IMPLEMENTATION OF WISCONSIN'S EMISSIONS REDUCTION ROADMAP TECHNICAL APPENDIX

The accompanying Excel-based modeling tool titled GHGcalcs_OSCE.xlsx, is included with our submission and contains the inputs, formulas, and outputs used to quantify the near-term and long-term cumulative GHG emission reductions detailed in this submission.

Program	Cumulative GHG emission reductions (mtCO2e)	
	2025–2030	**2025–2050**
Public Sector Lead-by-Example	178,217	738,904
Heat Pump Incentives	10,830	57,054
Tribal Climate Action Program	110,993	443,502
Transportation Electrification Program	235,172	802,635
Small Engine Replacement Program	3,918	27,024
Total	**539,131**	**2,069,119**

PROGRAM DESIGN SHEET

To determine the GHG offsets annually and cumulatively for the years 2025-2035 and 2025-2050, the implementation budget was pulled from our final budget spreadsheet. The implementation budget is then used to determine the individual budgets available for sub-programs and measures that directly impact the quantity of emissions reductions. Note that, unlike the others, the *"Small Engine"* budget is representative of the implementation budget after the subawards administration is factored in. The other programs will be administered by OSCE.

The model was developed to allow flexibility in the values of the sub-program and per-measure implementation categories. This is necessary to allow the program team to align the goals of the program and "fine-tune" the budget categories in terms of participating entities, measures funded, emissions reductions, and cost-effectiveness.

Award Amount

The model begins with inputting an implementation budget number pulled from the budget spreadsheet.

Implementation Budget and Sub-Program Category Allocations

The program budget and model allow each of the five sub-program categories to allocate a specific implementation budget. These are allocated as percentages of the Implementation Budget. Where possible, the Program Design sheet shows this breakdown. However, it should be noted that individualized formulas were used for small engine equipment and light-duty vehicles (both fleet replacements and level 2 charging infrastructure). The color-coding present on the *"Program Design"* sheet carries through to *"Annual CO2 Case Studies"* and *"Long-term Emissions"* sheets to aid in understanding the relationship between measures and programs. Not all measures will be included in all the sub-programs. The model does allow for each measure to be independently allocated by percentage, some accounting for 0% when not utilized in that sub-program.

Sub-program Categories	Measures
1. Public Sector Lead-by-Example 2. Heat Pump Incentives 3. Tribal Climate Action Program 4. Transportation Electrification 5. Small Engines Replacement Program	1. Commercial Heat Pumps 2. Residential Heat Pumps 3. Air-sealing/Insulation 4. Lighting 5. Weatherization 6. Geothermal 7. Heavy-duty Vehicles 8. Light-duty Vehicles 9. Commercial Mowers 10. Level 2 Charging Infrastructure 11. Residential Push Mowers 12. Residential Riding Mowers

Individual budgets for each measure within each sub-program

The resulting matrix shows the implementation budget allocations for each measure within each sub-program. This is important in program design and planning for each sub-program. Similarly, there is a percentage to show how much of the measure budget (used in the remaining parts of the model) is represented by each program, and the associated emissions for the measure within the program for 2025-2030 and 2025-2050.

ANNUAL CO2 CASE STUDIES SHEET

This sheet is used to identify emissions reductions caused by a single activity within each measure category. Where necessary, we have referenced data presented on other sheets used to support the assumptions made in this section.

The emissions calculations present are determined solely by the total implementation budget assigned to individual measures (across all sub-programs). For example, the total implementation budget for Commercial Heat Pumps is a total of Commercial Heat Pump implementation dollars across all five sub-programs shown on the *"Program Design"* sheet. The color-coding present in GHGcalcs_OSCE.xlsx will aid in showing the flow of data throughout.

Case studies are used to calculate emissions reductions.

Emissions reductions were calculated using representative case studies or emissions modeling for each measure. Case studies were selected from several sources.

Methodology: Heat Pumps, Air Sealing & Insulation, Lighting, Weatherization, Geothermal

Primarily, case studies are based on real, installed projects through programs administered by Wisconsin municipal governments, Elevate Energy, and Sustain Dane. Other case studies were modeled using the National Renewable Energy Laboratory (NREL) ComStock and ResStock data. The case studies for each measure (Commercial Heat Pumps, Residential Heat Pumps, Air Sealing and Insulation, Lighting, Weatherization, and Geothermal) are detailed here.

Key data from each case study used to calculate emissions reductions include 1) cost per unit of the measure, 2) reduction in energy from the installed measure, and 3) any incremental increase in energy from the installation of the measure. Energy reductions were captured as usage based on several energy unit types, including kilowatt-hours, therms, gallons of propane, and gallons of gasoline avoided. The projected avoided CO_2 for each case study was calculated as a $ per mtCO2e and averaged over the case studies for that measure. Then the implementation budgets were divided by that average $ per mtCO2e to determine the annual mtCO2e for that measure cumulative across all sub-programs.

For example: For Commercial Heat Pumps, three case studies were used with varying scopes of work, including 12-unit, 40-unit, and 104-unit projects. Two of these case studies represented switching from electric resistance heat to air-source heat pumps, and a third from gas forced air to air-source heat pumps. As such, the energy reduction and, hence, cost per mtCO2e avoided were quite different, from $5,690 to $56,312 per mtCO2e – but representative of commercial projects anticipated. The resulting average $ per mtCO2e for that measure was $6,154 per mtCO2e. The implementation budget of $7,707,000 for Commercial Heat Pumps was then divided by the average of $7,405 per mtCO2e resulting in 1,252 mtCO2e avoided annually for the measure. All measures were calculated in a similar way to determine the project mtCO2e reduction per measure.

Calculating mtCO2e for each energy unit

All measures used the same set of energy units and calculated the mtCO2e in the same way. All conversions were done using the US EPA Greenhouse Gas Reduction Calculator using national averages. Formulas for these conversions are as follows:

US EPA Conversion Calculations (1 unit = x CO^2)

kWh	1,540.1 lbs CO2/MWh × 1 metric ton/2,204.6 lbs × 0.001 MWh/kWh = 6.99 × 10-4 metric tons CO2/kWh
Therms	0.1 mmbtu/1 therm × 14.43 kg C/mmbtu × 44 kg CO2/12 kg C × 1 metric ton/1,000 kg = 0.0053 metric tons CO2/therm
Gallons of Gas	8,887 grams of CO2/gallon of gasoline = 8.887 × 10-3 metric tons CO2/gallon of gasoline
Gallon of Propane	41.9 gallons per home × 1/42 barrels/gallon × 236.0 kg CO2/barrel × 1/1,000 kg/metric ton = 0.24 metric tons CO2/home or .0057 per gallon

Methodology: Heavy Duty Vehicles

US EPA's Diesel Emissions Quantifier (DEQ) was used to generate emissions for one of each vehicle type, shown on the *"Heavy, Light, and Mowers"* sheet. To obtain emissions for an average vehicle, a model year was selected that aligned with the national average age estimate for that type of vehicle in 2024.

The default values from the DEQ were used for each vehicle type with the exception of fire trucks and dump trucks. Because the DEQ does not specifically include fire trucks, the short-haul single-unit Class 8 truck was used to represent fire truck emissions. The default values were used for this vehicle, but the idling hours were increased to 100 hours to account for additional idling these vehicles might make. Additionally, the default values present in the DEQ for dump trucks was not indicative of public sector dump truck usage in Wisconsin. Sample data was provided by the Barron County Highway Department to support a change in that category.

The *"Gross Cost"* column present on this sheet represents data found online from linked sources. In the case of the light-duty car and light-duty truck, average cost data is pulled from publicly available data found on dealer websites and gathered in the *"Approved Vehicle List"* spreadsheet, aggregated according to vehicle class. This sheet is also designed to allow flexibility in funding breakdowns and match percentages across vehicle types.

Final emissions reductions in this category assume electric charging provided by renewable energy sources.

CAP emissions were also pulled from the MOVES model, and totals were aggregated for the Public Sector Lead-by-Example and Tribal Climate Action programs by taking final numbers and multiplying them by the percentage of the measure represented by each program's budget.

Methodology: Light-Duty Vehicles

The US EPA's Motor Vehicle Emissions Simulator (MOVES) model, version 4.0.1 (issued January 2024), was used to estimate emissions for the state fleet of gasoline-powered light-duty vehicles, separately for cars and light trucks. This data was aggregated in the *"Heavy, Light, and Mowers"* sheet. MOVES calculates on-road vehicle emissions for each county in the United States. The on-road component of the model utilizes numerous built-in data including technology mixes, driving cycles, inspection/maintenance (I/M) programs, fuel properties, temperatures, and mileage accumulation to calculate the final emissions.

DNR ran MOVES for calendar year 2024 for Waukesha County for each of the 12 months of the year, using default inputs. Waukesha County was used since the presence of an I/M program in that county was deemed to be representative of the regular maintenance done to state fleet vehicles.

The MOVES output included vehicle emissions by model year and vehicle class. DNR then calculated, separately for cars and light trucks, the weighted averages of the by-model-year emissions, with the weights reflecting the model-year distributions of state fleet vehicles (as provided to DNR in February 2024). Of the 1,059 gasoline-powered cars in the state fleet, the average model year was 2016.52, and of the 3,145 gasoline-powered light trucks in the state fleet, the average model year was 2015.07 (see *"Heavy, Light, and Mowers"* sheet for this and other modeling inputs).

Final emissions reductions in this category assume electric charging provided by renewable energy sources.

CAP emissions were also pulled from the MOVES model, and totals were aggregated for the Public Sector Lead-by-Example and Tribal Climate Action programs by taking final numbers and multiplying them by the percentage of the measure represented by each program's budget.

Methodology: Small Engine – Commercial Lawn Mowers

MOVES version 4.0.1 was also used to estimate emissions for commercial riding mowers, separately for gasoline- and diesel-fueled mowers (shown on the *"Heavy, Light, and Mowers"* sheet). MOVES calculates mower emissions and populations for each county in the United States. The non-road component of the model utilizes numerous built-in data including technology mixes, fuel properties, temperatures, and usage by month to calculate the final emissions.

DNR ran MOVES for the calendar year 2025 for each of Wisconsin's 72 counties for each of the 12 months of the year. MOVES estimated a statewide population of 8,594 commercial riding lawnmowers (4,476 gasoline-powered and 4,118 diesel-powered).

Final emissions reductions in this category assume electric charging provided by renewable energy sources.

CAP emissions were also pulled from the MOVES model, and totals were aggregated for the Public Sector Lead-by-Example and Tribal Climate Action programs by taking final numbers and multiplying them by the percentage of the measure represented by each program's budget.

Methodology: Level 2 Charging Infrastructure

The "Smart Columbus Case Study 2018" was used to build the case study for this section (shown on *"Columbus Case Study"* sheet). Data was then pulled to the *"Charging Units"* sheet to show the impact of a Wisconsin state-run multi-unit dwelling charging infrastructure program. IRA incentives, like in all other case studies, were not integrated into the final calculations as they are not available to all applicants.

Emissions reduced per unit were found by assuming 2 EV or PHEV vehicles enabled for purchase by each charger installed at a multi-unit dwelling. Emissions numbers were taken from the Alternative Fueling Data Center's "Emissions from Electric Vehicles" webpage, selecting Wisconsin as the state, that accounts for charging emissions based on current electrical grid makeups. An attempt to account for variability between All Electric and Plug-in Hybrid purchases was made in the formula as well by calculating the make-up of the IRS-approved vehicle list for tax credits (*"Approved Vehicle List"* sheet), assuming most individuals would attempt to purchase vehicles from this list. The final formula for emissions reduced per charger is as follows:

G = Gasoline Vehicle Emissions

E = %EV x All Electric Emissions per vehicle

P = %PHEV x All Electric Emissions per vehicle

G – E – P x 2

Methodology: Small Engine Replacement Program

The DNR used the US EPA's Motor Vehicle Emissions Simulator (MOVES) model, version 4.0.1, released in January 2024 to estimate achievable emissions reductions from the Small Engine Replacement Program. MOVES utilizes numerous built-in data including technology mixes, fuel properties, temperatures, and usage by month deemed appropriate by US EPA to calculate emissions. Residential and commercial lawn mowers were used as surrogates for the broader category of small engine equipment in estimating emissions reductions for this program as they represent the most common type with the greatest potential for emissions reductions. DNR ran MOVES for the calendar year 2025 for each of Wisconsin's 72 counties for each of the 12 months of the year to generate the total annual estimated emissions for the following equipment categories:

- Gasoline - Walk-Behind Lawn Mowers (residential)
- Gasoline - Walk-Behind Lawn Mowers (commercial)
- Gasoline - Rear Engine Riding Mowers (residential)
- Gasoline - Rear Engine Riding Mowers (commercial)

- Gasoline - Front Riding Mowers (commercial)
- Diesel - Riding Mowers (commercial)

MOVES was run for the following five pollutants: carbon monoxide (CO), carbon dioxide (CO2), oxides of nitrogen (NOx), fine PM (PM2.5), and volatile organic compounds (VOC). Results can be found in the *"Mower Emissions from MOVES 4.1"* sheet.

To calculate emissions reductions from single pieces of equipment, DNR took the total emissions for each pollutant in the targeted nonattainment counties generated by MOVES divided by the total equipment population for each mower as defined in MOVES. Single-mower GHG emissions calculations can be found in the "*GHG Calculations* and *CAP Data Calculations"* sheet. Emissions calculated for a single mower in the targeted nonattainment area are representative of a single mower replacement statewide. Because the program will replace gas or diesel-powered equipment with zero-emitting equipment, the GHG reduction for each piece of equipment each year is assumed to be equivalent to the average emissions estimates produced by MOVES.

2025-2030 Emissions Reductions

Annual emissions reductions for a single mower were then used to calculate the cumulative emissions reductions. The total number of mowers expected to be replaced per year based on the proposed budget is described in the "*Mower Amounts and Funding"* sheet. These totals were multiplied by the unit-specific emissions reduction estimates described above and the number of years the reductions will occur in the 2025-2030 timeframe. In other words:

Emissions Reductions = (Emissions Reductions per mower x Quantity of mowers replaced) x Number of years from 2025-2030 emissions reductions will be achieved

Calculations for the CAP and GHG emissions reductions can be found in the "*CAP Reductions (Table 6)"* and *"GHG Reductions (Table 11)"* sheets.

2025-2050 Emissions Reductions

To calculate the long-term cumulative emissions reductions from the Small Engine Replacement Program, the annual emissions reductions for each piece of equipment are multiplied by the total number of mowers replaced over the full length of the program and the lifetime of the mower. The lifetime for both push and riding lawnmowers is estimated to be 20 years. "*CAP Reductions (Table 7)"* and "*GHG Reductions (Table 12)"* sheets demonstrate these calculations.

Final emissions reductions in this category assume electric charging provided by renewable energy sources.

LONG-TERM EMISSIONS SHEET

Lastly, data was then drawn to the *"Long-term Emissions"* sheet to calculate the annual long-term emissions reductions associated with each measure type. This sheet is further used to represent measure and program emissions on the "*Program Design*" sheet and to provide the final program emissions estimates for use in the application.

The yearly budgets were determined by taking the sum of the sub-program budgets for each measure and multiplying it by the program deployment percentages found on the "*Program Design*" sheet. Annual CO2 amounts and number of units were thus calculated by multiplying this number versus the respective annual amounts calculated on the "*Annual CO2 Case Studies*" sheet. This sheet also accounts for cumulative annual emissions reductions and phase out after the equipment is put out of service. Finally, annual numbers are summed to determine checksums for use on the "*Program Design*" sheet.