TECHNICAL APPENDIX: GREENHOUSE GAS REDUCTION ASSUMPTIONS

1. GENERAL ASSUMPTIONS AND ELECTRICITY EMISSION RATES

Emissions are reported in metric tons and converted to CO_2-equivalent tons using the IPCC AR5 global warming potentials.

Electricity emission rate projections for electricity use avoided were estimated using NREL Cambium data for the long-run marginal emission rate (LRMER) for direct combustion in Minnesota under the mid-case with 95% decarbonization by 2050 scenario.[1] The LRMER is an estimate of the rate of emissions induced or avoided by a change in demand, accounting for changes in the operation or structure of the electric grid. The actions proposed are intended to have long-term impacts, making the LRMER an appropriate estimate of future emission rates. The mid-case scenario with 95% decarbonization uses central estimates for inputs such as technology costs, fuel prices, and demand growth, includes nascent technologies, includes electric sector policies as they existed in September 2022, and there is a national electricity sector decarbonization constraint that linearly declines to 5%.

Year-over-year emission rates for the scenario were converted to common units and CO_2e to estimate the metric tons of CO_2e per MWh of 2024, 2026, 2028, 2030, 2035, 2040, 2045, and 2050 (Table 1). A polynomial function was then used to fit a curve and model the emission rates for 2024-2050 (Equation 1). The modeled emission rates are compared to the LRMER projections in Electricity emission rate projections for electricity use added were taken from the EIA Annual Energy Outlook 2023 (AEO2023) using a scenario with the impacts of the Inflation Reduction Act. These emission rate projections are higher than the LRMER projections (Figure 1). The AEO2023 projections are used for the average emission rates and applied, to the extent possible, to measure quantification where electricity consumption increases as an effect of the action. The LRMER projections are used for the marginal emission rates and applied, to the extent possible, to measure quantification where electricity consumption decreases as an effect of the action. Using the marginal emission rate when estimating the impact of reduced electricity demand instead of the grid average is appropriate.

Figure 1: Emission rates from electricity generation

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Table 1: Unlevelized, Year-over-Year Metric Tons CO_2e/MWH from Direct Combustion, 95% Decarbonization by 2050 scenario

2024	2026	2028	2030	2035	2040	2045	2050
0.24353	0.18685	0.11658	0.08289	0.09830	0.09890	0.06653	0.03971

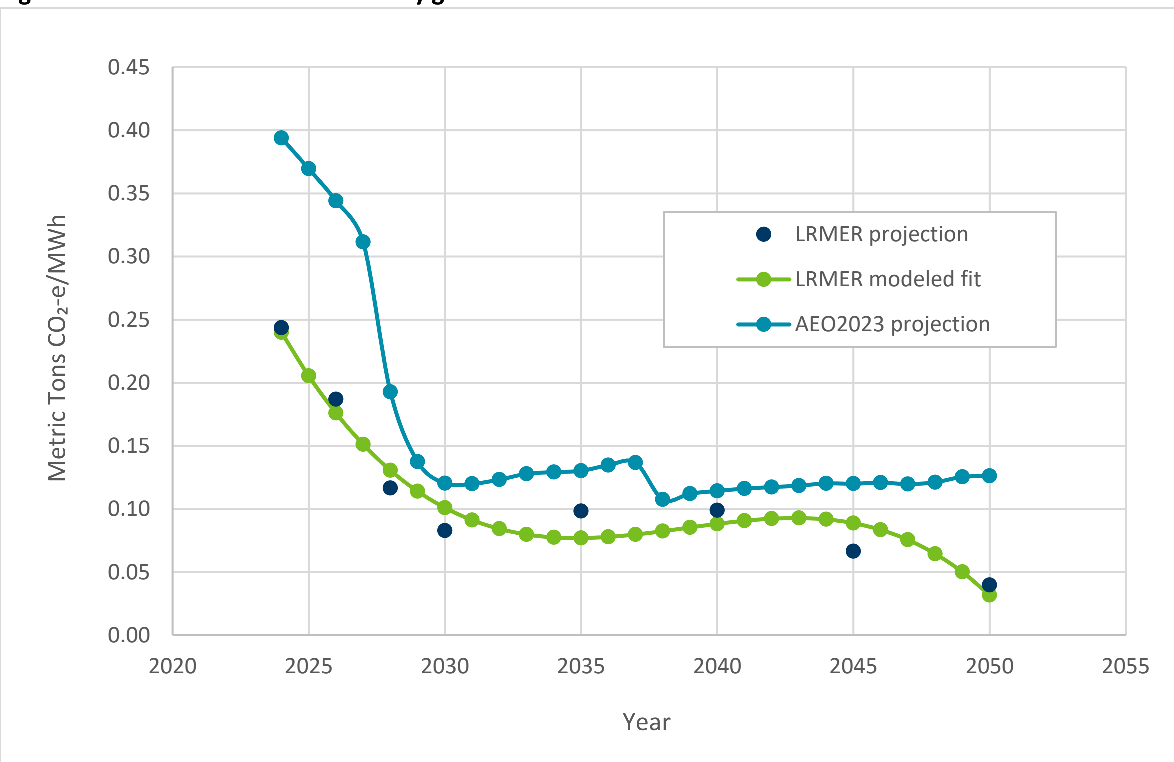
Equation 1:

$$f(x) = (7.0645 \times 10^{4}) - (4.1247 \times 10^{1} * x) - (3.2441 \times 10^{-3} * x^{2}) - (5.2711 \times 10^{-6} * x^{3}) + (2.6014 \times 10^{-9} * x^{4}) + (1.3026 \times 10^{-12} * x^{5}) + (4.1119 \times 10^{-16} * x^{6}) - (3.3301 \times 10^{-19} * x^{7})$$

[1] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. 2023. "Long-run Marginal Emission Rates for Electricity - Workbooks for 2022 Cambium Data." NREL Data Catalog. Golden, CO: National Renewable Energy Laboratory. Last updated: December 12, 2023. DOI: 10.7799/1909373. https://data.nrel.gov/submissions/206

Electricity emission rate projections for electricity use added were taken from the EIA Annual Energy Outlook 2023 (AEO2023) using a scenario with the impacts of the Inflation Reduction Act.[2] These emission rate projections are higher than the LRMER projections (Figure 1). The AEO2023 projections are used for the average emission rates and applied, to the extent possible, to measure quantification where electricity consumption increases as an effect of the action. The LRMER projections are used for the marginal emission rates and applied, to the extent possible, to measure quantification where electricity consumption decreases as an effect of the action. Using the marginal emission rate when estimating the impact of reduced electricity demand instead of the grid average is appropriate.

Figure 1: Emission rates from electricity generation



This is a conservative estimate of the carbon intensity of Minnesota's electricity grid because Minnesota has a law requiring all electricity used in the state to be from carbon-free sources by 2040. There are some off-ramps for affordability and feasibility concerns for smaller generators, which we cannot predict the need for. If the law functions as intended, any emissions from electricity will actually be lower than indicated here, especially by 2050.

2. PEATLAND RESTORATION

Emissions reductions from restoring peatlands were estimated based on the difference between the current land use continuing and a restored peatland. Land use changes analyzed were partially drained peatlands (5,000 acres), drained peatlands in crop agriculture (2,500 acres), and drained peatlands in pasture (2,500 acres), all converted to rewetted peatlands. Assumptions were based on initial work

[2] EIA Annual Energy Outlook 2023. Table 54: Electric Power Projections by Electricity Market Module Region, Case: High Uptake of Inflation Reduction Act, Region: Midcontinent West. Released March 16, 2023. https://www.eia.gov/outlooks/aeo/

performed by the MPCA[3] and in collaboration with workgroup members. All acreages are expected to be restored before or during 2029, yielding two full years of emissions reductions prior to the end of 2030. Restoring peatlands from crop agriculture is expected to mitigate 13.414 MT/year/acre. Restoring peatlands from pasture and partially drained peatlands is expected to mitigate 13.414 MT CO_2e/acre/year. Acreage of partially drained peatlands mitigated was determined by GIS analysis of existing and abandoned ditches within the restoration; we only included the acreage within 150 meters of ditches, as peatlands further from ditches remain relatively intact. We assume all restored peatlands remain intact in perpetuity.

2. CLIMATE-FRIENDLY AGRICULTURAL PRACTICES

The analysis assumes an average implementation year of 2027, yielding four years of emission reductions prior to the end of 2030. We assumed continuation of soil health-related practices for at least twenty years. Emission factors were based on initial work performed by the MPCA[4] were based on initial work performed by the MPCA[5] and acreage potential per management practice was determined collaboration with workgroup members.

The following actions, in addition to currently practiced climate-friendly activities, were evaluated:

- 2,000 acres of cropland retirement to grassland, 1.387 MT CO_2e/acre/year mitigated
- 20,000 acres of cropland to hayland, 1.031 MT CO_2-e/acre/year mitigated
- 6,500 acres of perennial grasses in a crop rotation, 0.366 MT CO_2e/acre/year mitigated
- 150,000 acres of no-till management, 0.138 MT CO_2e/acre/year mitigated
- 90,000 acres of reduced till management, 0.064 MT CO_2e/acre/year mitigated
- 360,000 acres of cover crops, 0.242 MT CO_2-e/acre/year mitigated
- 100,000 acres of nitrification inhibitor use, 0.243 MT CO_2e/acre/year mitigated
- 100,000 acres of controlled-release fertilizer use, 0.143 MT CO_2e/acre/year mitigated

No other state or federal funds are expected to contribute to these actions, and any additional costs will be funded by private capital.

3. INDUSTRIAL INNOVATION AND DECARBONIZATION

We have calculated the GHG emission reduction potential for a few industrial technologies eligible for this regranting program. It was not feasible to estimate the impact of every potentially applicable technology, so we used these specific project types as representatives, but we expect to fund a greater diversity of technologies than presented here, and therefore, will likely fund fewer projects of any single project type than used in these calculations. The impact of these technologies was calculated independently. However, in many cases, multiple technologies could work as part of an integrated system, affording additional GHG emission reductions and improved cost-effectiveness beyond what has been modeled here. In reality, we anticipate that many applicants to this regranting program will be able to combine technologies (e.g., anaerobic digestion with combined heat and power or a biochar facility with waste heat utilization via a heat pump), and we would prioritize these types of applications. There is much uncertainty around the

[3] Minnesota Pollution Control Agency. 2022. Greenhouse gas reduction potential of agricultural best management practices (Revised edition). https://www.pca.state.mn.us/sites/default/files/p-gen4-21.pdf

[4] Minnesota Pollution Control Agency. 2022. Greenhouse gas reduction potential of agricultural best management practices (Revised edition). https://www.pca.state.mn.us/sites/default/files/p-gen4-21.pdf

[5]Minnesota Polution Control Agency. 2022. Greenhouse gas reduction potential of agricultural best management practices (Revised edition). https://www.pca.state.mn.us/sites/default/files/p-gen4-21.pdf

magnitude of additional GHG benefits that could be achieved by combining technologies, so we have not incorporated these likely synergies into these greenhouse gas estimates.

Industrial heat pumps: Based on conversations with food industry experts, equipment and installation costs are highly variable, ranging from $100,000 to $500,000 per facility. Using an actual project with upfront costs of $145,000 and projections of the increasingly decarbonized US electric grid, we determined that if installed in 2025 and run for 8400 hours per year, this heat pump will reduce GHG emissions by approximately 1044 MT CO_2e by 2030 and 5450 MT CO_2e in 2050. By extrapolation, a hypothetical $10,000,000 investment funding 40% of project costs would yield approximately 172 projects and reduce emissions by 180,037 MT CO_2e by 2030 and 780,161 MT CO_2e by 2050. All remaining costs will be funded by private capital.

Condensing heat economizers: Based on conversations with food industry experts, equipment and installation costs vary widely, ranging from $500,000 to $3,000,000 per facility. Using an actual project from 2021 to determine the potential impact of these funds, upfront costs of $1,500,000 reduced natural gas use by 25 therms per hour or 212,500 therms per year, equivalent to 1,126 MT CO_2e per year. A hypothetical $10,000,000 investment funding 40% of project costs would yield approximately seven similar projects and 7,506 MT in CO_2e reductions per year, resulting in reductions of 37,542 MT CO_2e by 2030 and 187,708 MT CO_2e by 2050. All remaining costs will be funded by private capital. Boiler efficiency improvement projects are expected to be commonly sought after in this grant program, and condensing economizers are one of many improvements that could yield similar efficiency gains at similar cost savings.

Combined heat and power: Based on conversations with food industry experts, equipment and installation costs are widely variable but are typically about $1,000,000 per facility. Upfront project costs are generally in the $500-600 for a single year's worth of reduction of 1 MT CO_2e. We assumed an equipment plus installation cost of $550/MT CO_2e /year and that installations occur in 2025, yielding six years and 26 years of benefits by 2030 and 2050, respectively. A single project would reduce approximately 1,818 MT CO_2e per year. A hypothetical $10,000,000 investment funding 40% of upfront project costs would generate approximately 25 projects and 272,727 MT CO_2e reductions by 2030. All remaining costs will be funded by private capital. New combined heat and power systems would be eligible for a 30% federal clean energy investment tax credit, but for the purposes of this example, we assumed that an existing power generation source would have waste heat capture technologies added, so it would not qualify for that tax credit.

Biochar production and beneficial land application: A typical biochar production facility in Minnesota is expected to take in 1,500 tons of wood waste. Most commonly used pyrolysis methods yield approximately one-third of the input biomass as biochar. If we use $10,000,000 to fund 40% of upfront project costs, this will yield 25 biochar facilities. All remaining costs will be funded by private capital.

Given agricultural field application at rates of 15 MT per hectare (6.07 MT/acre), biochar from each facility would be land applied to approximately 75 acres per year. Based on peer-reviewed literature, each acre of biochar applied cropland would receive an immediate increase of 5.78 MT of carbon, or 21.176 MT CO_2e.[6] Carbon in biochar is stable and will not return to the atmosphere for 50-1000 years. Additionally, at this application rate, biochar reduces nitrous oxide from agricultural lands at a rate of 0.187 MT CO_2e per acre per year for at least 20 years. These 25 facilities would be responsible for reductions of 201,282 MT CO_2e by 2030 and 1,093,740 MT CO_2e by 2050.

Demonstration project: Washington-Ramsey County anaerobic digestion with biochar production: This facility is expected to be operating at full capacity before the end of 2025. Based on existing contracts, and

[6] Minnesota Pollution Control Agency. 2022. Greenhouse gas reduction potential of agricultural best management practices (Revised edition). https://www.pca.state.mn.us/sites/default/files/p-gen4-21.pdf

site-specific engineering, we assumed the anaerobic digestion facility would process 65,643 short tons of food scraps and 9,775 short tons of yard trimmings. We used EPA's WARM model (version 16) to estimate emissions of CO_2e from the counterfactual of landfilled food scraps and composted yard waste. We modified the the WARM model's dry anaerobic digestion with digestate curing calculations by subtracting the CO_2e fluxes generated from soil carbon storage and N2O emissions after land application because the digestate at this facility will be cured but not land applied. Anaerobic digestion at this facility is expected to reduce GHGe by 36,581 MT CO_2e annually.

Digestate will be converted to biochar via pyrolysis. This facility is expected to produce 9,072 MT of biochar per year, which will be land applied to improve soil health. We used peer-reviewed literature to estimate soil carbon sequestration and the ongoing benefit of reduced nitrous oxide production from soils due to biochar soil application in agricultural settings.[7] Assuming an application rate of 15 MT/hectare, biochar from this facility would be applied to 605 acres annually. Based on peer-reviewed literature, each acre of cropland with applied biochar would receive an immediate increase of 5.78 MT of carbon, or 21.2 MT CO_2e. Carbon in biochar is stable and will not return to the atmosphere for 50-1000 years. Additionally, at this application rate, biochar reduces nitrous oxide from agricultural lands at a rate of 0.187 MT CO_2e per year for at least 20 years, yielding a small but non-negligible ongoing benefit. Biochar produced and used from this facility in a single year will reduce GHGe by a minimum of 31,633 MT CO_2e.

Summing the GHG reductions of anaerobic digestion and biochar results in a facility total of 343,866 MT CO_2e by 2030 and 1,789,166 MT CO_2e by 2050. The total facility is expected to cost $100M. We expect this $10M grant to be paired with a 30% federal clean energy tax credit, such that these CPRG funds will be responsible for 25% of the total federal and state funding. The remaining $60M will be funded by private capital. Therefore, the benefits of these funds are scaled to 85,966 MT CO_2e by 2030 and 447,292 MT CO_2e by 2050.

Planning grants: We expect that the average planning grant will be just under $100,000, yielding a total of 73 grants. Each grant will include an energy audit that will identify cost-effective energy efficiency measures, some of which we assume that sites will self-fund. We relied on Department of Energy's Office of Manufacturing and Energy Supply Chain's (MESC) Industrial Assessment Center database, filtered to assessed sites with a NAICS code beginning with 311 (food manufacturing) to determine the likely magnitude of energy use reductions that will result from these planning grants. The sites in the MESC database are characterized as small to medium industrial sites, which suggests the energy reductions at the sites we will assess will be similar to or greater than these reductions. For sites with data on recommended measures that were enacted, average natural gas reductions were 1,966 MMBtu per year and average electricity reductions were 264 MWh per year. We assume that our energy assessments will lead to similar energy reductions, and that some of the more costly recommended actions that are not self-funded will be funded through our competitive implementation grant. Natural gas reductions at 73 sites results in reductions of 7,606.5 MT CO_2e per year. Given electricity grid decarbonization projections, electricity reductions have the greatest benefit in the earliest years, averaging 2,400 MT CO_2e per year between 2026 and 2050. We assume that all energy audits will be completed prior to 2026, resulting in five years of reductions by the end of 2030 and 25 years of reductions by 2050.

4. LOW AND ULTRA-LOW GWP REFRIGERANTS

Large commercial refrigeration projects: The GHG emission reduction estimate is based on a hypothetical project's emission reductions for replacing an existing refrigeration system as described in the California

[7] Minnesota Pollution Control Agency. 2022. Greenhouse gas reduction potential of agricultural best management practices (Revised edition). https://www.pca.state.mn.us/sites/default/files/p-gen4-21.pdf

Air Resources Board User Guide and Quantification Methodology for the California Energy Commission F-Gas Reduction Incentive Program.

The baseline system includes two systems using R-507A with a total refrigerant charge of 1,800 lbs. Per a contractor's input, this charge size is appropriate for a 40,000 square foot facility and is representative of potential projects. The replacement project models four condensing units that use R-744 (carbon dioxide) with a total charge of 600 lbs and 25 self-contained cases using R-290 with a total charge of 8.25 lbs. Also included in the calculation are annual and end-of-life leakage rates and annual electricity usage for baseline and new systems.

Grant award amounts are expected to range from $250,000 - $750,000, with an average of $500,000, resulting in 17 projects, each of which would reduce emissions by 798 MT CO_2e per year. Any remaining costs will be funded by private capital. Per IPCC methodology, no benefit of these equipment replacements beyond the expected 15-year equipment lifespan was included in our calculations. Contractor input indicates these systems can be in use for much longer, for example 30 years. Because the project idea is based on the proposition that facilities are choosing between continuing to repair and retrofit or replace existing equipment, we used a conservative quantification period of 15 years.

Small commercial refrigeration projects: The GHG emission reduction estimate is based on the average equipment lifetime, refrigerant charge size, annual average operating leak rates, and GWPs from the California Air Resources Board, Intergovernmental Panel on Climate Change, and industry input. Estimated project costs and common refrigerants were based on previous grant applications to the MPCA, as well as contractor and manufacturer input.

Grant award amounts will be $20,000, resulting in 45 projects, each of which would reduce emissions by 51 MT CO_2e per year. Any remaining costs will be funded by private capital. Per IPCC methodology, no benefit of these equipment replacements beyond the expected 15-year equipment lifespan was included in our calculations. Contractor input indicates these systems can be in use for much longer, for example 30 years. Because the project idea is based on the proposition that facilities are choosing between continuing to repair and retrofit or replace existing equipment, we used a conservative quantification period of 15 years. Current information says new refrigerants with GWPs less than 300, expected to be commercially available in a couple of years, will not be a drop-in replacement. There is uncertainty about the total project costs for these new refrigerants.

5. VEHICLE AND EQUIPMENT REPLACEMENT

GHG emissions and co-pollutant reductions were calculated using tools like AFLEET, the Diesel Emission Quantifier, and other highly credible methods to determine emissions reductions. We used data from previous heavy duty and agriculture vehicle replacements in Minnesota to determine the typical remaining life of the vehicle to be replaced and the typical pollutant reductions that accrue from replacements.

At the end of the useful life of the original replaced vehicle, we assume that, if not for this opportunity, the owner would replace it with a new, cleaner-burning diesel vehicle. New replacement vehicles were assumed to be active in 2025 and have a lifespan of 15 years, after which we assumed that funded charging infrastructure would increase the likelihood of the following replacement vehicle being electric rather than internal combustion. Because this measure increases electricity demand, we relied on AEO2023 GHG intensity projections for the Midcontinent West region under their "High uptake of Inflation Reduction Act" scenario to adjust the expected emissions avoided.

This grant opportunity will fund 25-50% of the cost of the new vehicle, dependent on vehicle type. There are no other state or federal funds contributing and the remaining costs will be funded by private capital. We assume that funds will be divided as follows: $6,788,815 for approximately 91 agricultural equipment replacements, $5,752,718 for approximately 30 electric on-road and off-road vehicle replacements, and $5,752,718 for approximately 36 electric terminal tractors.

6. PREVENTING FOOD WASTE AND ORGANICS MANAGEMENT

Composting: A hypothetical representative site was modeled for organics composting. Based on the modeled project, which requires $2.5 million in grant funding to construct, this measure can fund four organics composting sites. The remaining costs will be funded by private capital or local governments. Since funding will be competitive, the number and size of sites may differ from what was modeled, but the amount of material handled will likely be similar. The modeled site can compost 2,400 tons of SSOM or food waste annually. Yard waste and wood chips are already banned from disposal in landfills, so while they comprise about half of the weight of the compost recipe, they are not counted as waste diverted from landfills. We expect the sites funded to be operational by the end of 2028 and operating at full capacity during 2029. Based on the current operations of an existing, comparable facility in Minnesota, an additional 8,800 tons of food waste per year could be composted across the four facilities. The GHG emission reductions were estimated using the EPA's WARM model, with default settings, and the generic food waste category comparing composting and landfilling.

We would also allocate $6M to organics system support, which will enhance participation at currently existing compost facilities around the state, yielding an additional 1,836 tons of food waste diverted from landfills annually starting March 1, 2027. We assume these funds will continue to increase participation and efficiency until 2046, adding 1,836 tons of food waste diverted from landfills to compost annually every five years.

Finally, we will also offer a revolving organics loan program, half of which we assume will be used to fund facility expansions resulting in in additional contribution of 4,000 tons of food waste diverted from landfills to compost annually every five years.

Prevention of Wasted Food (PWF): Based on the final reports of eight previously awarded and completed MPCA PWF grant projects, per $1 million in grant funds, 6,686.72 MTCO2e can be reduced annually by PWF projects that are at full implementation (i.e., after projects are fully up and running). On average, a PWF project takes one year after being given access to funds to be fully operational and realize GHG savings. With $12.5 million going to approximately 45 PWF grant projects of varying sizes and project costs and realizing GHG savings at different points in time, the GHG emission reductions were calculated per million on two timelines. The GHG emission reductions were estimated using the EPA's WARM model.

Assuming half of the projects are fully operational beginning early 2027, and all remaining projects are fully operational in late 2027, then:

- GHGe reductions 2025-2030: 289,801 MT CO_2e
  - RFP Round #1 Projects: (6,686.72 x $6,260,703.44) x 3.84 years of full projects operations = 160,669.24 MTCO2e
  - RFP Round #2 Projects: (6,686.72 x $6,260,703.44) x 3.1 years of full projects operations = 129,131.74 MTCO2e
- GHGe reduction 2025-2050: 2,253,812 MT CO_2e
  - 2025-2030 = 289,801; plus
  - RFP Round #1 Projects 2031-2050: (6,686.72 x $6,686.72) x 23.8 years of full projects operations = 997,763.93 MTCO2e, plus
  - RFP Round #2 Projects 2031-2050: (6,686.72 x $6,686.72) x 23.08 years of full projects operations = 966,247.15 MTCO2e

Food-to-Livestock: Based on the reported data from the four farmers who feed swine with food waste in MN, each food-to-livestock operation diverts about 50,750 tons of food waste per year to livestock.[8] An

[8] MN SCORE report and Board of Animal Health

investment of $428,000 could fund four additional farmers beginning food-to-livestock operations, diverting about 203,000 tons of food annually. The total cost of an individual project is expected to be approximately $500,000, the remainder of which will be funded by private capital. The funds would primarily purchase the specialized trucks to haul and cook the food waste in preparation for feeding it to livestock. The cost of the truck is the significant expense involved in starting a food-to-livestock program, and substantial demand exceeds current capacity, so the projects should be self-sustained in the future after the initial investment. Food-to-livestock operations are assumed to be operational by the beginning of 2027. The GHG emission reductions were estimated using the EPA's WARM model using avoided methane from landfilling as a proxy for food-to-livestock.

Benefits from CPRG-funded investments can reasonably be assumed to continue after the initial funding because the grant dollars will primarily go towards capital costs such as construction, equipment purchases, and the costs of setting up programs. Prevention of wasted food projects are sustainable into the future once grant investments have been made. The food-to-livestock farmers have been in business for generations and consistently have more demand for their services than they have capacity, and grants will cover the initial equipment costs of new operations, so this is a very sustainable business model. Grants will cover the upfront costs of constructing new compost sites and kickstart sustainable collection and education programs designed to divert uncontaminated material to the sites. The revolving loan fund will allow compost sites to maintain and expand operations past the initial grant funding. Based on these insights, MPCA assumes that GHG savings for funded portions of these projects will remain constant through 2050.

7. FOOD SOVEREIGNTY AND VIBRANT LOCAL FOOD ECONOMIES

The GHG reduction activities for food sovereignty and local food economies are based on past and current work from MPCA's Prevention of Wasted Food grants, MDH SHIP, and RSDP projects.[9] The ReFED tool[10] was used to calculate most of the GHG emissions reductions from actions under this measure, using the database to extrapolate cost per ton to emissions reduced with a given investment.

Deep winter greenhouses were modeled using actual project specifications from existing greenhouses. A 60'x20' conventional hoop-house would require approximately 116 MMBtu of heating energy per year, and the deep winter greenhouse would need approximately 67.4 MMBtu of heating energy per year, a 42% reduction in energy use. The existing conventional greenhouse was assumed to use natural gas for heating, while a new deep winter greenhouse would use electricity. As this is added electricity demand, the AEO2023 electricity emission rate projections were used. A farm-scale deep winter greenhouse costs roughly $50,000 to build.

The funds set aside for Tribal Governments to spend on mitigation actions of their choice are assumed to be similar in cost effectiveness to the rest of this proposal. Therefore, we estimated the cost effectiveness of these funds by taking the dollar-weighted mean of all other GHG-mitigating actions in this proposal and then calculating the expected GHG reductions that would be accomplished by the funds apportioned to this project type.

[9] Regional Sustainable Development Partnerships projects, https://extension.umn.edu/regional-partnerships/rsdp-projects

[10] ReFED tool, https://insights-engine.refed.org/solution-database?dataView=total&indicator=us-dollars-profit