upgrading wall insulation to R-30=1.7% savings, and upgrade roof insulation to R-30 =1.4%=5% total savings on electricity. 2,764.5 x .05 =138.225 MT CO2 equivalent by 2030.

**Table 9 KBIC GHG emissions from Building stationary electricity**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Emissions by Sector (in CO2e)** | | | | |
|  | **CO2** | **CH4** | **N2O** | **Total** |
| Residential | 3,338.7 | 8.5 | 11.6 | 3,358.8 |
| Commercial/Institutional | 2,764.5 | 7.0 | 9.6 | 2,781.1 |
| Industrial | - | - | - | - |
| Energy Generation | (18) | (0) | (0) | (18) |
| **Total Emissions from Electricity Use** | **6,085.0** | **15.5** | **21.1** | **6,121.7** |

**Table 10 KBIC GHG emissions from Building Natural Gas**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Emissions by Sector (MT CO2e)** | | | | |
| **Sector** | **CO2** | **CH4** | **N2O** | **Total** |
| Residential | 1,209 | 3 | 1 | 1,213 |
| Commercial/Institutional | 1,000 | 2 | 1 | 1,003 |
| Industrial | - | - | - | - |
| Energy Generation | - | - | - | - |
| **Total Stationary Combustion Emissions Heat** | **2,210** | **5** | **1** | **2,216** |

The same measures have potential of adding window film =6.2% savings, upgrading wall insulation to R-30=5.4% savings, and upgrade roof insulation to R-30 =-2.4%=9.2% total savings on natural gas.

1000 x .092 =92 MT CO2 equivalent by 2030.

Total MT CO2 for Weatherization of 51 Buildings by 2030 is the sum of electricity avoidance 138.225 + natural gas avoidance 92 =230.225/year.

Total by 2050 = 230.225/year x 20 years=4,604.5 MT CO2

**Measure 4-Increase building energy efficiency for residential buildings.**

According to the Keweenaw Bay Indian Community enrollment office, there are 1,130 members located in Baraga County. There are 8,158 residents in Baraga County and 5052 housing units.[[7]](#footnote-8) 1,130 ÷8158 x 5052 = 700 Tribal member homes located in Baraga County. It is assumed that the Tribe will complete 100% of its 700 Tribal member residential homes and achieve the same 5% total savings on electricity and 9.2% of natural gas as the commercial retrofits.

Electricity savings (3338.7 x .05 =166.935)+ Natural Gas savings (1209 x .092=111.228)=278.163 MT CO2 by 2030. Total reduction by 2050 = 278.163 x 20=5,563.26

**Measure 5-Increase building energy efficiency for residential buildings by installing high energy appliances.**

*Installation of High-Efficiency Appliances*

Residential electricity use is made up of many components, including appliances used daily for cooking, cleaning, and cooling. These appliances include refrigerators, dishwashers, washing machines, clothes dryers, and air conditioning, among others. Installing newer appliances that are more energy- and water-efficient or abide by higher efficiency standards and certifications, such as EnergyStar rating, can help conserve energy and reduce emissions.

**Emissions Methodology**: To estimate the emissions reductions for high-efficiency appliances, the energy savings from each appliance and percent contribution to residential electricity were used to generate a percent energy reduction per appliance, then summed to get an overall percentage estimate for total energy and therefore emissions reduction potential. The basis for energy savings per appliance came from the DOE’s resources for various appliances (see table below), and an appliance’s contribution to residential electricity used was sourced from the EIA’s 2020 Residential Energy Consumption Survey.[[8]](#footnote-9)

Energy savings per appliance = energy savings from installing higher efficiency appliance % x appliances % contribution to overall residential electricity

Total Energy savings is the sum of each appliance.

**Table 11 Energy savings of each appliance type and contribution**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| **Appliance** | **Energy Savings from Installing Higher-Efficiency Appliances** | **Appliance’s Contribution to Scope 2 Energy [[9]](#footnote-10)** | **Total Energy Savings for Electricity** |
|  |  |  |  |
| Refrigerator | 12.0%[[10]](#footnote-11) | 0.7% | 0.1% |
| Dishwasher | 9.0%[[11]](#footnote-12) | 7.9% | 0.7% |
| Washing Machine | 25.0%[[12]](#footnote-13) | 0.5% | 0.1% |
| Clothes Dryer | 20.0%[[13]](#footnote-14) | 4.3% | 0.9% |
| Air Conditioning | 20.0%[[14]](#footnote-15) | 19.4% | 3.9% |
|  |  | Total | 6% |

3338.7 x .06 = 200.32 MT CO2 reduction by 2030 for installation of residential energy star appliances.

200.32 x 20 years =4006.44 MT CO2 reduction by 2050.

**Measure 6-Increase building energy efficiency for residential buildings by electrifying heat equipment.**

Residential and commercial heating can be a large source of emissions. Many buildings are heated using combustion-based equipment and if the system is older, it can often be inefficient, leading to further energy consumption. Transitioning from combustible fuels for heating involves replacing existing equipment with all- electric systems, such as heat pumps. Heat pumps are significantly more efficient than other heating systems due to their ability to utilize existing heat, making them a valuable heating choice for higher efficiency and emissions reductions.

**Emissions Methodology**: To quantify the reduction of Scope 1 emissions through electrification of heating equipment, a standard Coefficient of Performance or COP for typical heating systems was applied for each of the following fuel uses: natural gas (0.8), fuel oil (0.6), propane (0.8), wood stove (0.7), and electric heat pump (3.97). While there are electric resistance heating systems with a COP of 1.0, this reduction measure focuses on upgrading existing combustion heating systems to heat pump systems, which are significantly more efficient than electrical resistance and combine both heating and cooling capabilities in one system.

To calculate the percent reduction in Scope 1 emissions, the Tribe’s total natural gas (therms) calculated in the GHG Inventory are converted from their respective units to kWh usage so that the energy used for heating by different systems can be compared. The fuel usage for each fuel type becomes the baseline values to compare any reductions from electrification.

To calculate the energy needed for an electric heat pump to match the same amount of heating as the baseline fuel system, the energy used for each fuel type is multiplied by the respective fuel-based COP and divided by the electric heat pump COP. The electric heat pump COP used is 3.97[[15]](#footnote-16), representative of high-performing heat pumps in the Midwest climate.

This energy use from electrification is then converted into kWh for comparison with the baseline. A percent reduction in energy use is calculated for each fuel type by comparing the baseline energy use and “electrified equivalent” energy use. This percent reduction of energy for each heating system conversion is equal to the percent reduction of emissions.

**Table 12 KBIC Building emission by sector in mcf**

|  |  |
| --- | --- |
|  | Natural Gas mcf |
| **Residential** | 22,041 |
| **Commercial/Institutional** | 18,234 |
| **Industrial** | - |
| **Energy Generation** | - |
| **Total** | 40,275 |

The Tribe’s natural gas inventory for residential is shown to the left. The annual use is 22, 041 mcf. As stated in previous sections, there are estimated to be 700 Tribal homes located in Baraga County. The Tribe plans to electrify up to 100 homes or 1/7 of 22,041 mcf =3,149 mcf.

The calculated reduction is the 3149 mcf x 10.73 therms/mcf x 29.3 kwh/therm x .8 COP/3.97 COP =199,498 kwh. Using the EPA GHG equivalency calculator[[16]](#footnote-17)= 139 MT CO2 equivalent by 2030. To calculate reductions by 2050: 139 MT CO2 equivalent x 20 years =2,780 CO2 equivalent.

**Measure 7-Increase building energy efficiency by adopting Freen Building Standards for major renovations; layout framework for Tribal Utility formation.**

Introduce New Building Standards

*Adopt Green Building Standards for Major Renovations*

Green building standards are a comprehensive way to upgrade building systems for greater energy efficiency. Implementing energy codes and minimum efficiency standards facilitates emissions reduction for existing buildings and new construction. Green buildings tend to have HVAC (heating, ventilation, and air conditioning) and MEP (mechanical, electrical, plumbing) systems that are more efficient, more insulation, better window constructions, and can be all-electric.

**Baseline emissions**: All Buildings Scope 1+2 emissions for the Tribes are the baseline for this reduction measure.

**Key assumptions**:

•Adoption of green building codes for major renovation projects save 10.7 % for MI [[17]](#footnote-18)estimated by the USDOE.

**Table 13 Emission Factors by Building type**

|  |  |  |
| --- | --- | --- |
|  | **Number of Buildings/units** | **Emissions factor (Metric Tons CO2e/Building or Unit)** |
| **Residential Homes** | 700 | 6.5 |
| **Multi-family** | 20 | 6.5 |
| **Commercial** | 51 | 73.8 |

**Emissions Methodology:** The Scope 1+2 emissions from all buildings in the Tribe is divided by number of total number of buildings to get a scaling factor. Residential factor =(1209+ 3338.7) ÷ 700 Commercial =(1000+2764.5) ÷ 51 =This factor is used to calculate baseline emissions from the planned number of buildings to be renovated and adopt green building standards. The baseline emissions are then multiplied by the percent savings estimate from the DOE to calculate the emissions reduction from green building standards.

Emissions calculation:

[(700+20 ) x 6.5 MT CO2e + 10 planned buildings to majorly renovate x 73.8 MT CO2e] x .107=579.7 MT CO2equivalent by 2030. Assume rest of governmental buildings by 2050 =41 planned buildings x 73.8 x 10.7% =323.4. The total for 2050 would be 323.4 x 20 years=6.468 MT CO2 equivalent.

**Measure 8-Increase building energy efficiency for commercial buildings by electrifying heat equipment.**

Using the same method as describe in Measure 6, there are 18,234 mcf (see Table 12) for commercial buildings. The Tribe plans on electrifying 10 out 51 of their buildings or 10 ÷51 x 18234 mcf = 3,576 mcf.

The calculated reduction is 3,576 mcf x 10.73 therms/mcf x 29.3 kwh/therm x .8 COP Natural gas/3.97 COP Heat Pump= 226, 550 kwh. Using the EPA GHG equivalency calculator[[18]](#footnote-19) =158 MT CO2 equivalent avoided by 2030. To calculate the reductions by 2050: 158 MT CO2 equivalent x 20 years =3160 MT CO2 equivalent.

**Measure 9-Transportation Sector Measures-Replace 10 current government vehicle fleet with electric vehicles and install charging stations.**

**Table 14 Mobile MT CO2 equivalent emissions**

This measure is related to vehicle electrification by providing EV infrastructure to influence EV adoption among passenger vehicles. It is assumed that there would be a 25% adoption by the Tribe and 25% by the local residential Tribal members. There are 1,130 Tribal members located in Baraga County. The annual gallons of gas for passenger cars are 433 gallons and 636 gallons for light trucks for 2021[[19]](#footnote-20). This was the closest available data to the year 2020. It was also assumed that ½ Community members drove cars and ½ drove trucks for 2020. This equated to 433 gallons/year x 565(half of the 1130) Tribal members + 636 gallons x 565 Tribal members =244,645 gallons + 359340 gallons for a total of 603,985 gallons of gas. An average of 24.1 gal/mile for car and 18.5 for light truck was used since the amount was unknown to add to the Tribal data sheet to calculate vehicle miles traveled. Annual residential car miles were 244,645 gallons x 24.1 miles/gallon=5,898,968.6 miles. Annual truck miles were 359,340 gallons x 18.5 miles/gal =261,276,610 miles. The Tribal GHG inventory tool was used to calculate a total of 5,303 MT CO2 equivalents for residential Tribal members. Odometer readings were collected for all the government vehicles. The year of purchase was obtained from the vehicle inventory and the total miles were used to calculate mileage/year. All information was entered into the Tribal GHG inventory tool.



There are 1180 total Vehicles that produce 5523 MT CO2 equivalent. 5523 ÷ 1180 Commercial Vehicles =4.6 MT CO2 equivalent/commercial vehicle. An adoption of 25% EV is .25 x 1130 residential =282 and .25 x 50 commercial = 10 Commercial EV’s for a total of 292 EVs by 2030.

It is assumed that charging stations will be placed at locations where there is renewable energy installed, thus there would be 4.6 MT CO2 equivalent x 292 vehicles 1,343.2 MT CO 2 equivalent by 2030.

The amount by 1,343.2 x 20 years = 26,864 MT CO2 equivalent by 2050.

**Measure 10-Increase Carbon Sequestration through planting trees.**

For tree planting, the average of the sequestration potential for large deciduous and large evergreen trees (12.02 kgCO2e/unit) in the Northern region of the U.S. was used.[[20]](#footnote-21)

1000 trees/year x 12.02 kg CO2 equivalent x 5 years x .001 MT/kg=60.1 MT CO2 equivalent by 2030.

60.1 x 20 years =1,202 MT CO2 equivalent by 2050.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | GHG reduction MT CO2 equivalents | | |
|  | Reduction Measure | Cost |  | **2030** | **2050** |
| 1 | Energy Sector-Install 2-300 kW Solar PV Microgrid- NRD Complex, Police/Pines | $10,030,247 |  | 2,187 | 43,740 |
| 2 | Energy Sector-Install 4kw w storage Residential homes | $13,165,600 |  | 1,879 | 37,580 |
| 3 | Building Sector-Weatherize Govt. Buildings | $804,300 |  | 230 | 4,605 |
| 4 | Building Sector-Weatherize Residential Buildings | $3,411,160 |  | 278 | 5,563 |
| 5 | Building Sector-Energy Star Appliances | $8,459,113 |  | 200 | 4,006 |
| 6 | Building Sector-Electrifying heat equipment | $2,040,000 |  | 139 | 2,780 |
| 7 | Building Sector-Utility formation & Code development | $1,973,701 |  | 323 | 6,468 |
| 8 | Building Sector-Electrifying heat equipment | $430,500 |  | 158 | 3,160 |
| 9 | Transportation Sector-Replace Fleet with 10 EV + 5 charging station | $1,240,831 |  | 1,343 | 26,864 |
| 10 | Forestry Sector Measures | $1,500,000 |  | 60 | 1,202 |
|  |  | $43,055,451 |  |  |  |
|  |  |  | Totals | 6,798 | 135,968 |

1. [PVWatts Calculator (nrel.gov)](https://pvwatts.nrel.gov/pvwatts.php) [↑](#footnote-ref-2)
2. [Greenhouse Gas Equivalencies Calculator | US EPA](https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results) [↑](#footnote-ref-3)
3. [Greenhouse Gas Equivalencies Calculator | US EPA](https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results) [↑](#footnote-ref-4)
4. [Baraga County, Michigan - Census Bureau Search](https://data.census.gov/all?q=Baraga%20County,%20Michigan) [↑](#footnote-ref-5)
5. [Data Viewer (Commercial Electricity Savings Potential) | State and Local Planning for Energy | NREL](https://maps.nrel.gov/slope/data-viewer?filters=%5B%22upgrade_to_led_interior_lighting%22%2C%22upgrade_rtu_dx_air_conditioner%22%2C%22upgrade_outdoor_lights%22%2C%22upgrade_boiler_afue_94%22%2C%22add_heat_recovery%22%2C%22add_cool_roof%22%2C%22add_advanced_hybrid_rtus%22%5D&layer=comstock.electricity-savings-potential&geoId=G26&year=2012&res=state) [↑](#footnote-ref-6)
6. [Data Viewer (Commercial Natural Gas Savings Potential) | State and Local Planning for Energy | NREL](https://maps.nrel.gov/slope/data-viewer?filters=%5B%22upgrade_to_led_interior_lighting%22%2C%22upgrade_rtu_dx_air_conditioner%22%2C%22upgrade_outdoor_lights%22%2C%22upgrade_boiler_afue_94%22%2C%22add_heat_recovery%22%2C%22add_cool_roof%22%2C%22add_advanced_hybrid_rtus%22%5D&layer=comstock.gas-savings-potential&geoId=G26&year=2012&res=state) [↑](#footnote-ref-7)
7. [Baraga County, Michigan - Census Bureau Search](https://data.census.gov/all?q=Baraga%20County,%20Michigan) [↑](#footnote-ref-8)
8. [Electricity use in homes - U.S. Energy Information Administration (EIA)](https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php) [↑](#footnote-ref-9)
9. ibid [↑](#footnote-ref-10)
10. [Consumer Guide to Kitchen Appliances (energy.gov)](https://www.energy.gov/sites/default/files/2021-08/ES-KitchenAppliances_080221.pdf) [↑](#footnote-ref-11)
11. ibid [↑](#footnote-ref-12)
12. [Laundry | Department of Energy](https://www.energy.gov/energysaver/laundry) [↑](#footnote-ref-13)
13. ibid [↑](#footnote-ref-14)
14. [Save Money and Stay Cool with an Efficient, Well-Maintained Air Conditioner | Department of Energy](https://www.energy.gov/energysaver/articles/save-money-and-stay-cool-efficient-well-maintained-air-conditioner) [↑](#footnote-ref-15)
15. https://rmi.org/ three-questions-wisconsinites-are-asking-about-heat-pumps/ [↑](#footnote-ref-16)
16. [Greenhouse Gas Equivalencies Calculator | US EPA](https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results) [↑](#footnote-ref-17)
17. https://www.energycodes.gov/sites/default/files/2021-07/EED\_1365\_BROCH\_StateEnergyCodes\_states\_MICHIGAN.pdf [↑](#footnote-ref-18)
18. ibid [↑](#footnote-ref-19)
19. [Alternative Fuels Data Center: Maps and Data - Average Annual Fuel Use by Vehicle Type (energy.gov)](https://afdc.energy.gov/data/10308) [↑](#footnote-ref-20)
20. [Pathfinder — Improve Our Carbon Impact — Climate Positive Design](https://climatepositivedesign.com/pathfinder/) [↑](#footnote-ref-21)