

Technical Appendix: Assumptions, Costs, and Calculations

General

The following data sources were used throughout the modeling completed for this application:

- All energy costs were sourced from the U.S. Energy Information Agency, Annual Energy Outlook 2023.¹
- Projected electricity emissions factors were based on Michigan’s 100% Clean Energy Standard in Senate Bill 271. Emissions factors for years between 2024 and 2040 were derived by assuming a steady decrease from the current emissions factor to 0 in 2040.
- All other emissions factors were sourced from the EPA Community Inventory Tool (<https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool>).

Measure 1: Residential Building Retrofits

The following assumptions were made to calculation emissions reductions:

1. The retrofits will achieve the following on average in each dwelling (single- and multi-family):
 - 50% reduction in total energy (thermal and plug load)
 - Replacement of fossil fuel systems with air source heat pumps and electric appliances.
2. The source of current residential building stock data was from NREL’s State-Level Residential Building Stock and Energy Efficiency & Electrification Packages Analysis (<https://public.tableau.com/app/profile/nrel.buildingstock/viz/StateLevelResidentialBuildingStockandEnergyEfficiencyElectrificationPackagesAnalysis/Introduction>).
3. All buildings were assumed to currently have natural gas heating.
4. Retrofit Costs were assumed to be the following, to a maximum of \$18,000 per dwelling (source: Wayne County Metro Weatherization and Energy Efficiency Program actual average cost to retrofit homes)
 - Energy Audit - \$50-900 (source: homes.rewiringamerica.org)
 - Repairs - \$4,000 average per dwelling (source: Oakland Saves Program)
 - Weatherization - \$12,000 average per dwelling, for leak sealing, weather stripping, insulation and roof replacement (source: Wayne County Metro Weatherization and Energy Efficiency Program actual average cost for complete weatherization, plus 10% of residents requiring roof replacements.)
 - Energy Efficiency - \$10,000 average per dwelling for doors, windows, electric clothes dryer, electric stove, more energy-efficient refrigerator.
 - Electrification - \$10,000 average per dwelling for panel and plug upgrades, and space and water heat pumps. (source: homes.rewiringamerica.org)

¹ U.S. Energy Information Administration. “Annual Energy Outlook 2023 - Table 3 Energy Prices by Sector and Source”

Measure 2: Residential Renewable Electricity

The emissions reductions for this measure assumed that a 5 kW rooftop solar PV system will be installed on all participating, low-income homes. Each system was assumed to cost \$13,000. (Source: Michigan Local Solar for All: <https://www.localsolarforall.org/michigan>.)

Measure 3: Energy Advisor Service

The emissions reductions associated with the non-income-qualified residents who accessed the Energy Advisor Service, assumed that in the 1500 dwellings, the following upgrades will have been completed by 2030:

- 500 dwellings achieved 50% reduction in thermal and plug load energy.
- 500 dwellings achieve 25% reduction in thermal and plug load energy.
- 500 dwellings achieve 10% reduction in thermal and plug load energy.

The only cost to the Program for this was the Energy Advisor Service. Estimating the cost to stand up this service and operate it for five years was done two ways. The final budget was created by combining the results of the two estimates.

1. The first approach was to estimate the costs ‘from the bottom up’. To do this, the expected workload, expertise, staffing, and physical resources were aligned with the schedule of the Residential Decarbonization component of the program. Table 2 presents these calculations and proposes a total budget of \$26,200,500 for this Service.
2. The second estimate was based on guidance from similar work currently being done or that was done in the past. Experience with the Ann Arbor Energy Advisor pilot program, the Oakland Saves Program, the DTE Home Energy Program, and the guidance of Michigan Saves all indicated that this service will likely require funds equivalent to 25-30% of the ‘on-the-ground work’ that it will be catalyzing. In this case, this produces an estimated budget of between \$31.3 and \$41.3 million for the Energy Advisor Service. (For comparison, the first estimate is approximately 21% of the costs of Measures 1 to 4.)

Assumptions and cost data to develop these estimates included:

- Staff salaries
- PHIUS Builder Certification
- HEP Energy Auditor Certification
- HEP Quality Control Inspector
- Work space
- Electric vehicles for travel
- Funds passed through to supporting agencies
- Suggested training: The Building Performance Institute (BPI). bpi.org.
- Salary estimates: The Association of Energy Engineers (AEE). <https://www.aeecenter.org/>.
- Electric vehicle costs: “Update on Electric Vehicle Costs in the United States through 2030.” theICCT.org
- Programming costs and estimated staffing requirements: Ann Arbor’s pilot Energy Advisor Program

Measure 4: Climate-Resilient Trees

The emissions reductions and costs associated with tree planting assumed:

- 4000 Bur oak (*Quercus macrocarpa*), 4000 Red maple (*Acer rubrum*), and 1,850 Ginkgo trees (*Ginkgo biloba*) will be planted by 2030;
- Approximately 1% will die annually between 2030 and 2050, such that in 2050, approximately 8056 trees will still be alive.

The species-specific sequestration factor, average lifetime, air pollution reductions, canopy cover, rainfall interception, and avoided runoff values were calculated using i-Tree Planting Version 2.7.0 (<https://planting.itreetools.org/app/location/>.)

The costs were provided by coalition members based on tree-planting programs in their regions.

Measure 5: Municipal Retrofits

The emissions reductions achieved from retrofits in municipal buildings assumed:

- 50% reduction in total energy use, including space and water conditioning;
- Fossil fuel furnaces, boilers and water heaters are replaced with air source heat pumps.
- 518,000 square feet of floor space are retrofits between 2026 and 2030, distributed across small, medium and large offices, as well as stand-alone single-story buildings in all participating counties.

The criteria air contaminant reductions were calculated based for the retrofit work only (not the solar installations), using the EPA'S Co-Benefits Risk Assessment (COBRA) system.

The emissions reductions for this Measure assumed that 690 kW of rooftop solar PV systems were installed on municipal facilities by the end of 2029.

Calculations

All of the calculations shown in this section are derived from the Energy System Simulator modeling software provided by Sustainability Solutions Group.

Building Retrofits

The calculation of emissions savings from residential and municipal building retrofits (in Measures 1, 3 and 5) used the following formulas:

Part 1: Electricity Use

New NonSpace Conditioning Electricity Use (MMBTU) = $(1 - \text{Energy Reduction \%}) \times \text{Baseline NonSpace Conditioning Electricity Use (MMBTU)}$
New Space Conditioning Electricity Use (MMBTU) = $(1 - \text{Thermal Energy Reduction \%}) \times \text{Baseline Space Conditioning Natural Gas Use (MMBTU)} / \text{COP}$ $+ (1 - \text{Energy Reduction \%}) \times \text{Electricity of Baseline Buildings (MMBTU)}$
New Electricity Use (MMBTU) = New Space Conditioning Electricity Use (MMBTU) $+ \text{New NonSpace Conditioning Electricity Use (MMBTU)}$

Part 2: Natural Gas Use

New NonSpace Conditioning Natural Gas Use (MMBTU) = $(1 - \text{Energy Reduction \%}) \times \text{Baseline NonSpace Conditioning Natural Gas Use (MMBTU)}$
New Space Conditioning Natural Gas Use (MMBTU) = $(1 - \text{Thermal Energy Reduction \%}) \times \text{Baseline Space Conditioning Natural Gas Use (MMBTU)}$
New Natural Gas Use (MMBTU) = New Space Conditioning Natural Gas Use (MMBTU) $+ \text{New NonSpace Conditioning Natural Gas Use (MMBTU)}$

Part 3: Emissions Reduction

Net Electricity Emissions (MT CO ₂ e) = $\text{Baseline Electricity Use (MMBTU)} - \text{New Electricity Use (MMBTU)}$ $\times \text{Emission Factor of the Grid (MT CO}_2\text{e/MMBTU)}$
Net Natural Gas Emissions (MT CO ₂ e) = $\text{Baseline Natural Gas Use (MMBTU)} - \text{New Natural Gas Use (MMBTU)}$ $\times \text{Natural Gas Emission Factor (MT CO}_2\text{e/MMBTU)}$
Net Emission Reduction (MT CO ₂ e) = Net Electricity Emissions (MT CO ₂ e) $+ \text{Net Natural Gas Emissions (MT CO}_2\text{e)}$

Renewable Power: Measures 2 and 5

The calculation of emissions reductions from the installation of rooftop solar PV systems (in Measures 2 and 5) used the following formulas:

Part 1: Annual Power Generation

$$\text{Annual Generation (GWh)} = \text{Installed Capacity (GWh)} \times 8760 \text{ hours/year} \\ \times \text{Michigan's Rooftop Solar Capacity Factor}$$

Part 2: Emissions Reduction

$$\text{Emissions Reduction (MT CO}_2\text{e)} = \text{Emission Factor (MT CO}_2\text{e/GWh)} \times \text{Annual Generation (GWh)}$$

Climate-Resilient Trees: Measure 4

The calculation of emissions sequestered by climate-resilient trees planted as part of this Project (in Measure 4) used the following formulas:

Emissions Sequestered

$$\text{Carbon Sequestered (MT CO}_2\text{e)} = \text{number of trees} \\ \times \text{Species-Specific Carbon Sequestration Factor (MT CO}_2\text{e/tree)}$$

Results

The following tables present the results of the Energy System Simulator modeling results for Measures 1, 2, 3 and 5, and the results of i-Tree Planting Version 2.7.0 for Measure 4.

Measure 1: Residential Retrofits

Emissions Reductions, Energy Cost Savings, and CAC Reductions - For 2025-2030 and 2025-2050

	Cumulative Emissions Reductions (MT CO2e)		Cumulative Energy Costs		Cumulative CO Reductions (lbs)		Cumulative NOx Reductions (lbs)		Cumulative PM2.5 Reductions (lbs)		Cumulative SO2 Reductions (lbs)		Cumulative VOC Reductions (lbs)	
	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050
Measure 1: Residential Retrofits	7,383	51,725	-\$1,389,159	-\$9,800,424	38,375	257,659	90,181	605,499	413	2,770	576	3,865	5,277	35,428

Measure 2: Residential Renewable Energy

Emissions Reductions and Energy Cost Savings - For 2025-2030 and 2025-2050

	Cumulative Emissions Reductions (MT CO2e)		Cumulative Energy Costs	
	2025-2030	2025-2050	2025-2030	2025-2050
Measure 2: Residential Renewable Energy	30,773	119,042	-\$13,606,271	-\$119,216,803

Avoided criteria air contaminants were not calculated for Measure 2.

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Measure 3: Energy Advisor Service

Emissions Reductions and Criteria Air Contaminant Reductions - For 2025-2030 and 2025-2050

	Cumulative Emissions Reductions (MT CO2e)		Cumulative CO Reductions (lbs)		Cumulative NOx Reductions (lbs)		Cumulative PM2.5 Reductions (lbs)		Cumulative SO2 Reductions (lbs)		Cumulative VOC Reductions (lbs)	
	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050
500 Households Rcvg Basic Energy Advisor Service reduce energy use by 50%	5,918	34,233	20,549	137,973	48,290	324,235	221	1,483	308	2,070	2,826	18,971
500 Households Rcvg Basic Energy Advisor Service reduce energy use by 25%	2,959	17,117	10,275	68,986	24,145	162,118	110	742	154	1,035	1,413	9,486
500 Households Rcvg Basic Energy Advisor Service reduce energy use by 10%	1,184	6,847	4,110	27,595	9,658	64,847	44	297	62	414	565	3,794
Total	10,061	58,197	34,933	234,553	82,094	551,200	376	2,521	524	3,518	4,803	32,251

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Measure 4: Climate-Resilient Trees

Emissions Reductions, Pollution Reductions, and Other Environmental Benefits - 2025-2050.

Species	Number Planted	Year Planted	Initial DBH (inches)	2050 Surviving Trees	2050 Canopy Cover (square feet)	CO2 Sequestered (pounds)	Rainfall Interception (gallons)	Avoided Runoff (gallons)	O3 Removed (pounds)	NO2 Removed (pounds)	SO2 Removed (pounds)	PM2.5 Removed (pounds)
Bur oak(Quercus macrocarpa)	4,000	2,026	5	3,017	1,130,582	3,761,096	39,376,754	13,311,017	24,196	4,704	1,901	2,280
Red maple(Acer rubrum)	4,000	2,027	5	2,414	728,127	9,932,398	25,539,450	8,633,420	18,027	3,630	1,399	2,035
Ginkgo(Ginkgo biloba)	1,850	2,028	5	1,569	584,544	839,988	22,222,396	7,512,115	11,645	2,180	927	910
Total				7,000	2,443,253	14,533,481	87,138,600	29,456,553	53,869	10,514	4,227	5,225

Measure 4: Municipal Retrofits and Renewable Energy

Total Non-Residential Floorspace Impacted by Municipal Retrofits and Emissions Reductions, Years 1 - 5, Annual Average, 2025-2030 and 2025-2050.

	Year 1	Year 2	Year 3	Year 4	Year 5	Annual Average Emissions Avoided	2025-2030 Total Emissions Avoided	2025-2050 Total Emissions Avoided
Total Emissions Avoided	152	150	149	205	1621	455.4	2277	47817
Total Floorspace Impact	61,800	61,800	61,800	84200	518,500			

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Total Capacity of Municipal Solar PV Installed, and Emissions Reductions - Years 1 - 5, Annual Average, 2025-2030 and 2025-2050.

	Rooftop solar capacity installed on municipal facilities (kW) by 2026	Rooftop solar capacity installed on municipal facilities (kW) by 2029	Year 1 Emissions Avoided (MT)	Year 2 Emissions Avoided (MT)	Year 3 Emissions Avoided (MT)	Year 4 Emissions Avoided (MT)	Year 5 Emissions Avoided (MT)	Annual Average Emissions Avoided (MT)	2025-2030 Total Emissions Avoided (MT)	2025-2050 Total Emissions Avoided (MT)
Total	345	690	140	130	120	220	200	162	420	4420