MINNESOTA
ENVIRONMENTAL QUALITY BOARD

Minnesota Climate Calculator

Final Report

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1 Overview

1.1 Purpose

The Minnesota Climate Calculator was developed to help project developers and responsible governmental units (RGUs) assess the full greenhouse gas (GHG) emissions impact potential of a project in Minnesota. The calculator also supports identification and implementation of mitigation and adaptation strategies. Outputs from the calculator may be used to complete the Environmental Assessment Worksheet (EAW), as required by potential projects that meet or exceed the thresholds described in [Minnesota Administrative Rule 4410.4300](). Specifically, the calculator may be used to answer the EAW items shown in Exhibit 1-1.

Exhibit 1-1. Relevant EAW Form Items

Item 7: Climate Adaptation and Resilience.

a. Describe the climate trends in the general location of the project and how climate change is anticipated to affect that location during the life of the project.

b. For each Resource Category in the table below: Describe how the project's proposed activities and how the project's design will interact with those climate trends. Describe proposed adaptations to address the project effects identified.

Item 18. Greenhouse Gas (GHG) Emissions/Carbon Footprint.*

a. GHG Quantification: For all proposed projects, provide quantification and discussion of project GHG emissions. Include additional rows in the tables as necessary to provide project-specific emission sources. Describe the methods used to quantify emissions. If calculation methods are not readily available to quantify GHG emissions for a source, describe the process used to come to that conclusion and any GHG emission sources not included in the total calculation.

b. GHG Assessment

  - Describe any mitigation considered to reduce the project's GHG emissions.
  - Describe and quantify reductions from selected mitigation, if proposed to reduce the project's GHG emissions. Explain why the selected mitigation was preferred.
  - Quantify the proposed projects predicted net lifetime GHG emissions (total tons/#of years) and how those predicted emissions may affect achievement of the Minnesota Next Generation Energy Act goals and/or other more stringent state or local GHG reduction goals.

* Items 7 and 18 were added to the EAW in December 2022.

→ Note that use of the Climate Calculator is not required to complete the EAW. Project developers and RGUs may use other approaches and resources to complete the EAW.

The calculator is intended to make the process of answering EAW items 7 and 18 more efficient, effective, and consistent. The calculator aims to minimize both the time and cost of filling out the form by providing a single resource and simplified input requirements. The calculator also aims to increase the completeness, accuracy, and defensibility of the calculations through the standardization of GHG accounting methods across project types and emission sources. Finally, the calculator can support comparison with other similar projects to gain insight about mitigation and adaptation approaches.

1.2 Approach

The calculator was constructed using a lifecycle analysis (LCA) approach, which quantifies environmental impacts associated with all stages of a product or project lifespan.[1] For the purposes of this calculator, the GHG emissions impact of project construction and project operation are evaluated.[2] The calculator also evaluates the potential for direct and indirect impacts, where **direct emissions** are emissions that are caused by project activities that occur on-site, and **indirect emissions** are emissions that occur upstream and downstream of the project (e.g., emissions associated with fuel production and other material inputs).

Our approach to developing the calculator involved an initial scoping exercise to identify potential sources of emissions that may occur as a result of a project across all mandatory categories. This effort involved reviewing various GHG accounting standards and the 39 project categories defined in the Minnesota Administrative Rule 4410.4300. Commonalities across project categories were also considered. Publicly available resources and existing tools were then reviewed to assess data availability. A wide range of data sources were examined to determine the age, accessibility, and applicability of the data, with an emphasis on using open-source resources to support transparency and future updates. Informed by this assessment, evaluation criteria were then developed against which to assess the feasibility and value of quantifying each potential emissions source. Criteria considered included the anticipated prevalence and magnitude of emissions, the complexity and feasibility of quantification methods, and data availability. Using the evaluation matrix, priority emission sources were identified for inclusion in the calculator. Detailed quantification methodologies were developed, data were collected, and the methodologies were refined. Where available, the calculator relies on data specific to Minnesota. In cases where Minnesota-specific data were not available, regional or national data is used. To fill remaining gaps, the calculator relies on data from other states or international sources.

A Technical Advisory Team was convened and met monthly throughout the calculator development process to provide continuous review and feedback on interim project deliverables. Sixteen individuals from state agencies and partnering organizations participated in the Technical Advisory Team. Team members contributed their expertise on project scoping and methodology development. In particular, members helped identify data sources most relevant to Minnesota and advised on general approaches, nuances, and data gaps. Members also participated in user acceptance testing and reviewing the draft calculator.

1 Although the calculator follows an LCA approach, it does not meet the ISO standard for an LCA. Additionally, the results of the calculator are not comparable to a standard GHG inventory, which typically quantifies emissions that occur during a single calendar or fiscal year.

[2] Emissions associated with project decommissioning may also be considered as part of an LCA but are not included in the calculator at this time.

1.3 Scope

The emissions quantified in the calculator aim to account for the full GHG impact of a project throughout the construction and operational phases of the project. The calculator quantifies emissions from project activities that occur on-site as well as emissions that occur upstream and downstream of the project. The calculator defines and quantifies emissions from 18 sources, as shown in Figure 1-1 and summarized in Table 1-1.

Figure 1-1. Scope of the Minnesota Climate Calculator

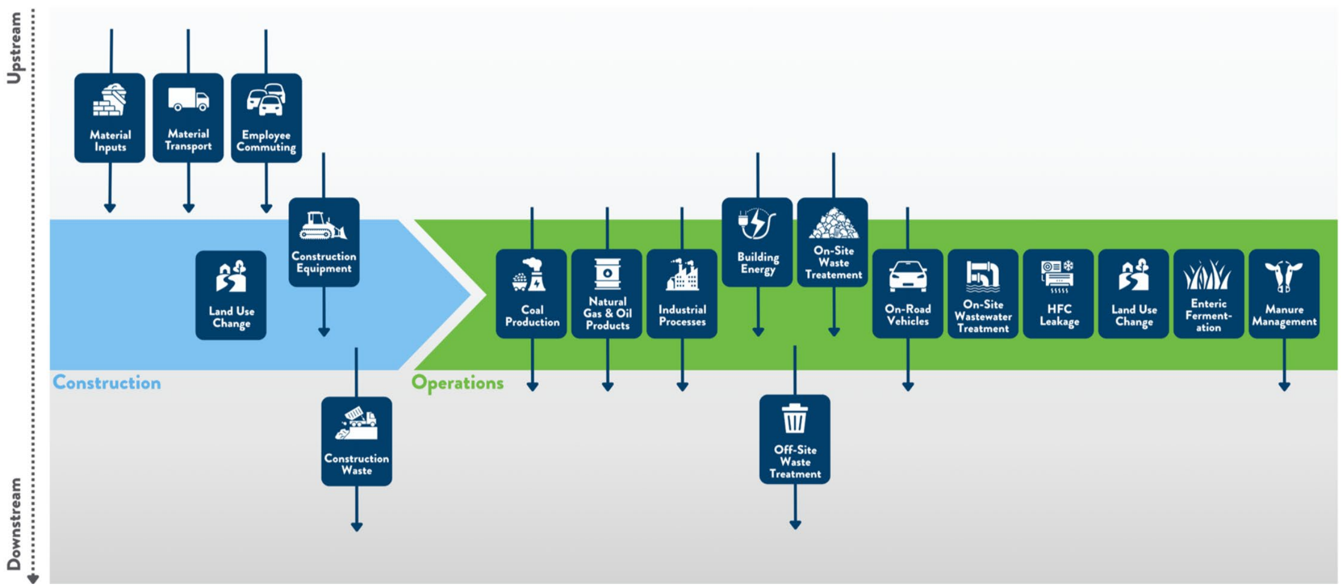

Table 1-1. Emission Sources Included in the Climate Calculator

Emissions Source	Description
Construction	
Material inputs	Emissions associated with the production of materials used during the construction phase of the project, including the extraction of raw materials, the transportation of raw materials to the manufacturing site, and the manufacturing of materials.
Transportation of material inputs	Emissions that result from transportation of construction materials from the manufacturing facility location to the project site (for use or installation) during the construction phase of the project.
Employee commuting	Emissions that result from employees commuting to the project site during the construction phase of the project.
Construction equipment	Emissions from electricity and fuel used in off-road construction equipment (e.g., dozers, excavators, loaders, generators, etc.) during the construction phase.
Land use change	The net carbon change from the transition of one land use type to another due to project construction.

Emissions Source	Description
Construction waste	Emissions from the transportation and treatment of waste generated during construction that is treated (e.g., landfilled) at a facility off-site.
Operation	
Building energy consumption	Emissions from a project's building energy consumption during the operational phase of the project. This includes on-site combustion of fuels (e.g., natural gas) as well as emissions from the generation of electricity consumed on-site.
Coal production	Emissions from the increased delivery of coal including upstream fugitive and direct emissions from the processing, storage, and transportation of coal as well as direct combustion emissions.
Natural gas and oil products	Emissions from the increased delivery of natural gas and oil products, including upstream fugitive and direct emissions from production, transmission, and distribution as well as direct combustion emissions.
Industrial processes	Emissions from the production of metals, minerals, chemicals, and other industrial activities. This includes emissions associated with the extraction of raw materials, their transportation to the industrial site, and the manufacturing process (including process emissions).
Land use change	The net carbon change from the transition of one land use type to another due to project operation.
HFC leakage	Emissions from hydrofluorocarbons (HFCs) that are used in air conditioning and refrigeration equipment during project operation. Leakage occurs from this equipment during installation, operation (including servicing), and disposal.
On-road vehicles	Emissions from on-road vehicles that are used during operation. This includes emissions generated on-site from vehicles that are driven on project roadways and downstream from vehicles driven to and from the project site by visitors or residents.
Treatment of waste on-site	Emissions from the on-site treatment of waste during project operations. This emissions source is applicable to landfills, waste incineration facilities, composting facilities, and anaerobic digesters.
Treatment of wastewater on-site	Emissions from municipal and industrial wastewater treatment plants including direct methane emissions from the wastewater treatment process and indirect nitrous oxide emissions from wastewater effluent.
Treatment of waste off-site	Emissions from the transportation and treatment of waste generated during project operation that is treated (e.g., landfilled, combusted) at a facility off-site.
Enteric fermentation	Emissions from enteric fermentation, or the digestive process of ruminant livestock, during project operation.
Manure management	Emissions from the process of managing livestock manure in solid or liquid systems during project operation, including direct and indirect emissions from managed manure and pasture and the land application of manure.

Emission Sources Not Included in the Climate Calculator

The applicability and degree of impact of each emissions source is heavily dependent on the specific project. Users of the calculator are encouraged to also assess and consider disclosing emissions from sources not covered by the calculator in their assessment of GHG emissions impact, to the extent possible. Emission sources that are not quantified in the calculator include:

- operational material inputs and transportation of material inputs;
- sulfur hexafluoride (SF_6) emissions from electrical transmission and distribution equipment;
- employee commuting during project operation;
- operational maintenance activities;
- changes in off-road vehicle, aircraft, or watercraft usage during project operation; and
- consumption of products generated.

These emission sources were deprioritized due to resource constraints and other factors such as difficulty in defining activities, expected magnitude of emissions, applicability across project types, and feasibility of accurate quantification.

2 Construction Emissions

This section details the methodologies used to quantify emissions that occur as a result of project construction.

2.1 Material Inputs

Emissions result from the production of materials used as inputs during project construction. Specifically, emissions result from the extraction of raw materials, the transportation of raw materials to the manufacturing site, and the manufacturing process. The calculator quantifies emissions for select material types based on the quantity of material used during construction and a material-specific emissions factor, as shown in Equation 1.

Equation 1. GHG Emissions from Material Inputs

$$GHG\ emissions = \sum material\ quantity_t \times emission\ factor_{t,s}$$

where,

Material quantity = Amount of material used as an input during construction by type, t (short tons)
Emissions factor = The emissions associated with the production of materials by type, t and geographic source, s ($kgCO_2e$/short ton)

Material Quantity

Users are required to provide data on the material quantity used during construction, by material type. All materials may be reported in short tons, though alternative units are available for select materials. The types of materials and the corresponding units for which users may provide data are summarized in Table 2-1.

Table 2-1. List of Material Types and Units Included in the Climate Calculator

Material Type	Available Units
Aluminum	short tons
Asphalt	short tons
Brick	short tons
Concrete	short tons, cubic yards
Glass	short tons
Insulation (residential)	short tons, square feet
Insulation (commercial)	short tons, square feet
Steel	short tons
Wood Products	short tons, cubic yards

Emission Factors

Emission factors for each material type are compiled from the Embodied Carbon Calculator (EC3) Tool.[3] The emission factors from the Environmental Product Declarations (EPD) in the EC3 database cover cradle to gate emissions, which include emissions from the extraction of raw materials; the energy consumption, process emissions, and ancillary input during manufacturing; the transportation of materials to the manufacturing site; and the waste generated during production. These activities are described as A1-A3 in compliance with the EPDs quantification methodology. For the purposes of this calculator, emission factors are developed for both domestically sourced and imported materials. Table 2-2 summarizes the availability of EPDs in the EC3 database as of December 2024, by material type and country of manufacturer.[4]

Table 2-2. EPD Availability from EC3 by Material as of December 2024

Material Type	United States	Other Countries
Aluminum	3	179
Asphalt	6,278	290
Brick	131	88
Concrete	74,074	7,665
Glass[a]	9	31
Insulation[b]	38	3
Steel	286	825
Wood Products	27	121

[a] Based on EPDs for flat glass products.

[b] Based on fiberglass batts (faced) insulation as fiberglass batts is commonly used for insulation in new construction.

To develop emission factors for imported materials, EPDs from select countries or regions are used as a proxy. For most material types, the largest importing country for each material serves as the proxy. However, due to limited EPD availability, in some cases EPDs from a specific region are relied on instead. Emission factors for imported concrete and asphalt are not developed, as these materials are typically sourced from local suppliers within a short driving distance of the construction site and are assumed to be domestically sourced. Table 2-3 summarizes the largest import country for each material and the proxy country/region used to develop the imported material emission factors used in the calculator.

[3] Building Transparency. "Embodied Carbon in Construction Calculator (EC3) Tool," 2025. https://www.buildingtransparency.org.

[4] The number of EPDs in EC3 vary over time as new EPDs are added to the database and other EPDs expire.

Table 2-3. Largest Source of Imports by Material Type

Material Type	Largest Import Country	Proxy	Source
Aluminum	Canada	Canada	Carbon Voyage Tool[5]
Asphalt	NA	NA	
Brick	China	Asia	The Observatory of Economic Complexity[6]
Concrete	NA	NA	
Glass	Belgium	Europe	The Observatory of Economic Complexity[7]
Insulation	Canada	Canada	Freedonia Group[8]
Steel	Canada	Canada	International Trade Administration[9]
Wood Products	Canada	Canada	United States International Trade Commission[10]

The EC3 interface provides the average emission factor for all EPDs that match the user's selected search criteria. Table 2-4 below shows the average emission factor by material type obtained from EC3 for the United States and each proxy import country/region listed in Table 2-3 above.

Table 2-4. Average Emission Factors from EC3, by Material Type

Material Type	Average Emissions Factor: U.S.	Average Emissions Factor: Top Importing Country/Region	Unit
Aluminum	3.24	3.27	$kgCO_2e$/pound
Asphalt	0.0351	NA	$kgCO_2e$/pound
Brick	0.203	0.345	$kgCO_2e$/pound
Concrete	287	NA	$kgCO_2e$/cubic yard
Glass	0.635	0.568	$kgCO_2e$/pound
Insulation[a]	0.0985	0.0985	$kgCO_2e$/square foot RSI[b]
Steel	0.787	0.792	$kgCO_2e$/pound

[5] Global Efficiency Intelligence. “Carbon Voyage Tool: Embodied Carbon in Trade,” 2024. https://www.carbonvoyagetool.com/.
[6] The Observatory of Economic Complexity. “Where Does United States Import Bricks from? (2022),” 2022. https://oec.world/en/visualize/tree_map/hs92/import/usa/show/136901/2022.
[7] The Observatory of Economic Complexity. “Float Glass in United States,” 2023. https://oec.world/en/profile/bilateral-product/float-glass/reporter/usa.
[8] Freedonia Group. “US Insulation,” 2022. https://www.freedoniagroup.com/industry-study/insulation-4304.htm.
[9] International Trade Administration. “U.S. Steel Executive Summary,” 2024. https://www.trade.gov/data-visualization/us-steel-executive-summary.
[10] Scott, Sarah and Ireland, Robert. “Forest Products.” United States International Trade Commission, 2017. https://www.usitc.gov/research_and_analysis/trade_shifts_2017/forestry.htm.

Material Type	Average Emissions Factor: U.S.	Average Emissions Factor: Top Importing Country/Region	Unit
Wood Products	150	140	$kgCO_2e$/cubic yard

[a] Insulation emission factors are based on a fiberglass batts (faced) North American Industry EPD from the North American Insulation Manufacturing Association (NAIMA) for domestic and imported products from Canada, the top importing country for Insulation.
[b] RSI stands for "R-value Systeme International," a metric system unit measurement of thermal resistance.

Using the conversion factors described in the subsequent section, the emission factors are converted to $kgCO_2e$/short ton. The resulting emission factors are summarized in Table 2-5.

Table 2-5. Emission Factors Used in the Climate Calculator, by Material Type

Material Type	Domestically Sourced	Imported	Units
Aluminum	6,480	6,540	$kgCO_2e$/short ton
Asphalt	70	NA	$kgCO_2e$/short ton
Brick	406	690	$kgCO_2e$/short ton
Concrete	147	NA	$kgCO_2e$/short ton
Glass	1,270	1,136	$kgCO_2e$/short ton
Insulation	2,284	2,284	$kgCO_2e$/short ton
Steel	1,574	1,584	$kgCO_2e$/short ton
Wood Products	339	316	$kgCO_2e$/short ton

Conversion Factors

For the purposes of the calculator, the emission factors in Table 2-4 are converted into $kgCO_2e$/short ton. For aluminum, asphalt, brick, glass, and steel, the emission factors are converted into $kgCO_2e$/short ton using the conversion rate of 2,000 pounds per short ton. For wood products, concrete, and insulation, additional assumptions regarding product density and RSI value are required, as described in the sections below. Key unit conversions are summarized in Table 2-6.

Table 2-6. Material-Specific Unit Conversions

Material Type	Conversion Factor	Units
Insultation (residential)	0.00030	short ton/square foot
Insultation (commercial)	0.00022	short ton/square foot
Concrete	1.958	short tons/cubic yard
Wood Products	0.443	short tons/cubic yard

Wood Products

The average density of the seven most used wood types in construction, including a mix of softwoods and hardwoods, are used to derive the density for the wood products material type in the calculator. The density of each of these seven wood types and the calculated average density are shown in Table 2-7. These average densities are derived from MT Copeland, an online platform that offers a variety of construction training courses.[11] The calculated average density in pounds per cubic yard are converted to short tons per cubic yard (as shown in Table 2-6) using the conversion rate of 2,000 pounds per short ton.

Table 2-7. Commonly Used Wood Type Densities, via MT Copeland

Wood Type	Average Density (pounds/cubic yard)
Aspen	702.0
Hickory	1,282.5
Balsa	216.0
Pine	1,012.5
Cedar	796.5
Spruce	931.5
Oak	1,255.5
Average	**885.2**

Concrete

The average density of the six most common ready mix concrete compressive strength products from the North Central Region of the United States (which includes Minnesota), is used to derive the density for the Concrete material type in the calculator. The density of each of these six ready mix concrete product types and the calculated average density are shown in Table 2-8. These densities are derived from table B4 in the 2022 cradle to gate life cycle assessment conducted by the National Ready Mixed Concrete Association (NRMCA).[12] The calculated average density in pounds per cubic yard is converted to short tons per cubic yard (as shown in Table 2-6) using the conversion rate of 2,000 pounds per short ton.

Table 2-8. NRMCA North Central Region Ready Mix Concrete Densities by Compressive Strength Product

Ready Mix Concrete Compressive Strength (psi)	Average Density (pounds/cubic yard)
Ready Mix Concrete 2500 psi	3,862

[11] M.T. Copeland Technologies. "Wood Density Explained, Plus Wood Density Chart," September 24, 2020. https://mtcopeland.com/blog/wood-density-explained-plus-wood-density-chart/.
[12] The Athena Sustainable Materials Institute. "A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by NRMCA Members," July 2022. https://www.nrmca.org/wp-content/uploads/2022/02/NRMCA_LCAReportV3-2_20220224.pdf.

Ready Mix Concrete Compressive Strength (psi)	Average Density (pounds/cubic yard)
Ready Mix Concrete 3000 psi	3,850
Ready Mix Concrete 4000 psi	3,860
Ready Mix Concrete 5000 psi	3,843
Ready Mix Concrete 6000 psi	4,032
Ready Mix Concrete 8000 psi	4,047
Ready Mix Concrete 2500 psi	3,862
Average	**3,916**

Insulation

R-values (thermal resistance values) for ceiling and wall insulation for residential and commercial buildings are obtained from the 2024 International Energy Conservation Code for Minnesota's specific climate type (6a) and then averaged to derive a single R-value for residential and commercial insulation.[13] These two residential and commercial R-values are then converted to RSI using the standard conversion factor of dividing the R-value by 5.678.[14] Table 2-9 summarizes the R-value and RSI value of both insulation types.

Table 2-9. Insulation Thermal Resistance (R-Value) Assumptions

Insulation Type	R-Value			RSI Value
	Ceilings	Walls	Average	
Residential	49.0	30.0	39.5	7.0
Commercial	38.0	19.6	28.8	5.1

The emission factor from EC3 for insulation in Table 2-4 is for $kgCO_2e$/square foot RSI where RSI=1. The RSI value assumptions summarized in Table 2-9 are multiplied by the emission factor from EC3 for insulation in Table 2-4 to derive separate emission factors for residential and commercial insulation in $kgCO_2e$ per square foot, as shown in Table 2-10.

Table 2-10. Insulation Emission Factors

Insulation Type	$kgCO_2e$/square foot
Residential	0.685
Commercial	0.500

[13] International Code Council. "2024 International Energy Conservation Code (IECC)," 2024. https://codes.iccsafe.org/content/IECC2024P1/index.

[14] The R-value is an imperial system unit of thermal resistance while RSI is a metric system unit of thermal resistance with a standard conversion factor. See: CleanBC Better Homes. "What Is R (or RSI) Value of Insulation?," 2022. https://www.betterhomesbc.ca/products/what-is-r-or-rsi-value/.

Assumptions regarding density and thickness are then used to convert the emission factors into $kgCO_2e$ per short ton. Density and thickness assumptions, as shown in Table 2-11, are taken directly from the NAIMA Fiberglass Batts EPD[15], which is the same source used for the insulation emission factor value in Table 2-4. The thickness per RSI value (in millimeters) is multiplied by the RSI value for each insulation type and then multiplied by the density (in kilograms/cubic meter) and converted to tons/square foot (as shown in Table 2-6) using the conversion rate of 907 kilograms per short ton and 0.093 square meters per square foot.

Table 2-11. Insulation Density and Thickness Assumptions

Density (kilogram/cubic meter)	Thickness per RSI value (mm)
12.03	35

When converted to $kgCO_2e$/short ton, the emission factors for residential and commercial insulation are the same, as shown in Table 2-5. This is because insulation of the same material type (e.g., fiberglass batts) has a constant density across RSI values.

Material Source Defaults

In the calculator, users may identify whether material inputs are domestically sourced or imported. In cases when the material sourcing is unknown, the calculator applies a weighted average emissions factor based on the estimated percent of the material imported into the United States. The import assumptions and data sources used to derive these assumptions are summarized in Table 2-12. For some material types (specifically wood products, insulation, and brick), sufficient information was not identified to develop a defensible assumption for the percent imported. In these cases, a default of 16 percent is applied, which is calculated by dividing the dollar value of all 2022 U.S. imports by 2022 U.S. Gross Domestic Product (GDP).[16]

Table 2-12. Material Percent Imported Assumptions

Material	Percent Imported	Source	Source Notes
Aluminum	30%	The Aluminum Association[17]	Imports represented nearly 30% of supply in 2018.
Asphalt	0%	National Asphalt Pavement Association (NAPA)[18]	Almost all (88%) of asphalt binder used in the United States is from U.S. refineries and manufacturers. Note that asphalt pavement is only 5% asphalt binder, 95% is aggregate.

[15] North American Insulation Manufacturers Association. "Fiberglass Batts (Faced)." Smart EPD, 2023. https://smartepd.com/epd-library/64133a6cceeabedac05df74d#.
[16] Statista. "U.S. Imports 1990-2022 as a Percentage of GDP," 2024. https://www.statista.com/statistics/259096/us-imports-as-a-percentage-of-gdp/.
[17] The Aluminum Association. "Industry Statistics," January 2020. https://www.aluminum.org/sites/default/files/2021-11/FactSheet2018.pdf.
[18] National Asphalt Pavement Association. "Imports & The Asphalt Pavement Industry," n.d. https://www.asphaltpavement.org/uploads/documents/Buy_America_Impacts_on_Asphalt.pdf.

Material	Percent Imported	Source	Source Notes
Brick	16%	NA	Assumed as Generic 2022 Imports to GDP Ratio.
Concrete	0%	SME	Ready mix concrete needs to be manufactured (mixed) within ~0.5-1-hr drive of site.
Glass	8%	World Glass Report 2022[19]	In 2022, the United States imported $122 million in float glass, which is about 8% of the total supply in North America. There is more uncertainty with this import assumption than steel.
Insulation	16%	NA	Assumed as Generic 2022 Imports to GDP Ratio.
Steel	23%	International Trade Administration[20]	Import penetration for steel mill products, excluding semi-finished products as of March 2024 (data from American Iron and Steel Institute).
Wood Products	16%	NA	Assumed as Generic 2022 Imports to GDP Ratio.

Limitations

Key limitations of the methodology used to quantify emissions from material inputs include:

- The emission factors for each material type are compiled using EPDs from EC3. The availability of EPDs in EC3 for each material type affects the relative certainty of the emission factors used in the calculator, as the calculator applies the average emission factor value for all EPDs that match the user's selected search criteria in EC3. Therefore, materials with a smaller sample size of EPDs, such as aluminum and glass, carry higher uncertainty. Additionally, as EPDs are self-reported by manufacturers, they are likely to underestimate the actual average material emissions intensities in the market as higher emitting manufacturers have no incentive to produce and report EPDs.
- The calculator assumes that all imported materials originate from the largest importing country for each material and applies the emission factor from that country to all imports. This simplified assumption introduces uncertainty in real-world applications. For instance, the calculator assumes that all steel imports come from Canada, the largest steel importer to the United States. However, if a development project in Minnesota sources all its steel from China, which has a more emissions-intensive manufacturing process, the calculator would underestimate the embodied emissions of the steel used in the project.
- Simplified density conversion factors are required to calculate emissions for wood, concrete, and insulation. These conversion factors carry uncertainty, due to the wide range of product-specific densities within the broader wood, concrete, and insulation material categories.

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[19] National Glass Association and Norah Dick. "World of Glass 2022 Report." Glass Magazine, 2023. https://www.glassmagazine.com/article/world-glass-2022-report.

[20] International Trade Administration. "U.S. Steel Executive Summary," 2024. https://www.trade.gov/data-visualization/us-steel-executive-summary.

- The material source defaults applied in the calculator, detailed in Table 2-12, also carry uncertainty. For some material types (specifically wood products, insulation, and brick), there is not enough information available to develop a defensible assumption for the percent imported. The default of 16% that is applied may not be representative of import frequency for a given material.

2.2 Transportation of Material Inputs

Emissions result from the transportation of construction materials from the manufacturing facility to the project site (for use or installation) during the construction phase of the project. The calculator quantifies emissions from the transportation of select material types based on the quantity of material used during construction, the average distance traveled from the source facility by transportation mode, and a mode-specific emissions factor, as shown in Equation 2.

Equation 2. GHG Emissions from Transportation of Material Inputs

$$GHG\ emissions = \sum material\ quantity_t \times distance_{m,s} \times emission\ factor_m$$

where,

Material quantity	= Amount of material used as an input during construction by type, t (short tons)
Distance	= Distance the material product travels from the manufacturing location to the project site by transportation mode, m, and geographic source, s (miles)
Emissions factor	= The emissions associated with the transportation of material quantity by transportation mode, m (kg CO_2e/ton-mile)

Material Quantity

The material quantity by material type is based on values provided by users. The input quantities used to calculate emissions from the transportation of materials to the construction site are the same inputs used to calculate the material inputs emissions that are summarized in Section 2.1, Table 2-1.

Distance Traveled

Data from the 2017 Census Commodity Flow Survey (CFS) on domestic shipments of goods to Minnesota by North American Industry Classification System (NAICS) code category is used to develop assumptions on the average distance traveled by material type.[21] As a first step, each material included in the calculator is mapped to the closest corresponding manufacturing NAICS code, as summarized below in Table 2-13.

[21] United States Census Bureau. "2017 Commodity Flow Survey Datasets," 2017. https://www.census.gov/data/datasets/2017/econ/cfs/historical-datasets.html.

Table 2-13. NAICS Codes Mapped to Material Types

Material Type	NAICS Code Mapped
Aluminum	331- Primary Metal Manufacturing
Asphalt[a]	NA
Brick	327- Nonmetallic Mineral Product Manufacturing
Concrete[a]	NA
Glass	327- Nonmetallic Mineral Product Manufacturing
Insulation	327- Nonmetallic Mineral Product Manufacturing
Steel	332- Fabricated Metal Product Manufacturing
Wood Products	321- Wood Product Manufacturing

[a] CFS data were not used to develop assumptions for Asphalt and Concrete.

The CFS data are then used to calculate the average distance traveled within the United States per shipment to Minnesota for each NAICS code category (see Table 2-14). This is calculated for each relevant NAICS code category by dividing the total number of miles traveled by the total number of shipments. For example, to calculate the average distance traveled of Steel (NAICS Code 331) shipped to Minnesota, the total miles of all 2017 steel shipments to Minnesota (roughly 260 million) is divided by the total number of steel shipments to Minnesota (roughly 553,000), resulting in an average steel shipment distance of approximately 470 miles.

Table 2-14. Average Distance Traveled by Materials Sourced Domestically

Material	Distance Traveled: Domestic Shipments (miles)
Aluminum	607
Asphalt	30[a]
Brick	196
Concrete	30[b]
Glass	196
Insulation	196
Steel	470
Wood Products	381

[a] This is a conservative estimate based on industry constraints for Asphalt to be delivered within 30 miles of the paving site.[22]
[b] This is a conservative estimate based on industry constraint for ready mix concrete to be delivered within a 30-60 minute drive of the project site. This 30-mile distance assumes a 45-minute drive at an average speed of 40 mph.

[22] Luton Group. "How Far Can Asphalt Be Transported," 2024. https://lutonmachinery.com/how-far-can-asphalt-be-transported/.

For imported materials, the distance traveled is derived by assuming that imports travel from the largest metro area in the largest import country for each material type. For Glass and Brick materials, which are sourced from outside of North America, it is assumed that the materials are shipped via water transport to the port of Newark, New Jersey and then transported from Newark to Minneapolis. The water shipping distance is calculated using travelmath.com[23] to determine the total non-land distance of the imported good. All other imported materials are assumed to be sourced from Canada and their import distance is calculated as the distance from Toronto to Minneapolis. Table 2-15 shows the top importing country, the largest metro area, and the assumed total import distances for each material.

Table 2-15. Import Transportation Assumptions and Distances

Material	Top Importing Country	Large Metro Area	Land Distance to Minneapolis	Non-Land Distance to Newark, NJ Port
Aluminum	Canada	Toronto	927	NA
Asphalt[a]	NA	NA	NA	NA
Brick	China	Shanghai	1,196	7,379
Concrete[a]	NA	NA	NA	NA
Glass	Belgium	Brussels	1,196	3,674
Insulation	Canada	Toronto	927	NA
Steel	Canda	Toronto	927	NA
Wood Products	Canada	Toronto	927	NA

[a] No imports for concrete and asphalt are assumed as these materials are typically sourced close to the construction site.

The total average distance traveled by imports to Minnesota by material type is then calculated based on the assumptions shown in Table 2-15. These distances are summarized in Table 2-16 below.

Table 2-16. Average Distance Traveled by Materials Imported

Material	Distance Traveled: Imports (miles)
Aluminum	927
Asphalt	NA
Brick	8,575
Concrete	NA
Glass	4,870
Insulation	927
Steel	927
Wood Products	927

[23] TravelMath. "Travelmath Trip Calculator," 2025. https://www.travelmath.com/.

Mode Distribution

The CFS data are used to determine the breakout of miles by mode for domestically sourced materials. The mode distribution for each material type is calculated by dividing the total number of miles traveled by mode by the total number of miles traveled for each relevant NAICS code category. For material imports for which the top import country is in North America (i.e., Steel, Wood Products, Aluminum, and Insulation), the calculator applies the domestic mode distribution assumptions developed using the CFS data. For Brick and Glass, where the top import country is outside of North America, the calculator assumes that the material is shipped via water transport from outside North America to Newark. For the domestic portion of the trip (i.e., Newark to Minneapolis), the calculator applies the domestic mode distribution assumptions developed using the CFS data. The resulting mode distributions for each material type are summarized in Table 2-17.

Table 2-17. Mode Breakout Assumptions by Material Type and Source

Material	Domestically Sourced				Imports			
	Truck	Air	Rail	Water	Truck	Air	Rail	Water
Aluminum	94.7%	3.9%	1.4%	0%	94.7%	3.9%	1.4%	0%
Asphalt	100%	0%	0%	0%	NA	NA	NA	NA
Brick	98.4%	0%	1.6%	0%	13.7%	0%	0.2%	86.1%
Concrete	100%	0%	0%	0%	NA	NA	NA	NA
Glass	98.4%	0%	1.6%	0%	24.2%	0%	0.4%	75.4%
Insulation	98.4%	0%	1.6%	0%	98.4%	0%	1.6%	0%
Steel	98%	1.8%	0.2%	0%	98%	1.8%	0.2%	0%
Wood Products	95.6%	0%	4.4%	0%	95.6%	0%	4.4%	0%

The resulting distances by mode for domestically sourced and imported materials by material type are summarized in Table 2-18. If the source of the material is unknown, the distances are weighted based on the material source defaults summarized in Section 2.1, Table 2-12.

Table 2-18. Distance Traveled Assumptions by Material Type and Source

Material	Domestically Sourced (miles)				Imports (miles)			
	Truck	Air	Rail	Water	Truck	Air	Rail	Water
Aluminum	574.8	23.8	8.5	0.0	877.7	36.3	13.0	0.0
Asphalt	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brick	192.4	0.0	3.2	0.0	1,176.7	0.0	19.3	7,379.0
Concrete	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glass	192.4	0.0	3.2	0.0	1,176.7	0.0	19.3	3,674.0
Insulation	192.4	0.0	3.2	0.0	912.0	0.0	15.0	0.0

Material	Domestically Sourced (miles)				Imports (miles)			
	Truck	Air	Rail	Water	Truck	Air	Rail	Water
Steel	192.4	0.0	3.2	0.0	912.0	0.0	15.0	0.0
Wood Products	461.0	8.4	1.0	0.0	908.4	16.6	2.0	0.0

Emission Factors

Emission factors by transportation mode were compiled from the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model.[24] The emission factors from GREET 1 2024 cover "well to wheel" emissions associated with the transportation of goods, covering all life cycle stages from the extraction of raw materials (well) to the final use of the fuel in vehicles (wheels). Table 2-19 below summarizes the emission factors by transportation mode while Table 2-20 summarizes the assumptions selected in GREET 1 2024 to develop them. The emission factors in Table 2-19 are linearly interpolated to derive year-specific factors for all other years between 2025 to 2050 and are applied in the calculator based on the year in which the project is constructed. Transportation emission factors are expected to change slightly over time as improvements in vehicle technology and/or regulatory standards are implemented.

Table 2-19. Emission Factors by Transportation Mode and Year

Mode	Emission Factor (kgCO_2e/ton-mile)*					
	2025	2030	2035	2040	2045	2050
Truck	0.079	0.071	0.065	0.065	0.065	0.058
Rail	0.026	0.026	0.026	0.026	0.026	0.026
Aircraft	0.437	0.415	0.413	0.413	0.412	0.409
Watercraft	0.025	0.025	0.025	0.025	0.025	0.025

* Values shown are based on AR5 global warming potentials.

Table 2-20. Emission Factors Assumptions by Transportation Mode

Mode	Fuel Type	Modifications to GREET Default Assumptions
Truck	Diesel	MN Grid Electricity; Combination Long-Haul Trucks, diesel is baseline fuel
Rail	Diesel	MN Grid Electricity, Freight Rail
Aircraft	HEFA from Soybeans	MN Grid Electricity, Freight Aircraft, Large Twin Aisle, HEFA from Soybean
Watercraft	FT-Diesel (NG)	MN Grid Electricity; Medium Speed Diesel engine type; FT-Diesel (NG) fuel used to cruise; Large Container; Foreign Travel in Atlantic Ocean

[24] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Limitations

Key limitations of the methodology used to quantify emissions from transportation of material inputs include:

- The average domestic distance traveled for each material type is based on 2017 data, which is the latest year for which CFS data are available. Additionally, the CFS data are organized by NAICS codes, which do not correspond directly to each material type included in the calculator.
- For imported materials, the distance traveled is estimated by assuming all imports originate from the largest importing country for each material. For materials like glass and brick, sourced from outside North America, the calculator assumes they are shipped via water transport to Newark and then transported from Newark to Minneapolis. This is a simplified assumption due to the high variability of how imported goods may travel to Minnesota.
- The simplified import distance assumptions introduce additional uncertainty in real-world applications. For instance, the calculator assumes that all steel imports come from Canada, the largest steel importer to the United States. However, if a development project in Minnesota sources all its steel from China, the calculator would underestimate the emissions from transportation of steel to the construction site for the project.

2.3 Employee Commuting

Emissions result when employees commute to and from the project site during project construction.[25] This includes emissions from driving personal vehicles and taking public transit. The calculator quantifies emissions from employee commuting based on estimates of the total distance traveled, the commuter mode, and mode-specific emission factors, as shown in Equation 3 and Equation 4.

Equation 3. Total Distance Traveled by Employees

$$total\ distance = \sum employees_p \times construction\ days_p \times distance$$

where,

Employees	= Number of employees commuting each day by construction phase, p (employees/day)
Construction days	= Number of construction days by phase, p (days)
Distance	= Average distance traveled by employees to and from the project site each day (miles/day)

[25] Emissions may also result from employee commuting during project operation; however, these emissions are not currently included within the scope of the climate calculator.

Equation 4. GHG Emissions from Employee Commuting

$$GHG\ emissions = \sum total\ distance \times\ emission\ factor_m\ \times mode_m$$

where,

Total distance	= Total miles traveled by employees to and from the project site, as calculated in Equation 3
Emission factor	= GHG emissions per mile traveled per person by commuting mode, m (kgCO_2e/passenger mile)
Mode	= The percent of employees that commute to work by commuting mode, m (%)

Employees

Users are required to provide data on the number of employees that will commute to the construction site during each phase of construction. The construction phases for which users must provide data include:

- Demolition
- Site Preparation
- Grading
- Building Construction
- Architectural Coating
- Paving

Construction Days

Default assumptions regarding the number of construction days by construction phase are available in the calculator. The default number of construction days by construction phase are based on values derived from the California Emissions Estimator Model (CalEEMod).[26] Specifically, Appendix G, Table G-7 of the User Guide provides estimates of the number of construction days by construction phase and project size (in acres).[27] These data were used to estimate the number of construction days by construction phase per acre, as summarized in Table 2-21. Users may apply the default values that are derived using user provided project acreage to estimate the number of construction days by phase, or they may enter the number of days by phase directly into the calculator.[28]

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[26] California Air Pollution Control Officers Association. "CalEEMod," 2022. https://www.caleemod.com/.

[27] The default data in CalEEMod was derived using results from the South Coast Air Quality Management District Construction Survey. The survey collected data from a set of construction projects in Southern California ranging from 0-30 acres in size. Survey results were extrapolated out to projects over 30 acres based on data trends. See Appendix D1 of the CalEEMod user guide for more information on the methodology and results of this survey data, https://www.caleemod.com/user-guide.

[28] The South Coast Air Quality Management District survey data are from building construction projects only. Therefore, it is only appropriate to use this data to develop default assumptions for proposed building construction projects. For other project types that are considered non-building construction (e.g., pipelines, roads, recreational trails), it is recommended that users manually input data on the number of construction days.

Table 2-21. Project Duration Assumptions

Project Acreage		Project Duration (Days/Acre)					
Low	High	Demolition	Site Preparation	Grading	Building Construction	Architectural Coating	Paving
0.01	1.99	10.0	1.0	2.0	100.0	5.0	5.0
2.00	2.99	10.0	1.0	2.0	100.0	5.0	5.0
3.00	4.99	6.7	1.0	2.0	73.3	3.3	3.3
5.00	9.99	4.0	1.0	1.6	46.0	3.6	3.6
10.00	14.99	2.0	1.0	2.0	23.0	2.0	2.0
15.00	19.99	1.3	0.7	2.0	20.0	1.3	1.3
20.00	24.99	1.0	0.5	1.5	15.0	1.0	1.0
25.00	29.99	0.8	0.4	1.4	14.8	0.8	0.8
30.00	33.99	1.0	0.7	1.5	14.7	1.2	1.2
34.00	49.99	0.9	0.6	1.3	14.7	1.0	1.0
50.00	74.99	1.0	0.6	1.5	14.8	1.1	1.1
75.00	99.99	0.9	0.5	1.5	14.8	1.0	1.0
100.00	10,000	1.0	0.6	1.6	15.5	1.1	1.1

Commuting Distance

The average commuting distance was acquired from the U.S. Environmental Protection Agency (EPA) Local GHG Inventory Tool, which assumes an average one-way commuting distance of 13.2 miles or a round-trip distance of 26.4 miles.[29] Users may apply the default commuting distance value or enter their own value.

Commuting Mode

The commuting mode assumptions were derived from EPA's Local GHG Inventory Tool, as summarized in Table 2-22.[30] Users may apply the default commuting mode breakout assumptions or enter their own values.

Table 2-22. Commuting Mode Assumptions

Commuting Mode	Percent of Employees[a]
Single Occupancy Vehicle	81.7%
Carpool	10.6%

[29] EPA. "Local GHG Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool.
[30] EPA. "Local GHG Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool.

Commuting Mode	Percent of Employees[a]
Motorcycle	0.2%
Bus	1.9%
Transit Rail	2.2%
Bike/Walk	3.4%

[a] Assumptions exclude the following mode types: "work from home" and "other."

Emission Factors

Upstream emission factors by mode in kgCO_2e/passenger mile were derived by multiplying fuel consumption estimates in Btu/passenger mile by emission factors in kgCO_2e/Btu. Fuel consumption estimates for single occupancy vehicles, buses, and transit rail were acquired from GREET1 2024 for calendar year 2025.[31] The value for carpools was calculated by dividing the value for single occupancy vehicles by the average number of people in a carpool (2.47), as acquired from EPA's Local GHG Inventory Tool.[32] The value for motorcycles was calculated by multiplying the heat content of gasoline (in Btu/gallon) from EPA's GHG Emission Factors Hub[33] by the fuel use assumption for motorcycles from EPA's Local GHG Inventory Tool (in gallons/mile).[34] The resulting fuel consumption assumptions in Btu/passenger mile along with the assumed fuel used by each mode are summarized in Table 2-23.

Table 2-23. Assumed Fuel Type and Energy Consumption by Mode

Commuting Mode	Fuel Type	Energy Use (Btu/passenger mile)[a]
Single Occupancy Vehicle	Gasoline	4,004
Carpool	Gasoline	1,621
Motorcycle	Gasoline	2,841
Bus	Diesel	471
Transit Rail	Electricity	789
Bike/Walk	NA	0

[a] Although values are likely to decrease over time, estimates for calendar year 2025 are conservatively assumed to remain constant at calendar year 2025 levels.

The emission factors in kgCO_2e/Btu were derived based on data obtained from EPA's GHG Emission Factors Hub and GREET1 2024. The upstream emission factors for gasoline and diesel were derived from GREET1 2024 (see

[31] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[32] EPA. "Local GHG Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool.
[33] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[34] EPA. "Local GHG Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/local-greenhouse-gas-inventory-tool.

Table 2-24).[35] The combustion emission factors by vehicle type for passenger cars, motorcycles, and buses were acquired directly from EPA's GHG Emission Factors Hub (see Table 2-25).[36] The grid average electricity emission factors by year for electricity consumed by transit rail were derived based on the methodology described in Appendix C (see Table 2-26). The resulting emission factors by mode are shown in Table 2-27.

Table 2-24. Upstream Emission Factors

Fuel Type	Upstream Emission Factor ($kgCO_2e/MMBtu$)[a]
Gasoline	22.86
Diesel	16.11

[a] Values shown are based on AR5 global warming potentials.

Table 2-25. Combustion Emission Factors

Vehicle Type	Combustion Emission Factor[a]	Unit
Passenger Car	0.30	$kgCO_2e$/vehicle mile
Motorcycle	0.37	$kgCO_2e$/vehicle mile
Bus	0.07	$kgCO_2e$/passenger mile

[a] Values shown are based on AR5 global warming potentials.

Table 2-26. Electricity Emission Factors

Electricity Provider	Emission Factor ($kgCO_2e/MMBtu$)[a]					
	2025	2030	2035	2040	2045	2050
Grid Average	116.62	42.63	21.32	0.00	0.00	0.00

[a] Values shown are based on AR5 global warming potentials.

Table 2-27: Emission Factors by Mode

Commuting Mode	Emission Factor ($kgCO_2e$/passenger mile)[a]		
	Upstream	Combustion	Total
Single Occupancy Vehicle	0.09	0.30	0.39
Carpool	0.04	0.12	0.16
Motorcycle	0.06	0.37	0.43
Bus	0.01	0.07	0.07
Transit Rail	NA	NA	0.09[b]

[35] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[36] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Commuting Mode	Emission Factor ($kgCO_2e$/passenger mile)[a]		
	Upstream	Combustion	Total
Bike/Walk	0.00	0.00	0.00

[a] Values shown are based on AR5 global warming potentials.

[b] Value shown reflects a 2025 construction start date and accounts for upstream and combustion emissions.

Limitations

Key limitations of the methodology used to quantify emissions from employee commuting include:

- The default mode breakdown, which is based on national averages, may not accurately reflect the actual commuting behavior of employees for a given project. In some cases, certain commuting modes, such as bus and transit rail, may not be viable options depending on the location of the project.
- The default commuting distance, which is based on national averages, may not reflect the actual average commuting distance of employees to a project site, depending on the location of the project.
- Emission factors for different modes of transportation can vary based on numerous factors such as vehicle type, fuel efficiency, and driving conditions. The methodology assumes a single representative emission factor for each mode, which may not reflect actual project conditions. The upstream emission factors conservatively assume use of conventional fuels (i.e., gasoline and diesel) and are not tailored to the current mix of vehicles on the road. In addition, the emission factors are based on estimates for calendar year 2025 and are not assumed to change over time, even though it is likely that these emission factors will decrease.

2.4 Construction Equipment

Emissions result from the fuel and/or electricity used by construction equipment (e.g., dozers, excavators, loaders) during project construction. The calculator quantifies emissions from construction equipment based on estimates of total construction hours by equipment type, energy consumption per hour, and equipment-specific emission factors, as shown in Equation 5 and Equation 6.

Equation 5. Total Construction Hours by Equipment Type

$$total\ hours_t = \sum construction\ days_p \times hours_{t,p}$$

where,

Construction days = Number of construction days by phase, p (days)
Hours = Total hours per day each equipment type, t, is used by phase, p (hours/equipment/day)

Equation 6. Emissions from Construction Equipment

$$GHG\ emissions = \sum total\ hours_t \times horsepower_t \times load\ factor_t \times consumption\ rate_t \times emission\ factor_{t,s}$$

where,

Total hours	= Total construction hours by equipment type, t, as calculated in Equation 5
Horsepower	= Horsepower of equipment type, t
Load factor	= Ratio of actual load carried by equipment to its maximum rated capacity by equipment type, t
Consumption rate	= Hourly energy consumption by equipment type, t (Btu/horsepower-hour)
Emission factor	= GHG emissions per unit of energy consumed by equipment type, t, and energy source, s ($kgCO_2e$/Btu)

Construction Days

Default assumptions regarding the number of construction days by construction phase are available in the calculator. The default number of construction days by construction phase are based on values derived from CalEEMod, as described in Section 2.3 and summarized in Table 2-21.[37] Users may apply the default values that are derived using user provided project acreage to estimate the number of construction days by phase, or they may enter the number of days by phase directly into the calculator.[38]

Construction Equipment Use

Data on the number of construction equipment by type used per day and the number of hours each equipment type is used per day by construction phase are obtained from CalEEMod Appendix G, Table G-9.[39] These data vary by project acreage. Users have the option to apply the default values that correspond with the user provided project acreage to derive the total number of hours per day by equipment type per construction phase, or they may provide their own estimates of the total hours per day by equipment type per construction phase.[40] User provided estimates on the total hours per day by equipment type per construction phase should account for multiple pieces of equipment being used each day. For example, if the project uses 3 forklifts for 6

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[37] California Air Pollution Control Officers Association. "CalEEMod," 2022. https://www.caleemod.com/.

[38] The South Coast Air Quality Management District survey data are from building construction projects only. Therefore, it is only appropriate to use this data to develop default assumptions for proposed building construction projects. For other project types that are considered non-building construction (e.g., pipelines, roads, recreational trails), it is recommended that users manually input data on the number of construction days.

[39] The default data in CalEEMod is derived using results from a construction survey conducted by the South Coast Air Quality Management District. The survey collected data from a set of construction projects in Southern California ranging from 0-30 acres in size. Survey results were extrapolated out to projects over 30 acres based on data trends. See Appendix D1 of the CalEEMod user guide for more information on the methodology and survey data: California Air Pollution Control Officers Association. "User Guide for CalEEMod Version 2022.1," 2022. https://www.caleemod.com/user-guide.

[40] The South Coast Air Quality Management District survey data are from building construction projects only. Therefore, it is only appropriate to use this data to develop default assumptions for proposed building construction projects. For other project types that are considered non-building construction (e.g., pipelines, roads, recreational trails), it is recommended that the user be required to provide data on the total number of hours each equipment type is used per day by construction phase.

hours per day during the building construction phase, then the total number of hours per day for forklifts during the building construction phase would equal 18 (3 forklifts times 6 hours per day).

Fuel Type

As a default, it is assumed that construction equipment use diesel. However, users have the option to select from the following list of fuels for each type of equipment:

- Diesel
- Electric
- Biodiesel 100
- Biodiesel 20
- Renewable Diesel

Horsepower and Load Factor

Data on the horsepower and load factor for each type of electric and diesel-powered construction equipment are obtained from CalEEMod Appendix G, Table G-12.[41] The values summarized in Table 2-28 below reflect assumptions for both electric and diesel-powered equipment. These values are also applied to equipment using biodiesel 100, biodiesel 20, and renewable diesel.

Table 2-28. Horsepower and Load Factor by Construction Equipment Type

Equipment Type	Horsepower	Load Factor
Air Compressors	37	0.48
Cement and Mortar Mixers	10	0.56
Concrete/Industrial Saws	33	0.73
Cranes	367	0.29
Excavators	36	0.38
Forklifts	82	0.20
Generator Sets	14	0.74
Graders	148	0.41
Pavers	81	0.42
Paving Equipment	89	0.36
Rollers	36	0.38
Rubber Tired Dozers	367	0.40

[41] California Air Pollution Control Officers Association. "User Guide for CalEEMod Version 2022.1 Appendix G," 2022. https://www.caleemod.com/user-guide. These horsepower and load factor values were obtained from the California Air Resources Board's (CARB) OFFROAD2017 – ORION model, which is reflective of the California statewide fleet.

Equipment Type	Horsepower	Load Factor
Scrapers	423	0.48
Tractors/Loaders/Backhoes	84	0.37
Welders	46	0.45

Energy Consumption Rate

Energy consumption per horsepower-hour of operation in British Thermal Units (Btu) for each construction equipment type is derived using data from CalEEMod. Specifically, Table G-11 of CalEEMod Appendix G provides California statewide average annual off-road equipment emission factors in grams of carbon dioxide per horsepower-hour for construction equipment by fuel type (diesel, CNG, and gasoline), model year (2010 to 2050), and horsepower.[42] These emission factors represent combustion emissions derived from the California Air Resources Board's (CARB) OFFROAD2017 – ORION model. Estimates (in gCO_2/hp-hr) for diesel-powered equipment for model year 2025[43] that correspond to the horsepower assumed in Table 2-28 are used to calculate the hourly energy consumption rate by equipment type (in Btu/hp-hr) using the following equation:

Equation 7. Construction Equipment Energy Consumption Rate

$$consumption\ rate_t = emissions\ factor_{h,t} \times 0.001 \div diesel\ EF \times 1{,}000{,}000$$

where,

emissions factor	= GHG emissions for diesel-powered equipment for model year 2025 for horsepower, h, by equipment type, t (gCO_2/hp-hr)
diesel EF	= Combustion CO_2 emissions factor for diesel, 73.96 ($kgCO_2$/MMBtu)[44]
0.001	= kilogram to gram unit conversion
1,000,000	= Btu to MMBtu unit conversion

The emission factors from CalEEMod and the resulting energy consumption rates for each equipment type are summarized in Table 2-29.

Table 2-29. Hourly Energy Consumption by Equipment Type

Equipment Type	Emission Factor (gCO_2/hp-hr)	Consumption Rate (Btu/hp-hr)
Air Compressors	568	7,685
Cement and Mortar Mixers	570	7,709

[42] California Air Pollution Control Officers Association. "User Guide for CalEEMod Version 2022.1 Appendix G," 2022. https://www.caleemod.com/user-guide.
[43] Due to the low variability in emission factors from 2010 to 2050, the emission factors for model year 2025 equipment are assumed to remain constant over time.
[44] Based on the emissions factor for distillate fuel oil No. 2 from EPA's GHG Emission Factors Hub. EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Equipment Type	Emission Factor (gCO_2/hp-hr)	Consumption Rate (Btu/hp-hr)
Concrete/Industrial Saws	575	7,775
Cranes	528	7,133
Excavators	587	7,939
Forklifts	527	7,127
Generator Sets	568	7,684
Graders	531	7,182
Pavers	527	7,119
Paving Equipment	528	7,135
Rollers	587	7,935
Rubber Tired Dozers	532	7,195
Scrapers	529	7,152
Tractors/Loaders/Backhoes	530	7,164
Welders	568	7,684

Emission Factors

Diesel and Biofuel

Emission factors by fuel and equipment type are derived based on data obtained from GREET 1 2024.[45] Upstream emissions by fuel type, which include crude oil or biofuel feedstock recovery, refining, and transportation of the fuel to the construction equipment's tank, are summarized below in Table 2-30.

Table 2-30. Diesel and Biofuel Upstream Emission Factors

Fuel	Emission Factor ($kgCO_2e$/MMBtu)*
Diesel	16.11
Biodiesel 100	26.87
Biodiesel 20	17.81
Renewable Diesel II	37.38

* Values shown are based on AR5 global warming potentials.

[45] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Combustion emission factors vary by fuel and equipment type. To compile equipment-specific combustion emission factors from GREET 1 2024, each construction equipment type is mapped to an equipment type category in GREET 1 2024. This mapping is detailed in Table 2-31 below.

Table 2-31. GREET 1 2024 Equipment Type Mapping

Equipment Type	GREET 1 2024 Equipment Type
Air Compressors	Stationary Reciprocating Engine
Cement and Mortar Mixers	Stationary Reciprocating Engine
Concrete/Industrial Saws	Stationary Reciprocating Engine
Cranes	Heavy Duty Vocational Vehicle
Excavators	Heavy Duty Vocational Vehicle
Forklifts	Light Duty Vocational Vehicle
Generator Sets	Stationary Reciprocating Engine
Graders	Medium Duty Vocational Vehicle
Pavers	Medium Duty Vocational Vehicle
Paving Equipment	Stationary Reciprocating Engine
Rollers	Heavy Duty Vocational Vehicle
Rubber Tired Dozers	Heavy Duty Vocational Vehicle
Scrapers	Heavy Duty Vocational Vehicle
Tractors/Loaders/Backhoes	Heavy Duty Vocational Vehicle
Welders	Stationary Reciprocating Engine

The combustion emission factors from GREET 1 2024 by fuel and equipment type are summarized below in Table 2-32.[46] These combustion emission factors reflect estimates for model year 2025 equipment. Due to the low variability in emission factors from 2025 to 2050, the emission factors for model year 2025 equipment are assumed to remain constant over time. All biofuels assume a soybean oil base and exclude CO_2 emissions, which are considered biogenic.

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[46] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Table 2-32. Diesel and Biofuel Combustion Emission Factors Used in the Climate Calculator by Equipment Type

Equipment Type	Emission Factor ($kgCO_2e/MMBtu$)[a]			
	Diesel	Biodiesel 100[b]	Biodiesel 20[b]	Renewable Diesel[b]
Stationary Reciprocating Engine	77.63	0.06[c]	65.52[d]	0.50[e]
Light Duty Vocational Vehicle	81.30	6.42	67.25	2.23[f]
Medium Duty Vocational Vehicle	82.01	7.13	67.96	2.94[f]
Heavy Duty Vocational Vehicle	80.97	6.09	67.25	1.90[f]

[a] Values shown are based on AR5 global warming potentials.
[b] Excludes CO_2 emissions, which are considered biogenic.
[c] Not available from GREET 1 2024. Assumes the stationary combustion factor for biodiesel 100 from the EPA Emission Factors Hub.
[d] Assumes combustion emissions for soybean oil Biodiesel 20 CIDI vehicle from GREET 1 2024.
[e] Assumes combustion emissions for soybean oil Renewable Diesel CIDI vehicle from GREET 1 2024.
[f] Forest residue to renewable diesel pathway is used as a proxy because GREET 1 2024 does not provide soy oil to renewable diesel pathway combustion emissions for heavy duty vehicles.

The resulting life cycle emission factors by fuel and equipment type, which reflect a sum of upstream (Table 2-30) and combustion emissions (Table 2-32), are summarized in Table 2-33 below.

Table 2-33. Life Cycle Diesel and Biofuel Construction Equipment Emission Factors

Equipment Type	Emission Factor ($kgCO_2e/MMBtu$)[a]			
	Diesel	Biodiesel 100	Biodiesel 20	Renewable Diesel
Stationary Reciprocating Engine	93.74	26.93	83.33	37.87
Light Duty Vocational Vehicle	97.41	33.28	85.06	39.60
Medium Duty Vocational Vehicle	98.12	34.00	85.77	40.31
Heavy Duty Vocational Vehicle	97.08	32.96	85.06	39.28

[a] Values shown are based on AR5 global warming potentials.

Electricity

The grid average electricity emission factors by year for electricity consumed by electric construction equipment, as shown in Table 2-34, are derived based on the methodology described in Appendix C.

Table 2-34. Electricity Emission Factors

Electricity Provider	Emission Factor ($kgCO_2e/MMBtu$)[a]					
	2025	2030	2035	2040	2045	2050
Grid Average	116.62	42.63	21.32	0.00	0.00	0.00

[a] Values shown are based on AR5 global warming potentials.

Limitations

Key limitations of the methodology used to quantify emissions from construction equipment include:

- The CalEEMod data used to develop default assumptions for the number of construction days and the number of hours each construction equipment type is used per day (based on project size in acres) is derived using results from a construction survey conducted by the South Coast Air Quality Management District. This survey gathered data exclusively from building construction projects in California. Therefore, it is only appropriate to use this data to develop default assumptions for proposed building construction projects. For other project types that are considered non-building construction (e.g., pipelines, roads, recreational trails), it is recommended that the user manually input data on the number of construction days. The calculator uses the data provided by CalEEMod, despite its limitations, as it was the most comprehensive data publicly available to develop default assumptions on construction days, construction equipment use per day, and construction equipment capacity.
- The equipment types available in GREET 1 2024 and the construction equipment types included in the calculator are not one-to-one. Therefore, to compile equipment-specific combustion emission factors from GREET 1 2024, each construction equipment type in the calculator is mapped to an equipment type category in GREET 1 2024 using expert judgment (see Table 2-31).
- There are limitations in the data availability for biofuel combustion emission factors for certain equipment types in GREET 1 2024. As such, the calculator applies emission factor data from similar biofuels in some instances where biofuel specific combustion emission factor data are not available. These instances are detailed in the text below Table 2-32.
- The methodology used to quantify emissions from construction equipment is based on the type and frequency of equipment used. The calculator does not allow for direct entry of anticipated fuel consumption to quantify emissions from construction equipment. However, as an alternative approach, users may use the emission factors provided to quantify emissions from Natural Gas and Oil Products (see Section 3.3) to quantify emissions from construction equipment if data on anticipated fuel consumption are more readily available.

2.5 Land Use Change

This emissions source (or sink) includes the net carbon change from the transition of one land use type to another during project construction. This may include clearing land for construction or otherwise converting it to another land type. The method described below uses a stock change approach to calculate carbon gains or losses, which are used as a proxy for emissions. To account for lifecycle emissions, the net carbon change calculations assume full realization of the land transition. The calculator quantifies net carbon change from land use change based on land area pre- and post-construction, the number of trees removed and/or added during construction (outside of forests), and the carbon stock of each land type and tree, as shown in Equation 8.

Equation 8. Net Change in Carbon Stock from Construction

$$GHGs\ emitted\ or\ sequestered = \left(\sum (area\ pre\ construction_t - area\ post\ construction_t) \times carbon\ stock_t \times \frac{44}{12}\right) + [(trees\ removed - trees\ added) \times carbon\ stock_{tree} \times \frac{44}{12}]$$

where,

Area pre-construction	= Number of acres of land by type, t, pre-construction (acres)
Area post-construction	= Number of acres of land by type, t, post-construction (acres)
carbon $stock_t$	= Amount of carbon stored per acre for land type, t (MTC/acre)
44/12	= Conversion factor of C to CO_2
trees removed	= Number of trees removed during construction[47]
trees added	= Number of trees planted during construction[48]
carbon $stock_{tree}$	= Amount of carbon (MT C) stored by an individual tree

Land Types

Users are required to provide the number of acres by land cover type pre-construction and post-construction. Consistent with the EAW, the land cover types for which users may provide data include:

- Wetlands, forested
- Wetlands, not forested
- Forest
- Rivers and streams
- Brush and grassland
- Cropland
- Livestock rangeland/pastureland
- Lawn/landscaping
- Green infrastructure: constructed wetlands, vegetated
- Green infrastructure: constructed wetlands, paved
- Green infrastructure: constructed green roofs
- Green infrastructure: constructed permeable pavements
- Impervious surface
- Stormwater pond (wet sedimentation basin)

Carbon Stocks by Land Type

Carbon stocks by land type were derived from various sources including Minnesota-specific studies, national reports, and Intergovernmental Panel on Climate Change (IPCC) Guidelines. Numerous sources were used to

[47] Excluding trees removed as part of converted forest area.
[48] Excluding trees added as part of reforestation.

derive the best available estimates for the state for the land types defined by the EAW. The values represent carbon stocks from aboveground biomass, belowground biomass, soil carbon, and dead organic matter, including litter and woody debris. The carbon stocks by land type are summarized below in Table 2-35. The basis for these values is described in the sections that follow.

Table 2-35. Carbon Stocks by Land Type

Land Type	MTC per Acre
Wetlands, forested	256.7
Wetlands, not forested	211.7
Forest	99.0
Rivers and streams	0
Brush and grassland	40.8
Cropland	32.5
Livestock rangeland/pastureland	40.8
Lawn/landscaping	19.1
Green infrastructure: constructed wetlands, vegetated	43.4
Green infrastructure: constructed wetlands, paved	0
Green infrastructure: constructed green roofs	19.1
Green infrastructure: constructed permeable pavements	0
Impervious surface	0
Stormwater pond (wet sedimentation basin)	0

Wetlands

Wetlands store the most carbon per acre of all land types in Minnesota. This is in part due to the prevalence of prairie pothole wetlands in the state. Carbon stock values for wetlands were obtained from the U.S. Forest Service's *Second State of the Carbon Cycle Report*.[49] Specifically, the values are based on area and carbon pool estimates for the conterminous United States, as obtained from Chapter 13, Table 13.1 and summarized below in Table 2-36. The carbon pool (in petagram of carbon, or Pg C) was divided by the area to derive a per acre carbon stock. Values for peatland and mineral soil were then averaged to derive an estimate for forested and not forested wetlands.

[49] Kolka et al. "Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report, Chapter 13: Terrestrial wetlands," U.S. Global Change Research Program, Washington, DC, USA, (2013) pp. 507-567: https://carbon2018.globalchange.gov/chapter/13/.

Table 2-36. Area and Carbon Pool by Wetland Type

Wetland Type	Area (km^2)	Carbon Pool (Pg C)
Peatland, Nonforested	42,903	3.9
Peatland, Forested	40,823	4.4
Mineral Soil, Nonforested	138,381	1.9
Mineral Soil, Forested	173,091	3.3

Forest

The carbon stock for forests is based on the findings from a report on the potential for terrestrial carbon sequestration in Minnesota, prepared for the Minnesota Department of Natural Resources, as summarized in Table 2-37.[50] The value represents the average carbon stock of an acre of forest across the state, even though the actual carbon stock for a given acre will vary based on the type and age of the forest.

Table 2-37. Minnesota Forest Carbon Stock

Area (million acres)	Carbon Stock (million MT C)	Carbon Stock (MT C per acre)
16.21	1,607	99

Brush, Grasslands, and Rangelands

The carbon stock for brush and grasslands was derived by combining the estimated carbon stocks of aboveground biomass, belowground biomass, and soil organic carbon pools. Aboveground and belowground biomass estimates for cool temperate and wet climates were obtained from the 2006 IPCC Guidelines[51] (see Table 2-38). The soil organic carbon stock assumption was derived based on carbon stock estimates by soil type for grazing land systems for cold temperate, moist climates, as obtained from the United States Department of Agriculture (USDA) (see Table 2-39),[52] and the breakdown of soil types across grassland in Minnesota, as obtained from the Gridded Soil Survey Geographic (gSSURGO) Database (see Table 2-40).[53] The resulting estimate of 64.8 metric tons carbon per hectare was then multiplied by a factor of 1.37 to account for the

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[50] Anderson et al. "The Potential for Terrestrial Carbon Sequestration in Minnesota." University of Minnesota, St. Paul, MN (2008). https://files.dnr.state.mn.us/aboutdnr/reports/carbon2008.pdf.
[51] Verchot et al. "IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use" (2006). https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf.
[52] USDA. "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory." April 2024. https://www.usda.gov/about-usda/general-information/staff-offices/office-chief-economist/office-energy-and-environmental-policy/climate-change/greenhouse-gas-inventory-and-assessment-program/quantifying-greenhouse-gas-fluxes-methods-entity-scale-inventory.
[53] USDA. "Gridded Soil Survey Geographic (gSSURGO) Database." 2023. https://www.nrcs.usda.gov/resources/data-and-reports/gridded-soil-survey-geographic-gssurgo-database.

carbon stock change factor for uncultivated land in cool moist climates,[54] resulting in a soil carbon stock assumption of 88.8 metric tons carbon per hectare for grassland. Carbon stocks for rangelands are assumed equal to those of brush and grasslands.

Table 2-38. Biomass Stocks Present on Grassland (MT C per hectare)

IPCC climate zone	Peak aboveground biomass	Total (aboveground and below ground) non-woody biomass
Cold Temperate - Wet	2.4	12.0

Table 2-39. Soil Organic Carbon Stocks for Grazing Land Systems

IPCC Soil Category	Carbon Stock (MT C per hectare)
High clay activity mineral soils	65
Low clay activity mineral soils	52
Sandy soils	40
Spodic soils	74
Aquic soils	89

Table 2-40. Soil Type Across Grassland in Minnesota

Order	Suborder	Area (m^2)	Percent	IPCC Soil Category
Mollisols	Aquolls	56,979,000	6.96%	Aquic soils
Alfisols	Aqualfs	52,473,600	6.41%	Aquic soils
Inceptisols	Udepts	169,608,600	20.73%	Low clay activity mineral soils
Histosols	Saprists	21,278,700	2.60%	Aquic soils
Mollisols	Udolls	145,549,800	17.79%	High clay activity mineral soils
Alfisols	Udalfs	158,363,100	19.35%	Low clay activity mineral soils
Entisols	Aquents	9,690,300	1.18%	Aquic soils
Entisols	Psamments	67,998,600	8.31%	Sandy soils
Inceptisols	Aquepts	104,538,600	12.77%	Aquic soils
Histosols	Hemists	10,688,400	1.31%	Aquic soils
Entisols	Fluvents	829,800	0.10%	Aquic soils

[54] USDA. "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory." April 2024. https://www.usda.gov/about-usda/general-information/staff-offices/office-chief-economist/office-energy-and-environmental-policy/climate-change/greenhouse-gas-inventory-and-assessment-program/quantifying-greenhouse-gas-fluxes-methods-entity-scale-inventory.

Order	Suborder	Area (m^2)	Percent	IPCC Soil Category
Vertisols	Aquerts	346,500	0.04%	High clay activity mineral soils
Entisols	Orthents	12,484,800	1.53%	Sandy soils
Mollisols	Albolls	293,400	0.04%	Aquic soils
Spodosols	Orthods	1,446,300	0.18%	Spodic soils
Vertisols	Uderts	233,100	0.03%	High clay activity mineral soils
Mollisols	Ustolls	1,818,900	0.22%	High clay activity mineral soils
Alfisols	Ustalfs	218,700	0.03%	High clay activity mineral soils
Inceptisols	Ochrepts	424,800	0.05%	High clay activity mineral soils
Alfisols	Boralfs	3,085,200	0.38%	Low clay activity mineral soils

Cropland

The carbon stock for cropland was derived by combining the estimated carbon stocks of aboveground biomass, belowground biomass, and soil organic carbon pools. Total carbon stock in aboveground and belowground biomass for annual cropland were obtained from Chapter 5 of the 2019 Refinement to the 2006 IPCC Guidelines (see Table 2-41).[55] The soil organic carbon stock assumption was derived based on carbon stock estimates by soil type for cropland for cold temperate, moist climates, as obtained from USDA (see Table 2-42),[56] and the breakdown of soil types across cropland in Minnesota, as obtained from the Gridded Soil Survey Geographic (gSSURGO) Database (see Table 2-43).[57] The resulting soil carbon stock assumption for cropland in Minnesota is 75.6 metric tons carbon per hectare.

Table 2-41. Default Biomass Carbon Stock Present on Land Converted to Cropland

Crop type by climate region	Carbon stock in biomass after one year (MT C per hectare)
Annual cropland	4.7

[55] IPCC. “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Chapter 5: Cropland (2019). https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch05_Cropland.pdf
[56] USDA. "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory." April 2024. https://www.usda.gov/about-usda/general-information/staff-offices/office-chief-economist/office-energy-and-environmental-policy/climate-change/greenhouse-gas-inventory-and-assessment-program/quantifying-greenhouse-gas-fluxes-methods-entity-scale-inventory.
[57] USDA. “Gridded Soil Survey Geographic (gSSURGO) Database.” 2023. https://www.nrcs.usda.gov/resources/data-and-reports/gridded-soil-survey-geographic-gssurgo-database.

Table 2-42. Soil Organic Carbon Stocks for Cropland

IPCC Soil Category	Carbon Stock (MT C per hectare)
High clay activity mineral soils	65
Low clay activity mineral soils	52
Sandy soils	40
Spodic soils	74
Aquic soils	89

Table 2-43. Soil Type Across Cropland in Minnesota

Order	Suborder	Area (m^2)	Percent	IPCC Soil Category
Mollisols	Aquolls	38,084,803,200	49.85%	Aquic soils
Alfisols	Aqualfs	1,203,071,400	1.57%	Aquic soils
Inceptisols	Udepts	4,594,850,100	6.01%	Low clay activity mineral soils
Histosols	Saprists	876,636,900	1.15%	Aquic soils
Mollisols	Udolls	19,367,215,200	25.35%	High clay activity mineral soils
Alfisols	Udalfs	7,252,569,900	9.49%	Low clay activity mineral soils
Entisols	Aquents	301,269,600	0.39%	Aquic soils
Entisols	Psamments	939,126,600	1.23%	Sandy soils
Inceptisols	Aquepts	549,849,600	0.72%	Aquic soils
Histosols	Hemists	32,713,200	0.04%	Aquic soils
Entisols	Fluvents	205,584,300	0.27%	Aquic soils
Vertisols	Aquerts	2,145,022,200	2.81%	High clay activity mineral soils
Entisols	Orthents	216,510,300	0.28%	Sandy soils
Mollisols	Albolls	65,246,400	0.09%	Aquic soils
Spodosols	Orthods	2,430,000	0.00%	Spodic soils
Histosols	Fibrists	3,600	0.00%	Aquic soils
Vertisols	Uderts	207,955,800	0.27%	High clay activity mineral soils
Mollisols	Ustolls	344,592,900	0.45%	High clay activity mineral soils
Alfisols	Ustalfs	5,832,000	0.01%	High clay activity mineral soils
Mollisols	Borolls	13,500	0.00%	High clay activity mineral soils
Inceptisols	Ochrepts	594,000	0.00%	High clay activity mineral soils
Alfisols	Boralfs	840,600	0.00%	Low clay activity mineral soils

Lawn, Landscaping, and Green Roofs

The carbon stock for lawn and landscaping (turfgrass) was derived by combining the estimated carbon stocks of aboveground biomass, belowground biomass, and soil organic carbon pools, as summarized below in Table 2-44. The soil organic carbon stock assumption was obtained from a study conducted by Selhorest and Lal (2013) on the carbon sequestration potential in home lawn turfgrasses in the United States and reflects the mean potential soil organic carbon sink capacity identified by the study.[58] Estimates for aboveground and belowground biomass for turfgrass are based on a study completed by Kong et al. (2014).[59] The estimated carbon stock for constructed green roofs is assumed to equal the estimated carbon stock for turfgrass.

Table 2-44. Estimated Carbon Stock of Lawn, Landscaping, and Green Roofs (MT C per hectare)

Soil Carbon	Aboveground	Belowground
45.8	1.3[a]	0.0

[a] Based on a range of 0.5 to 2.1 MT C per hectare.

Restored Vegetated Wetlands

The carbon stock for restored vegetated wetlands was derived by combining the estimated carbon stocks of soil organic carbon, aboveground biomass, and below ground biomass carbon pools. The estimated soil organic carbon content of restored prairie pothole wetlands was obtained from a study of carbon storage in native and restored wetlands in North America.[60] The estimate of aboveground biomass was obtained from a different regional study on the potential of restored prairie wetlands to sequester carbon.[61] Finally, the estimate for belowground biomass was derived based on the ratio of 1.15 of above to belowground biomass for wetlands, as obtained from the 2013 Supplement to the 2006 IPCC Guidelines.[62] A summary of the estimated carbon stocks for restored vegetated wetlands is shown in Table 2-45.

Table 2-45. Estimated Carbon Stock of Restored Vegetated Wetlands (MT C per hectare)

Soil Carbon	Aboveground	Belowground
96.50	5.00	5.75

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[58] Selhorst, A. and Lal, R. “Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States.” Environmental Management 51, 198–208 (2013). https://doi.org/10.1007/s00267-012-9967-6.
[59] Kong et al. “Carbon Emission and Sequestration of Urban Turfgrass Systems in Hong Kong.” Science of The Total Environment, Volumes 473–474, Pages 132-138, ISSN 0048-9697 (2014), https://doi.org/10.1016/j.scitotenv.2013.12.012.
[60] Euliss et al. “North American Prairie Wetlands Are Important Nonforested Land-based Carbon Storage Sites.” Science of the Total Environment 361, pp 179-188 (2005). doi:10.1016/j.scitotenv.2005.06.007
[61] Gleason et al. "Potential of Restored Prairie Wetlands in the Glaciated North American Prairie to Sequester Atmospheric Carbon," USGS Northern Prairie Wildlife Research Center, p 92 (2005). https://digitalcommons.unl.edu/usgsnpwrc/92.
[62] IPCC. “2013 Supplement to the 2006 Guidelines for National Greenhouse Gas Inventories: Wetlands, Annex 3A.1, Table 4.9 (2013). https://www.ipcc.ch/site/assets/uploads/2018/03/Wetlands_Supplement_Entire_Report.pdf

Other Land Types

All paved surfaces, including impervious surfaces and permeable pavements, are assumed to have a carbon stock of zero. The same assumption of 0 MT C/acre is applied to rivers and streams. While water bodies are generally emissive due to the decomposition of organic material, unlike other land types that accumulate carbon over time, rivers and streams primarily transport carbon rather than store or emit it. Standing water with impervious surface beneath it (stormwater basins, paved wetlands) is also assumed to store zero carbon due to the lack of organic matter decomposition.

Carbon Stock, Individual Tree

The assumption for the carbon stock of an individual tree planted and removed was derived from EPA's Greenhouse Gas Equivalencies Calculator, which estimates that an urban tree sequesters on average 36.4 pounds of carbon per year over a 10-year growth period.[63] For the purposes of this calculator, the estimated carbon stock of a mature tree is based on a 30-year lifetime, as summarized in Table 2-46.

Table 2-46. Estimated Carbon Sequestration Rate and Carbon Stock Per Tree

Tree Type	lbs C/tree/year	MT C/tree/year	MT C/tree
Urban Tree[a]	36.4	0.02	0.50[b]

[a] Based on a sampling of 11% coniferous trees and 89% deciduous trees.
[b] Assumes a 30-year lifetime.

Limitations

Key limitations of the methodology used to quantify emissions from land use change include:

- The quantification method employs a stock-based approach to estimate net carbon changes from land use conversion, which provides a simplified snapshot of carbon stocks before and after the land transition. Unlike a net flux approach, this method does not directly account for the dynamic processes of carbon sequestration and release over time, such as annual plant growth, decomposition rates, or soil carbon dynamics following disturbance. Therefore, it provides a static estimate of long-term carbon impacts rather than a detailed accounting of annual carbon fluxes.
- The land types included in the calculator are consistent with the land types defined in the EAW. Several limitations arise from the use of pre-defined carbon stock values for each land type. These values are derived from various sources, including regional and national studies, as well as IPCC Guidelines, and represent averages that may not fully capture the specific conditions of the project site. Site-specific factors such as soil type, vegetation composition, forest age and type, management practices, and microclimate can significantly influence actual carbon stocks.
- The method assumes full realization of the land transition over 30 years. Therefore, the results assume that no further changes to the converted land will occur in the foreseeable future.

[63] EPA. "Greenhouse Gas Equivalencies Calculator – Calculations and References," 2024. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-calculations-and-references

- The estimated carbon stocks do not account for impacts from maintenance activities (e.g., lawn moving, irrigation) or fertilizer application. These impacts should be considered separately.
- The carbon stock estimate for an individual tree is based on the carbon sequestration of coniferous or deciduous trees planted in an urban setting over 10-year growth period. The average annual carbon sequestration rate of an individual tree over a 30-year time period may differ. In addition, the carbon sequestration rate of a given tree will vary based on the species, location, and other conditions.

2.6 Construction Waste

Emissions result from the transportation and treatment of waste that is generated during construction and treated at a facility off-site. The calculator assumes that all waste generated during construction is disposed of at a landfill. The calculator quantifies emissions from construction waste based on the estimated quantity of waste by material type and material-specific emission factors, as shown in Equation 9 and Equation 10.

Equation 9. Quantity of Construction Waste

$$construction\ waste_t = material\ quantity_t \times\ loss\ rate_t$$

where,

Material quantity	= Amount of material used as an input during construction by type, t (tons)
Loss rate	= The percent of each material input that is discarded as waste (%)

Equation 10. GHG Emissions from Construction Waste

$$GHG\ emissions = \sum construction\ waste_t \times\ emission\ factor_t$$

where,

Construction waste	= Tons of waste material generated during construction by type, t, as calculated by Equation 9
Emissions factor	= The emissions associated with the transportation and treatment of waste by type, t ($MTCO_2e$/ton)

Material Quantity

The material quantity by material type is based on values provided by users. The input quantities used to calculate emissions from construction waste are the same inputs used to calculate the material inputs emissions that are summarized in Section 2.1, Table 2-1.

Loss Rate

Construction material loss rates were obtained from a 2018 study published by the EPA.[64] The study identifies loss rates for all material types except for aluminum, glass, and insulation. The calculator applies the loss rate for steel to aluminum, the loss rate for concrete to glass, and the loss rate for drywall to insulation. Table 2-47 summarizes the loss rate assumptions by material type.

Table 2-47. Material Loss Rate Assumptions

Material Type	Loss Rate (%)	Notes
Aluminum	0%	Proxied based on steel
Asphalt	0%	Based on asphalt pavement
Brick	4%	
Concrete	3%	
Glass	3%	Proxied based on concrete
Insulation	10%	Proxied based on drywall
Steel	0%	
Wood Products	5%	

Construction Waste

In addition to calculating construction waste from material input quantities and loss rates, the calculator allows users to directly enter the quantity of mixed construction and demolition (C&D) waste. For the purposes of this calculator, the breakdown of C&D waste is based on a 2020 Minnesota Pollution Control Agency study that reviewed C&D materials composition in Minnesota, as summarized in Table 2-48.[65]

Table 2-48. C&D Waste Composition Assumptions

Material Type	Percent of C&D Waste
Concrete	21.8%
Roofing Shingles	19.3%
Brick	7.2%
Dirt/Sand/Rock/Gravel	13.0%
Yard Waste	0.4%

[64] EPA. "Construction and Demolition Debris Generation in the United States, 2015." 2018. https://www.epa.gov/sites/default/files/2018-09/documents/construction_and_demolition_debris_generation_in_the_united_states_2015_final.pdf.
[65] Minnesota Pollution Control Agency. "Construction and Demolition Materials Composition Study," 2020. https://www.pca.state.mn.us/sites/default/files/w-sw5-55.pdf

Material Type	Percent of C&D Waste
Treated/Painted/Processed Wood	8.3%
Clean Wood	7.2%
Gypsum Board	8.1%
Metal	2.5%
Mixed municipal solid waste (MSW)	1.3%
Mixed Plastics	0.3%
Asphalt	2.1%
Carpet	0.4%
Insulation	0.4%
Glass	0.2%
Other	7.5%

Emission Factors

Emission factors associated with the landfilling of construction materials, as summarized in Table 2-49, were obtained from EPA's GHG Emissions Factors Hub.[66] The emissions factors, which are based on factors from EPA's Waste Reduction Model (WARM), include emissions from the decomposition of waste as well as the transportation of waste to the waste treatment facility.[67] The assumed composition of C&D waste (shown in Table 2-48) was used to derive the emissions factor for mixed C&D waste.

Table 2-49. Construction Waste Emission Factors

Material Type	Landfilling Emission Factor ($MTCO_2e$/short ton)
Aluminum	0.02
Asphalt	0.02
Brick	0.02
Concrete	0.02
Glass	0.02
Insulation	0.02
Steel	0.02
Wood Products	0.18
Mixed C&D Waste	0.05

[66] EPA. "GHG Emission Factor Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[67] The emission factors do not include avoided emissions associated with energy recovery or landfill carbon sequestration.

Limitations

Key limitations of the methodology used to quantify emissions from construction waste include:

- The calculator only allows users to generate default construction waste estimates for the eight materials for which material input emissions are quantified (as summarized in Section 2.1, Table 2-1). The default waste values are based on estimated construction loss rates, which will vary by project. Additionally, for materials where loss rate data were unavailable, the loss rates are proxied based on other materials.
- Emissions from the transportation of waste that are accounted for in the emission factors are based on a default assumption regarding the distance traveled from the project site to the waste management facility, which may vary from the actual distance traveled for a specific project.
- The landfill emission factors are based on typical landfill gas collection practices and average landfill moisture conditions. Actual emissions will vary based on the characteristics of the landfill where the waste is treated.

3 Operational Emissions

3.1 Building Energy Consumption

Emissions result from building fuel and electricity consumption during the operational lifetime of a building. The calculator quantifies emissions from building energy consumption based on building square footage, fuel-specific building energy intensities, and fuel-specific emission factors, as shown in Equation 11 and Equation 12.

Equation 11: Annual Building Energy Consumption

$$annual\ energy\ consumed_s = \sum (building\ square\ footage_t \times building\ energy\ intensity_{t,s})$$

where,

Building square footage	= Square footage by building type, t (square feet)
Building energy intensity	= Average annual fuel or electricity consumed per square foot by building type, t, and fuel source, s (Btu/square foot/year)

Equation 12. Annual Emissions from Building Energy Consumption

$$annual\ GHG\ emissions = annual\ energy\ consumed_s \times emission\ factor_s \times 0.000001$$

where,

Annual energy consumed	= Building energy consumed by energy source, s, as calculated by Equation 11 (Btu/year) [68]
Emission factor	= GHG emissions per unit of energy consumed ($kgCO_2e$/MMBtu)
0.000001	= Unit conversion from Btu to MMBtu

Building Square Footage

Users are required to provide data on the building square footage by building type. The building types for which users may provide data include:

- Residential
- Commercial
- Industrial
- Institutional
- Other

[68] For electricity consumption, users have the option to specify the portion of electricity that they anticipate will be generated on-site via renewables or supplied through the purchase of renewable energy credits. This consumption is excluded from the emissions calculation. For natural gas consumption, users also have the ability to input the portion sourced from renewable natural gas.

Building Energy Intensity

Default building energy intensities by building type are available in the calculator. Default building energy intensities were derived from data obtained from the U.S. Energy Information Administration (EIA). Table 3-1 summarizes the data tables that were used for this analysis along with the year for which the data was last released. The tables include fuel consumption (Tables CE2.3, C18, C35, C28, and 1.1) for different building types and/or building floorspace (Tables HC10.3, 9.1, C18, C35, and C28).

Table 3-1. EIA Building Energy Intensity Data Tables

Tables	Year	Data Source
Tables CE2.3 and HC10.3	2020	Residential Energy Consumption Survey (RECS)
Tables C28, C35, C18	2018	Commercial Buildings Energy Consumption Survey (CBECS)
Tables 1.1 and 9.1	2018	Manufacturing Energy Consumption Survey (MECS)

Energy intensities in Btu/square foot/year were derived for the following four building types: residential, commercial, industrial, and institutional.[69] The energy intensity by fuel type and building type are shown in Table 3-2. The methodology used to derive these values from the EIA data is described in detail below.

Table 3-2. Energy Intensity Assumptions by Energy Source and Building Type

Building Type	Annual Energy Intensity (Btu/square foot/year)			
	Natural Gas	Propane	Fuel Oil or Kerosene[a]	Electricity
Residential	24,460	3,619	234	18,097
Commercial	35,535	NA	1,662	30,766
Industrial	656,393	NA	8,192	229,952
Institutional	48,219	NA	3,660	46,860

Note: NA indicates lack of available data.
[a] RECS uses the fuel type “fuel oil or kerosene” and MECS uses “residual fuel oil or distillate fuel oil.”

Residential Buildings

Total energy consumption by residential buildings for the West North Central census division in the Midwest region by fuel type in million Btu were obtained from RECS Table CE2.3[70] while total square footage of residential buildings in the West North Central census division in the Midwest were obtained from Table

[69] Users are required to provide the energy intensity for “Other” building types.
[70] EIA. “2020 Residential Energy Consumption Survey (RECS),” accessed April 1, 2025. https://www.eia.gov/consumption/residential/data/2020/.

HC10.3.[71] These data are summarized in Table 3-3. Total energy consumption by fuel type was divided by total square footage to derive the values for residential buildings shown in Table 3-2 above.

Table 3-3. Total Square Footage and Energy Consumption for Midwest Residential Buildings

Total square footage (billion square feet)	Total Energy Consumption (trillion Btu)			
	Natural Gas	Propane	Fuel Oil or Kerosene	Electricity
17.13	419	62	4	310

Commercial Buildings[72]

Natural gas energy intensities by building type for the West North Central census division in the Midwest region in cubic feet per square foot were obtained from CBECS Table C28.[73] These values were averaged and converted to Btu per square foot based on a conversion factor of 1,049 Btu/cubic foot as obtained from EIA.[74] Fuel oil energy intensities by building type for the Midwest region in gallons per thousand square feet were obtained from CBECS Table C35.[75] These values were averaged and converted to Btu/square foot based on conversion factors of 42 gallons/barrel of oil and 6,287,000 Btu/barrel residual fuel oil, as obtained from EIA.[76] Electricity energy intensities by building type for the West North Central census division in the Midwest region in kWh/square foot were obtained from CBECS Table C18.[77] These values were averaged and converted to Btu/square foot based on a standard conversion factor of 3,412.14 Btu per kWh. Table 3-4 summarizes the data obtained from CBECS that was used to derive the values for commercial buildings shown in Table 3-2 above.

Table 3-4. Energy Intensity by Building Type for Midwest Commercial Buildings

Building Type	Energy Intensity		
	Natural Gas (cubic feet/square foot)	Fuel Oil (gallons/1000 square feet)	Electricity (kWh/square foot)
Food sales	Q[b]	NA	Q
Food service	Q	NA	Q
Lodging	44.0	NA	11.0

[71] EIA. "2020 Residential Energy Consumption Survey (RECS)," accessed April 1, 2025. https://www.eia.gov/consumption/residential/data/2020/.
[72] Based on EIA's definitions, commercial buildings include sewage treatment facilities.
[73] EIA. "2018 Commercial Buildings Energy Consumption Survey (CBECS)," accessed April 1, 2025. https://www.eia.gov/consumption/commercial/data/2018/.
[74] EIA. "Heat Content of Natural Gas Consumed," Accessed April 1, 2025. https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm. Value for Minnesota for 2018.
[75] EIA. "2018 Commercial Buildings Energy Consumption Survey (CBECS)," accessed April 1, 2025. https://www.eia.gov/consumption/commercial/data/2018/.
[76] EIA. "Monthly Energy Review," accessed December 20, 2024. https://www.eia.gov/totalenergy/data/monthly/index.php#appendices.
[77] EIA. "2018 Commercial Buildings Energy Consumption Survey (CBECS)," accessed April 1, 2025. https://www.eia.gov/consumption/commercial/data/2018/.

Building Type	Energy Intensity		
	Natural Gas (cubic feet/square foot)	Fuel Oil (gallons/1000 square feet)	Electricity (kWh/square foot)
Mercantile[a]	33.0	NA	13.8
Office	30.7	5.2	11.6
Religious worship	Q	NA	5.3
Service	Q	NA	4.3
Warehouse and storage	27.8	NA	8.1
Other	Q	17.0	Q
Vacant	Q	NA	Q

[a] Mercantile includes Retail (other than mall) and strip malls.
[b] Q = Data withheld either because the relative standard error was greater than 50% or the reporting sample had fewer than 20 buildings.

Industrial Buildings

Total energy consumption by fuel type by industrial buildings in the United States was obtained from MECS Table 1.1[78] while approximate enclosed floorspace of industrial buildings was obtained from MECS Table 9.1.[79] While energy consumption data for industrial buildings are available for the Midwest region, building floorspace is only available at the national level. As a result, national data were used to derive the building energy intensity for industrial buildings. Conversion factors of 1,049 Btu/cubic foot of natural gas, 5,770,000 Btu/barrel distillate fuel oil,[80] and 3,412.14 Btu/kWh were used to convert energy consumption values to Btu. Table 3-5 summarizes the data obtained from MECS that was used to derive the values for industrial buildings shown in Table 3-2.

Table 3-5. Total Floorspace and Energy Consumption for United States Industrial Buildings

Enclosed Floorspace (million square feet)	Total Energy Consumption		
	Natural Gas (billion cubic feet)	Distillate Fuel Oil (million bbl)[a]	Electricity (million kWh)
11,270	7,052	16	759,512

[a] No residual fuel oil was consumed in the Midwest region.

[78] EIA. “2018 Manufacturing Energy Consumption Survey (MECS),” accessed April 1, 2025. https://www.eia.gov/consumption/manufacturing/data/2018/.
[79] EIA. “2018 Manufacturing Energy Consumption Survey (MECS),” accessed April 1, 2025. https://www.eia.gov/consumption/manufacturing/data/2018/.
[80] EIA. “Monthly Energy Review,” accessed December 20, 2024. https://www.eia.gov/totalenergy/data/monthly/index.php#appendices.

Institutional Buildings

The same data sources and approach that were used to derive values for commercial buildings were used to derive values for institutional buildings. Table 3-6 summarizes the data obtained from CBECS[81] that was used to derive the values for institutional buildings shown in Table 3-2 above.

Table 3-6. Energy Intensity by Building Type for Midwest Institutional Buildings

Building Type	Energy Intensity		
	Natural Gas (cubic feet/square foot)	Fuel Oil (gallons/1000 square feet)	Electricity (kWh/square foot)
Education	33.8	28.8	8.8
Health care[a]	65.9	20.1	21.3
Public assembly	38.2	NA	11.1
Public order and safety	Q[b]	NA	Q

[a] Health care includes inpatient and outpatient.

[b] Q = Data withheld either because the relative standard error was greater than 50% or the reporting sample had fewer than 20 buildings.

Emission Factors

For electricity consumed by buildings, users have the option to use a grid average emission factor or utility-specific emission factors for select electricity providers in Minnesota. The grid average and utility-specific electricity emission factors by year for building electricity consumption, as shown in Table 3-7, were derived based on the methodology described in Appendix C.

Table 3-7. Electricity Emission Factors

Electricity Provider	Emission Factor (kgCO_2e/MMBtu)[a]					
	2025	2030	2035	2040	2045	2050
Grid Average	116.62	42.63	21.32	-	-	-
Xcel Energy	69.75	19.84	12.97	-	-	-
Minnesota Power	162.74	49.69	16.88	-	-	-
Great River Energy	161.81	91.92	33.76	-	-	-
Otter Tail Power Company	141.40	91.44	45.66	-	-	-

[a] Values shown are based on AR5 global warming potentials.

[81] EIA. "2018 Commercial Buildings Energy Consumption Survey (CBECS)," accessed April 1, 2025. https://www.eia.gov/consumption/commercial/data/2018/.

For other building energy sources, emission factors were derived based on data obtained from EPA's GHG Emission Factors Hub[82] and GREET 1 2024.[83] Emissions from combustion were obtained from EPA while upstream emissions were obtained from GREET. The emission factors by fuel type and lifecycle stage are shown in Table 3-8.

Table 3-8. Fossil Fuel Emission Factors for Stationary Combustion

Fuel Type	Emission Factor ($kgCO_2e/MMBtu$)[a]		
	Upstream	Combustion	Total
Natural Gas	12.03	53.11	65.15
Renewable Natural Gas	18.50[b]	0.05[c]	18.56
Propane	18.17	63.11	81.28
Kerosene	16.11[d]	75.44	91.55
Fuel Oil	16.11[d]	74.20[e]	90.31

[a] Values shown are based on AR5 global warming potentials.
[b] Based on the emissions factor for landfill gas to natural gas.
[c] Excludes CO_2 emissions, which are considered biogenic.
[d] Based on the emissions factor for conventional diesel.
[e] Based on the emissions factor for Distillate Fuel Oil No. 2.

Limitations

Key limitations of the methodology used to quantify emissions from building energy consumption include:

- Default building energy intensities are estimated by building type (i.e., residential, commercial, industrial, and institutional). Significant variation is expected within these categories based on the specific building use. In particular, the energy intensity of industrial buildings is highly dependent on the industry type. Users are encouraged to tailor the energy intensities to their specific project, as feasible.
- Where data was available, building energy intensity was calculated for the Midwest region. However, in the case of industrial buildings, floorspace data were only available at the national level. Therefore, the building energy intensity for industrial buildings was calculated at a national level.
- Building energy intensity data are from 2018 for commercial, industrial, and institutional buildings and 2020 for residential buildings. These values are expected to change over time as buildings become more efficient. Additionally, these default values are derived based on actual energy consumption data for the region and do not consider energy efficiency standards for new or retrofitted buildings in Minnesota.

[82] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[83] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

3.2 Coal Production

Emissions from coal production include emissions tied to the underground mining, surface mining, coal cleaning, transportation of the coal to a power plant, and combustion activities.[84] The calculator quantifies these emissions based on estimates of additional coal production, the heat content of the coal, and emission factors, as shown in Equation 13.

Equation 13. Annual Emissions from Coal Production

$$annual\ GHG\ emissions = \sum (quantity_t \times heat\ content_t \times emission\ factor_t \times 0.000001)$$

where,

Quantity	= Amount of additional coal production by coal type, t (short tons/year)
Heat content	= Heat content conversion factor by coal type, t (Btu/ton)
Emission factor	= Life cycle coal emissions, from coal production through combustion, by type, t ($kgCO_2e$/MMBtu)
0.000001	= Unit conversion from Btu to MMBtu

Coal Quantity and Heat Content

Users are required to provide data in short tons on the additional quantity of coal produced and consumed as a result of the proposed project. Table 3-9 below lists the coal types that are included in the calculator and their assumed heat content, as obtained from EPA's GHG Emission Factors Hub.[85]

Table 3-9. Heat Content of Coal by Type

Coal Type	Heating Value (Btu/ton)
Mixed*	19,730,000
Anthracite	25,090,000
Bituminous	24,930,000
Subbituminous	17,250,000
Lignite	14,210,000
Coal Coke	24,800,000

*Based on an assumed electric power sector mix.

[84] Some of the emissions tied to the intermediate steps from coal mining to the final coal product assumed for combustion, such as coal processing, are not included. Data were not readily available for the emissions tied to these intermediate steps and are likely to vary by coal type.

[85] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Emission Factors

The emission factors for coal were derived based on data obtained from EPA's GHG Emission Factors Hub[86] and GREET 1 2024.[87] Emissions from combustion were obtained from EPA while upstream emissions associated with coal mining, coal cleaning, and the transportation of coal to power plants were derived from GREET 1 2024. GREET 1 2024 does not distinguish between different coal types. Consequently, a single upstream emissions factor from GREET 1 2024 is assumed for all coal types. The emission factors for each coal type broken out by upstream activities and product combustion are summarized in Table 3-10.

Table 3-10. Coal Emission Factors

Coal Type	Emission Factor ($kgCO_2e/MMBtu$)*		
	Upstream	Combustion	Total
Mixed**	5.76	96.25	102.02
Anthracite	5.76	104.42	110.19
Bituminous	5.76	94.01	99.78
Subbituminous	5.76	97.90	103.67
Lignite	5.76	98.45	104.22
Coal Coke	5.76	114.40	120.17

* Values shown are based on AR5 global warming potentials.

**Based on electric power sector mix.

Limitations

Key limitations of the methodology used to quantify emissions from coal production include:

- Emissions from coal mining are heavily dependent on the characteristics of the coal and the way it is handled after leaving the mine. As a result, the proposed methodology relies on users to identify the coal type, and the emissions quantified may simplify some of the project-specific operational considerations relevant for this source.

3.3 Natural Gas and Oil Products

Natural Gas Systems

Emissions from natural gas systems occur during natural gas recovery, gathering and boosting, processing, transmission and storage, distribution, and ultimately from the combustion of the fuel. This emission source is applicable to projects that expand the delivery capacity of natural gas (e.g., pipelines, processing plants,

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[86] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

[87] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

storage). The calculator quantifies emissions from natural gas systems based on estimates of additional natural gas throughput, the heat content of natural gas, and a fuel-specific emission factor, as shown in Equation 14.

Equation 14. Annual Emissions from Natural Gas Systems

$$aannual\ GHG\ emissions = (throughput \times heat\ content \times emission\ factor\ \times 0.000001)$$

where,

Throughput	= Amount of additional natural gas throughput (cubic feet/year)
Heat content	= Heat content conversion factor natural gas, 1,026 (Btu/cubic foot)[88]
Emission factor	= Life cycle emissions, from recovery through combustion ($kgCO_2e/MMBtu$)
0.000001	= Unit conversion from Btu to MMBtu

Natural Gas Throughput

Users are required to provide data in cubic feet on the additional quantity of natural gas produced and consumed as a result of the proposed project.

Emission Factor

The emission factor for natural gas was derived based on data obtained from EPA's Emission Factors Hub[89] and GREET 1 2024.[90] Emissions from combustion were obtained from EPA, and upstream emissions from natural gas recovery through distribution to the end user were derived from GREET 1 2024. The emission factor broken out by lifecycle stage is summarized in Table 3-12.

Table 3-11. Natural Gas Emission Factors

Fuel Type	Emission Factor ($kgCO_2e/MMBtu$)*		
	Upstream	Combustion	Total
Natural Gas	12.03[a]	53.11	65.15

[a] Based on GREET's default assumptions for the share of conventional and shale gas in North America and the transmission and distribution loss factor for natural gas.
* Values shown are based on AR5 global warming potentials.

Leakage and Venting

The upstream emissions for natural gas in Table 3-12 include methane emissions from equipment leaks and venting. Equipment leaks, commonly referred to as fugitive emissions, are unintentional methane leaks that can occur from equipment components during operational/fueling activities. Venting is the intentional, direct

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[88] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[89] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[90] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

release of natural gas into the atmosphere, which is commonly done for operational, safety, and maintenance purposes. A further breakdown of the methane leakage and venting emissions, which represent approximately 6.35% of the total natural gas life cycle emissions for average U.S. production, is shown in Table 3-12.

Table 3-12. Methane Leakage and Venting Emissions

Natural Gas Supply Chain Segment	gCH_4/MMBtu	$kgCO_2e$/MMBtu[a]
Recovery	93.88	2.63
Processing	5.70	0.16
Transmission and Distribution	53.32	1.49
Total	**152.90**	**4.28**

Note: Based on GREET 1 2024 default assumptions for the pathway of natural gas production for stationary fuel, including an assumed transmission and distribution loss factor for natural gas.
[a] Values shown are based on AR5 global warming potentials.

To accommodate the implementation of technologies and practices that minimize these emissions, the calculator allows users to adjust the default emissions associated with leakage and venting. Specifically, users may enter a value between 0–75% to indicate the percent by which leakage and venting emissions are expected to be reduced relative to the default assumption.[91] Equation 15 details the equation used to adjust the lifecycle natural gas emission factor in the calculator.

Equation 15: Adjusted Natural Gas Emission Factor

$$EF_{adjusted} = emission\ factor - \ leakage\ \&\ venting\ + \left(leakage\ \&\ venting\ \times (1 - reduction)\right)$$

where,

Emission factor = Default life cycle natural gas emissions, from natural gas recovery through combustion ($kgCO_2e$/MMBtu)
Leakage & venting = Default leakage and venting emissions ($kgCO_2e$/MMBtu)
Reduction = Percent of leaking and venting emissions that are reduced due to implementation of mitigation strategies (%)

Petroleum Products

Emissions from petroleum products include emissions tied to crude oil recovery, transportation to refineries, storage, oil product refinement (e.g., from crude oil to conventional gasoline), and the subsequent transportation, distribution, storage, and combustion of petroleum products. This emissions source is applicable

[91] The reduction percentage is capped at 75% to prevent the user from eliminating all methane leakage and venting emissions associated with natural gas systems. The 75% cap was derived according to a 2021 report from the International Energy Agency that states that 75% of methane emissions from oil and gas operations can be avoided with readily available technologies. See: IEA. "Curtailing Methane Emissions from Fossil Fuel Operations." 2021. https://www.iea.org/reports/curtailing-methane-emissions-from-fossil-fuel-operations.

to projects that expand the delivery capacity of oil products (e.g., pipelines, refineries, storage). The calculator quantifies emissions from oil products based on estimates of additional product throughput, the heat content of the petroleum product, and a fuel-specific emission factor, as shown in Equation 16.

Equation 16. GHG Emissions from Petroleum Products

$$annual\ GHG\ emissions = \left(throughput \times\ heat\ content_p \times emission\ factor_p\right)$$

where,

throughput	= Amount of additional oil product (gallons/year)
heat content	= Heat content conversion factor for petroleum product, p (Btu/gallon)
Emission factor	= Life cycle emissions from crude oil recovery through fuel combustion for petroleum product, p ($kgCO_2e$/MMBtu)

Petroleum Product Throughput and Heat Content

The additional throughput of petroleum products will be provided by the user in gallons. Table 3-13 below lists the petroleum products that are included in the calculator and their assumed heat content from EPA's Emission Factors Hub.[92]

Table 3-13. Heat Content of Petroleum Products

Petroleum Product	Heating Content (Btu/gallon)
Propane	91,000
Gasoline	125,000
Distillate Fuel Oil No. 1	139,000
Distillate Fuel Oil No. 2	138,000
Distillate Fuel Oil No. 4	146,000
Residual Fuel Oil No. 5	140,000
Residual Fuel Oil No. 6	150,000
Liquefied Petroleum Gas (LPG)	92,000
Kerosene	135,000
Kerosene Jet Fuel	135,000

[92] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Emission Factors

The emission factors for petroleum products were derived based on data obtained from the EPA Emission Factors Hub[93] and GREET 1 2024.[94] Emissions from combustion were obtained from EPA while upstream emissions from crude oil recovery through distribution of the product to the end user (identified as Upstream in Table 3-14), were derived from GREET 1 2024. The emission factors, broken out by lifecycle stage, are summarized in Table 3-14.

Table 3-14. Oil Product Emission Factors

Fuel Type	Emission Factor ($kgCO_2e$/MMBtu)*		
	Upstream	Combustion	Total
Propane	18.17	63.11	81.28
Gasoline	22.86	70.46	93.33
Distillate Fuel Oil No. 1	16.11	73.49	89.60
Distillate Fuel Oil No. 2	16.11	74.20	90.31
Distillate Fuel Oil No. 4	16.11	75.28	91.39
Residual Fuel Oil No. 5	12.80	73.17	85.97
Residual Fuel Oil No. 6	12.80	75.34	88.14
Liquefied Petroleum Gas (LPG)	18.76	61.95	80.71
Kerosene	16.11	75.44	91.55
Kerosene Jet Fuel	11.85	72.46	84.31

[a] Reflects the upstream emissions factor for Conventional Diesel from GREET 1 2024.

* Values shown are based on AR5 global warming potentials.

Biofuels

Emissions from biofuel products include emissions tied to feedstock production, transportation, and the refining/processing of feedstocks into biofuels, along with emissions tied to the transportation, distribution, storage, and combustion of the finished biofuel products. Emissions are applicable to projects that expand the delivery capacity of biofuels (e.g., pipelines, processing plants, storage). The calculator quantifies emissions from biofuel products based on estimates of additional product throughput, the heat content of the biofuel product, and a fuel-specific emission factor, as shown in Equation 17.

[93] EPA. "GHG Emission Factors Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

[94] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Equation 17. GHG Emissions from Biofuels

$$annual\ GHG\ emissions = (throughput \times\ heat\ content_p \times emission\ factor_p)$$

where,

throughput = Amount of additional biofuel product (gallons/year or cubic ft/year)
heat content = Heat content conversion factor for biofuel product (Btu/gallon or Btu/cubic ft)
Emission factor = Life cycle biofuel product emissions from feedstock production through fuel combustion ($kgCO_2e$/MMBtu)

Biofuel Throughput and Heat Content

The additional throughput of biofuels as a result of the proposed project will be provided by the user in gallons for liquid fuels and cubic feet for gaseous fuels. Table 3-15 below lists the biofuels that are included in the calculator and their assumed heat content from the EPA Emission Factors Hub.[95]

Table 3-15. Heat Content of Biofuel Products

Biofuel	Heating Value	Units
Biodiesel 100	128,000	Btu/gallon
Biodiesel 20[a]	128,000	Btu/gallon
Renewable Diesel II[b]	122,887	Btu/gallon
Renewable Natural Gas	1,026	Btu/cubic ft

[a] Not available from EPA Emission Factors Hub. Assumes the same heat content as BD100.

[b] Not available from EPA Emission Factors Hub. Based on low heating value for Renewable Diesel II from GREET.

Emission Factors

The emission factors for biofuels were derived based on data obtained from the EPA Emission Factors Hub[96] and GREET 1 2024.[97] Emissions from combustion were obtained from EPA when available, and from GREET 1 2024 for other biofuels. Upstream emissions from biofuel feedstock production through distribution of the biofuel to the end user were derived from GREET 1 2024. The emission factors for each biofuel, broken out by lifecycle stage, are summarized in Table 3-16.

[95] EPA. "GHG Emission Factors Hub." 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[96] EPA. "GHG Emission Factors Hub." 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[97] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Table 3-16. Biofuel Emission Factors

Fuel Type	Emission Factor ($kgCO_2e/MMBtu$)[a]		
	Upstream	Combustion [b]	Total
Biodiesel 100	26.87[c]	0.06	26.93
Biodiesel 20	17.81[c]	65.52	83.33
Renewable Diesel II	37.38[c]	0.50	37.87
Renewable Natural Gas	18.50[d]	0.05	18.56

[a] Values shown are based on AR5 global warming potentials.

[b] Excludes CO_2 emissions, which are considered biogenic.

[c] Obtained from GREET 1 2024. Assumes soybean oil base.

[d] Based on the emissions factor for landfill gas to natural gas.

Limitations

Key limitations of the methodology used to quantify emissions from natural gas and oil products include:

- The pathways and associated emission intensities of oil-based products are often specific to site characteristics and operational practices. However, the calculator relies on national/regional average values, which may embed assumptions that do not reflect specific project context. Furthermore, users have limited ability to modify these embedded assumptions within the calculator.
- In some cases, the GREET1 2024 model does not offer the same level of fuel disaggregation as EPA's GHG Emission Factor Hub. To enable life cycle emissions factor development for all fuel types, assumptions were made to align the data between sources based on fuel characteristics and best-fit methodologies. Additionally, combustion emission factors derived from EPA's GHG Emission Factor Hub are not technology-specific, and therefore may not accurately capture the characteristics of particular equipment or vehicle types. These tradeoffs were made to balance the need for detailed fuel differentiation with a streamlined and usable quantification framework.

3.4 Industrial Processes

Emissions result from industrial processes that occur during project operation. This source accounts for emissions associated with the extraction of raw materials, their transportation to the industrial site, and the manufacturing process (including process emissions) of industrial products. The calculator quantifies these emissions based on estimates of annual product output and product-specific emission factors, as shown in Equation 18.

Equation 18. Annual GHG Emissions from Industrial Processes

$$annual\ GHG\ emissions = \sum quantity_p \times emission\ factor_p$$

where,

Quantity	= Amount of product, p, produced annually (tons/year)
Emissions factor	= GHG emissions per unit of product, p ($kgCO_2e$/ton)

Quantity of Product

Users are required to provide the quantity of product produced annually (in short tons) by industrial process. The types of industrial outputs for which users may provide data include the following:[98]

- Cement
- Lime
- Limestone
- Magnesium
- Iron and steel
- Ammonia
- Aluminum
- Nitric acid

Emission Factors

Default emission factors are available in the calculator. Users may apply the default values, or they may enter their own value. Default emission factors for each industrial process were compiled from GREET 1 2024,[99] GREET 2 2024,[100] the Aluminum Association,[101] and EC3.[102] Table 3-17 summarizes emission factors by industrial process.[103] Additional detail on the activities accounted for in the emission factors are summarized in Table 3-18.

[98] Additional industrial process emission sources were identified but excluded due to lack of data availability (e.g., soda ash manufacture and consumption and semiconductor manufacture).
[99] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[100] Argonne National Laboratory. "GREET 2 2024 Excel-based Vehicle-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[101] Aluminum Association. "Pathways to Decarbonization: A North American Aluminum Roadmap," Arlington, VA: Aluminum Association, May 2024. https://www.aluminum.org/sites/default/files/2024-06/North-American-Decarbonization-Roadmap_6.11.24.pdf.
[102] Building Transparency. "Embodied Carbon in Construction Calculator (EC3)." Accessed April 1, 2025. https://buildingtransparency.org/ec3.
[103] The emission factors are cradle-to-gate and typically include raw material extraction, transportation to manufacturing site, and manufacturing emissions (including energy use, ancillary inputs and process emissions). Users should review the table to ensure that these emissions do not overlap with emissions quantified by other emission sources.

Table 3-17. Industrial Process Emission Factors

Industrial Process	$kgCO_2e/ton$[a]	Source
Cement production	863.12	GREET 2, 2024
Lime manufacture	1,162.63	GREET 1, 2024
Limestone	8.59	GREET 1, 2024
Magnesium production and processing	16,178.31	GREET 2, 2024
Iron & steel production[b]	1,326.60	GREET 1, 2024; EC3
Ammonia production & urea consumption	937.36	GREET 1, 2024
Aluminum production[b]	9,332.16	Aluminum Association
Nitric acid production	1,804.37	GREET 1, 2024

[a] Values shown are based on AR5 global warming potentials.

[b] Emission factor is only available in CO_2e; AR5 global warming potentials were used by the Aluminum Association. Global warming potentials from EC3 vary across EPDs.

Table 3-18: Emission Sources Selected and Lifecycle Stages Quantified

Product	Product Description[a]	Emissions Quantified
Cement production	Cement Product: Combined Emissions	• Cement energy use • Facility emissions based on federal datasets • Avoided landfill gas emissions • On-site mobile fuel use • Transportation • Gypsum and clay quarrying (based on national average material shares in cement) • Energy use
Lime manufacture	Lime	• Lime: production, process emissions, transportation • Limestone: mining, process emissions
Limestone	Limestone ($CaCO_3$), Emissions of Material Inputs for Plastics Pathways	• Mining • Process emissions • Transportation as fertilizer
Magnesium production and processing	Virgin Magnesium	• Ore mining • Electrolytic production • Thermal production • Casting • Molding
Iron & steel production	Average of Cast and Forged Iron Production and Steel Production products[b]	• Energy use and emissions for material • Iron: recycling, casting, forging, and machining • Steel: electric arc furnace, rod and bar mill, and machining emissions

Product	Product Description[a]	Emissions Quantified
Ammonia production & urea consumption	Urea	• Ammonia production • Urea production • Process emissions (urea and ammonia) • Transportation (urea and ammonia, as fertilizer products)
Aluminum production	NA Domestic Production of Primary Aluminum (Aluminum Ingot)	• Primary Aluminum Production from Virgin Ore to Aluminum Ingot
Nitric acid production	Nitric Acid	• Nitric acid production • Process emissions • Transportation

[a] Products are quantified for U.S. National Average unless otherwise specified.
[b] Multiple products were available, so four emission factors were averaged to calculate a U.S. average emission factor for the iron and steel industry together.

Limitations

Key limitations of the methodology used to quantify emissions from industrial processes include:

- The default emission factors were estimated based on a representative industrial process for the eight industrial processes included in the calculator. Due to variation across industries, users are encouraged to tailor the emission factor based on the proposed project.
- The default emission factors consider the lifecycle impact of the activity. Users should review what is included in the default emission factors (see Table 3-18) to ensure they do not double-count emissions quantified by other emission sources in the calculator (e.g., building energy consumption).
- Additional industrial processes may be relevant that are not currently included in the calculator. These include soda ash manufacture and consumption and semiconductor manufacture. Further research is needed to develop default emission factors for these additional industrial processes.

3.5 HFC Leakage

Emissions result from the leakage of hydrofluorocarbons (HFCs) that are used in air conditioning (A/C) and refrigeration equipment. Leakage occurs from this equipment during installation, operation (including servicing), and disposal. The calculator quantifies emissions from HFC leakage based on the assumed type of equipment and refrigerant installed, the estimated charge size of equipment, and the annual leak rate of equipment, as shown in Equation 19, Equation 20, and Equation 21.

Equation 19. Refrigerant Charge

$$charge_{r,e} = (area_t * area\ utilized_t) \times capacity_{r,e}$$

where,

Area	= Area by building type, t (square feet)
Area utilized	= Percent of area by building type, t, that is actively utilized (%)
Capacity	= Refrigerant capacity per square foot by equipment type, e, and refrigerant type, r (kg HFC/square foot)

Equation 20. Annual HFC Leak Rate

$$annual\ leak\ rate_e = \frac{installation_e}{lifetime_e} + operating_e + \left(remaining_e \times \frac{(1 - recovery_e)}{lifetime_e}\right)$$

where,

Installation	= Installation emission rate by equipment type, e (% of capacity)
Lifetime	= Refrigerant lifetime by equipment type, e (years)
Operating	= Operating emission factor by equipment type, e (% of capacity/year)
Remaining	= Refrigerant remaining at disposal by equipment type, e (% of capacity)
Recovery	= Recovery efficiency by equipment type, e (% of remaining)

Equation 21. GHG Emissions from HFCs

$$annual\ GHG\ emissions = \sum charge_{r,e} \times annual\ leak\ rate_e \times GWP_r$$

where,

Charge	= Total refrigerant charge by equipment type, e, and refrigerant type, r (kg HFC)
Leak rate	= Annual HFC leak rate by equipment type, e (%)
GWP	= Global warming potential (GWP) by refrigerant type, r

Building Area

Users are required to provide the total building area and the portion of the building area that is actively utilized. The area that is actively utilized is any area in the building that contains refrigeration and A/C equipment (for example, this would exclude a warehouse that is not air conditioned). As a default, the calculator assumes 100 percent of building area is utilized. The types of buildings for which users may provide data include the following:

- Commercial
- Institutional
- Residential
- Industrial

Equipment and Refrigerant Types

Assumptions regarding the type of refrigeration and A/C equipment found in each building type and the type of refrigerant found in each equipment type are based on EPA's HFC Accounting Tool.[104] Table 3-19 summarizes which building types from EPA's HFC Accounting Tool are used as a proxy for each of the building types in the calculator and the equipment and refrigerant types each building are assumed to contain.

Table 3-19. Building Type Matching

Building Type	EPA Building Type	Equipment Type	Refrigerant Type
Residential	Family Housing	Household refrigerators and/or freezers	R-134a
		Room A/C or Other residential A/C and heat pumps	R-410a
Institutional	School	Household refrigerators and/or freezers	R-134a
		Stand-alone retail refrigerators and freezers	R-134a
		Walk-in refrigerators and freezers	R-404a
		Other commercial A/C and heat pumps	R-410a
Commercial	Office	Household refrigerators and/or freezers	R-134a
		Other commercial A/C and heat pumps	R-410a
Industrial	Warehouse, Service & Industrial	Other commercial A/C and heat pumps	R-410a

Note: The composition of R-410a is 50% HFC-32 and 50% HFC-125. The composition of R-404a is 44% HFC-125, 4% HFC-134a, and 52% HFC-143a.

Refrigerant Capacity

The refrigerant capacity for each equipment type in kilograms per thousand square feet is calculated using data obtained from Appendix C of EPA's HFC Accounting Tool Supporting Documentation, as summarized by building type in Table 3-20. The capacity per square foot is provided in kilograms/square foot for some equipment types. For equipment types where the capacity was not provided, the capacity is calculated by multiplying the units per thousand square feet by the refrigerant charge size per unit.

[104] EPA. "Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions," 2016. https://www.epa.gov/sites/default/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf.

Table 3-20. Refrigerant Capacity by Building and Equipment Type

Building Type	Equipment Type	Refrigerant Charge Size per Unit (kg)	Units per 1,000 Square Feet	Refrigerant Capacity (kg/sq ft)	Refrigerant Capacity (kg/1,000 sq ft)
Residential	Household refrigerators and/or freezers	0.15	0.769	NA	0.1154
	Average room A/C & other residential A/C and heat pumps	2.75	NA	0.00225	2.2500
Institutional	Stand-alone retail refrigerators and freezers	0.40	0.094	NA	0.0376
	Walk-in refrigerators and freezers	10.00	0.040	NA	0.4000
Commercial	Household refrigerators and/or freezers	0.15	0.112	NA	0.0168
	Other commercial A/C and heat pumps	13.00	NA	0.00180	1.8000
Industrial	Other commercial A/C and heat pumps	13.00	NA	0.00030	0.3000

Leak Rate

The annualized leak rate by equipment type is calculated based on assumptions regarding the installation emissions rate, the operating emissions rate, the percent of refrigerant remaining at disposal, the recovery efficiency, and the equipment lifetime, as obtained from Table 3-3 and Table 3-6 in EPA's HFC Accounting Tool Supporting Documentation, and shown in Table 3-21.[105]

[105] EPA. "Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions," 2016. https://www.epa.gov/sites/default/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf

Table 3-21. Leak Rate by Equipment Type

Equipment Type	Installation Emissions Rate (% of capacity)	Operating Emission Factor (% of capacity/yr)	Refrigerant Remaining at Disposal (% of capacity)	Recovery Efficiency (% of remaining)	Equipment Lifetime (years)	Annualized Leak Rate
Household refrigerators and/or freezers	0%	0.5%	91%	31%	14.0	4.99%
Other commercial A/C and heat pumps	0%	8.0%	80%	70%	25.0	8.96%
Average room A/C & other residential A/C and heat pumps	0%	4.5%	87%	36%	13.5	8.61%
Stand-alone retail refrigerators and freezers	0%	1.0%	90%	25%	10.0	7.75%
Walk-in refrigerators and freezers	2%	12.0%	90%	70%	20.0	13.45%

Limitations

Key limitations of the methodology used to quantify emissions from HFC leakage include:

- This calculation method is one of four approaches for estimating emissions from HFC leakage presented by the EPA. It represents the most simplified option among the available methods. This approach relies on limited inputs (i.e., building square footage) and incorporates numerous assumptions regarding the type of refrigeration and A/C equipment and the refrigerants used in each building.
- The HFC Accounting Tool was developed prior to the enactment of the American Innovation and Manufacturing (AIM) Act of 2020, which establishes a phasedown schedule for HFCs in the United States. The default assumptions therefore do not account for the anticipated transition away from HFCs in refrigeration and A/C equipment.
- The calculator characterizes buildings into four types: residential, institutional, commercial, and industrial. Each category is mapped to a representative building type from the HFC Accounting Tool. This mapping introduces some uncertainty, as there is variation in equipment use across building subcategories.

3.6 Land Use Change

This emissions source (or sink) includes the net carbon change from the transition of one land use type to another during project operation. The method described below uses a stock change approach to calculate carbon gains or losses, which are used as a proxy for emissions. To account for lifecycle emissions, the net carbon change calculations assume full realization of the land transition. The calculator quantifies net carbon change from land use change based on land area post-construction and post-operation, and the carbon stock of each land type and tree, as shown in Equation 22.

Equation 22. Net Change in Carbon Stock from Operation

$$GHGs\ emitted\ or\ sequestered\ = \sum(area\ post\ construction_t - \ area\ post\ operation_t) \times\ carbon\ stock_t\ \times \frac{44}{12}$$

where,

Area post-construction = Number of acres of land by type, t, post-construction (acres)
Area post-operation = Number of acres of land by type, t, post-operation (acres)
carbon $stock_t$ = Amount of carbon stored per acre for land type, t (MT C/acre)
44/12 = Conversion factor of C to CO_2

Land Types

Users are required to provide the number of acres by land cover type post-construction and post-operation. The land cover types for which users may provide data are the same as those listed in Section 2.5.

Carbon Stocks by Land Type

Carbon stocks by land type were derived from various sources including Minnesota-specific studies, national reports, and IPCC Guidelines. The values represent carbon stocks from aboveground biomass, belowground biomass, soil carbon, and dead organic matter, including litter and woody debris. The carbon stocks by land type are summarized below in Table 3-22. See Section 2.5 for additional details on the basis for these values.

Table 3-22. Carbon Stocks by Land Type

Land type	MT C per acre
Wetlands, forested	256.7
Wetlands, not forested	211.7
Forest	99.0
Rivers and streams	0
Brush and grassland	40.8
Cropland	32.5
Livestock rangeland/pastureland	40.8
Lawn/landscaping	19.1
Green infrastructure: constructed wetlands, vegetated	43.4
Green infrastructure: constructed wetlands, paved	0
Green infrastructure: constructed green roofs	19.1
Green infrastructure: constructed permeable pavements	0

Land type	MT C per acre
Impervious surface	0
Stormwater pond (wet sedimentation basin)	0

Limitations

Key limitations of the methodology used to quantify emissions from land use change include:

- The quantification method employs a stock-based approach to estimate net carbon changes from land use conversion, which provides a simplified snapshot of carbon stocks before and after the land transition. Unlike a net flux approach, this method does not directly account for the dynamic processes of carbon sequestration and release over time, such as annual plant growth, decomposition rates, or soil carbon dynamics following disturbance. Therefore, it provides a static estimate of long-term carbon impacts rather than a detailed accounting of annual carbon fluxes.
- The land types included in the calculator are consistent with the land types defined in the EAW. Several limitations arise from the use of pre-defined carbon stock values for each land type. These values are derived from various sources, including regional and national studies, as well as IPCC Guidelines, and represent averages that may not fully capture the specific conditions of the project site. Site-specific factors such as soil type, vegetation composition, forest age and type, management practices, and microclimate can significantly influence actual carbon stocks.
- The method assumes full realization of the land transition over 30 years. Therefore, the results assume that no further changes to the converted land will occur in the foreseeable future.
- The estimated carbon stocks do not account for impacts from maintenance activities (e.g., lawn moving, irrigation) or fertilizer application. These impacts should be considered separately.

3.7 On-Road Vehicles

This emissions source includes emissions from on-road vehicles that are used during the operational phase of the project. This includes emissions generated from vehicles that are driven on project roadways and downstream from vehicles driven to and from the project site by visitors or residents. The calculator quantifies incremental on-road emissions based on estimates of additional vehicle miles traveled (VMT) and an on-road vehicle emission factor, as shown in Equation 23.

Equation 23. Annual GHG Emissions from On-Road Vehicles

$$annual\ GHG\ emissions\ = \sum VMT_s \times\ emission\ factor_s$$

where,

VMT = Number of additional VMT by speed bin, s (miles/year)
Emission factor = Emissions per additional mile traveled by speed bin, s (CO_2e/mile)

Speed Bin

Users have the option to provide VMT broken out by speed bin, if available. The speed bins for which users may provide additional VMT input data include the following:

- 0-30 mph
- 31-55 mph
- 56-75 mph
- Fleet average

Emission Factors

Emission factors for on-road vehicles were obtained from MICE3.0.[106] The factors are based on emissions generated using MOVES5[107] and Minnesota-specific inputs. The output from MOVES represents tailpipe-only emissions. Therefore, MICE3.0 applies a scaling factor of 1.2894 to account for upstream emissions. The lifecycle emission factors for the on-road fleet and by speed bin are summarized in Table 3-24.

Table 3-23. Emission Factors for On-Road Vehicles by Speed Bin

Speed Bin	Emission Factor[a] (gCO_2e/mile)					
	2025	2030	2035	2040	2045	2050
0-30	854.89	717.55	558.62	446.81	382.78	351.40
31-55	529.47	445.57	348.27	279.83	240.56	221.16
56-75	518.99	436.81	342.00	275.38	237.17	218.36
Fleet Average	578.91	485.73	378.31	302.92	259.65	238.31

[a] Emission factors from the Minnesota Infrastructure Carbon Estimator (MICE) Tool were derived using AR5 global warming potentials.

Limitations

Key limitations of the methodology used to quantify emissions from on-road vehicles include:

- The calculator currently limits users in quantifying increases in operational on-road emissions based on the emission estimates tied to the fleet composition outputted from the MOVES model, per the user selected (or defaulted) speed bin. Further tailoring of emission factors by vehicle type (e.g., light-duty vehicles, heavy-duty vehicles) is not currently available.
- While projects may also impact traffic congestion in addition to trip generation, the methodology only accounts for emissions from trip generation.

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[106] Minnesota Department of Transportation. "Minnesota Infrastructure Carbon Estimator (MICE) Tool, version 3.0," 2025. (unpublished). https://www.dot.state.mn.us/project-development/subject-guidance/greenhouse-gas-analysis/process.html
[107] EPA. "MOVES5: Latest Version of MOtor Vehicle Emission Simulator (MOVES)," 2025. Available at https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

3.8 Treatment of Waste On-Site

Emissions result from the on-site treatment of waste during project operations. This emissions source is applicable to landfills, waste incineration facilities, composting facilities, and anaerobic digesters. The calculator quantifies emissions the treatment of waste on-site based on the estimated quantity of waste and treatment-specific emission factors, as shown in Equation 24.

Equation 24. Annual GHG Emissions from Waste Treated On-Site

$$annual\ GHG\ emissions = \sum waste\ treated_p \times emission\ factor_p$$

where,

Waste treated	= Amount of waste material treated each year by treatment type, p (tons/year)
Emissions factor	= Emissions associated with the treatment of waste by treatment type, t ($MTCO_2e$/ton)

Waste Treated

The quantity of waste treated annually is based on values provided by users in short tons by waste treatment practice. The types of waste treatment practices for which users may provide data include:

- Landfilling (MSW)
- Landfilling (C&D)
- Combustion
- Composting
- Anaerobic Digestion (Dry)
- Anaerobic Digestion (Wet)

Emission Factors

Emission factors associated with the waste treatment practice, as summarized in Table 3-24, were derived from EPA's GHG Emissions Factors Hub.[108] The emission factors, which are based on factors from WARM, include emissions from the decomposition and combustion of waste as well as the transportation of waste to the waste treatment facility.[109] The landfilling emissions factor for C&D waste is consistent with the emissions factor derived in Section 2.6 to quantify emissions from construction waste.

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[108] EPA. "GHG Emission Factor Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[109] The emission factors do not include avoided emissions associated with displaced electric utility generation, landfill carbon sequestration, soil carbon storage, or avoided fertilizer application.

Table 3-24: Waste Emission Factors by Treatment Type

Treatment Practice	Emission Factor ($MTCO_2e$/ton)
Landfilling (MSW)	0.58
Landfilling (C&D)	0.05
Combustion	0.43
Composting	0.13
Anaerobic Digestion (Dry)	0.13
Anaerobic Digestion (Wet)	0.11

Limitations

Key limitations of the methodology used to quantify emissions from the treatment of waste on-site include:

- The emission factors reflect assumptions regarding the typical composition of municipal solid waste, C&D waste, or organic waste. The actual composition of the waste treated at these sites may differ from these typical compositions.
- Emissions from the transportation of waste that are accounted for in the emission factors are based on a default assumption regarding the distance traveled from the generation site to the waste management facility, which may vary from the actual distance traveled for a specific project.
- The landfill emission factors are based on typical landfill gas collection practices and average landfill moisture conditions. Actual emissions will vary based on the characteristics of the actual landfill.
- The anaerobic digestion factors are based on the treatment of food and yard waste. An emissions factor to quantify emissions from the treatment of biosolids is not currently available. Users may use the Manure Management emissions source to quantify emissions from the treatment of manure by an anaerobic digester.

3.9 Treatment of Wastewater On-Site

Emissions result from the treatment of municipal and industrial wastewater, including direct methane emissions from the wastewater treatment process and indirect nitrous oxide emissions from wastewater effluent.

Municipal Wastewater Emissions

The calculator quantifies emissions from the treatment of municipal wastewater based on the population served by the wastewater treatment plant, the assumed per capita biological oxygen demand (BOD) and protein consumption, and the resulting methane and nitrous oxide emissions, as shown in the equations below.

Equation 25. Methane Emissions from Municipal Wastewater

$$annual\ CH_4\ emissions = population \times BOD \times 365 \times emission\ factor_{BOD} \times AD$$

where,

Population	= Population served by the wastewater treatment plant
BOD	= Per capita 5-day BOD (kg/person/day)
365	= Conversion factor for days/year
BOD emission factor	= Methane emissions per unit of BOD production (kg CH_4/kg BOD)
AD	= Fraction of wastewater anaerobically digested (%)

Equation 26. Nitrous Oxide Emissions from Municipal Wastewater

$$annual\ N_2O\ emissions = population \times protein \times nitrogen\ content \times fraction \times emission\ factor_{N2O} \times \frac{N2O}{N2}$$

where,

Population	= Population served by the wastewater treatment plant
Protein	= Annual per capita protein consumption (kg/person/year)
Nitrogen content	= Fraction of nitrogen in protein (kg N/kg protein)
Factor	= Factor to adjust for of nitrogen in the protein not consumed
N_2O emission factor	= Nitrous oxide emissions per nitrogen treated (kg N_2O-N/kg sewage N-produced)
N_2O/N_2	= Conversion factor of N_2O-N to N_2O

Equation 27. Annual GHG Emissions from Municipal Wastewater Treatment

$$annual\ GHG\ emissions = (CH_4\ emissions \times GWP_{CH_4}) + (N_2O\ emissions \times GWP_{N_2O})$$

where,

GWP_{CH4}	= GWP of methane
GWP_{N2O}	= GWP of nitrous oxide
CH_4 emissions	= Annual CH_4 emissions from municipal wastewater treatment (kg CH_4)
N_2O emissions	= Annual N_2O emissions from municipal wastewater treatment (kg N_2O)

Population

The population served by the municipal wastewater treatment plant is based on the value provided by the user.

Default Values

Default values, as summarized in Table 3-25, were obtained from EPA's State Inventory Tool.[110]

[110] EPA. "State Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool.

Table 3-25: Municipal Wastewater Treatment Default Values

Data Element	Value	Units
BOD	0.09	kg/person/day
BOD emission factor	0.6	kg CH_4/kg BOD
Percent anaerobically digested	12.38	Percent
Protein	35.7[a]	kg/person/year
Nitrogen content in protein	16	Percent
Factor to adjust for non-consumed protein	1.75	kg N/kg N
N_2O emission factor	0.005	kg N_2O/kg BOD

[a] Based on the 2022 value published in the 1990-2022 U.S. GHG Inventory, Table 7-34.

Limitations

Key limitations of the methodology used to quantify emissions from the treatment of municipal wastewater on-site include:

- The emission estimates are calculated based on a variety of assumptions about the treatment system, BOD production, and protein content of the population served, which are not editable in calculator. Actual emissions will vary based on the specific characteristics of the treatment plant.
- The wastewater treatment calculations currently assume that no nitrogen is removed as sludge and do not separately calculate emissions from the treatment of sludge or the use of biosolids as a fertilizer.

Industrial Wastewater Emissions

The calculator quantifies emissions from the treatment of industrial wastewater based on the product quantity, water consumption per product, the oxygen demand, and product-specific emissions factor, as shown in Equation 28.

Equation 28. Annual GHG Emissions from the Treatment of Industrial Wastewater

$$Annual\ GHG\ emissions = production_p \times outflow_p \times \frac{1000\ L}{m^3} \times BOD\ or\ COD_p \times emission\ factor_p \times \frac{kg}{1000\ g} \times AD \times GWP_{CH4}$$

where,

Production = Amount of product produced annually by product type, p (MT/year)
Outflow = Amount of water consumed per unit output by product type, p (m^3/MT)
BOD or COD = Biological oxygen demand (BOD) or chemical oxygen demand (COD) per wastewater outflow by product type, p (g/L)
Emission factor = Methane emissions per unit of BOD or COD production (g CH_4/g BOD/COD)
AD = Fraction of wastewater anaerobically digested (%)
GWP_{CH4} = GWP of methane

Product Quantity

The amount of product produced annually is based on the value provided by the user in metric tons. The types of products users may select from include the following:

- Fruits and vegetables
- Red meat
- Poultry
- Pulp and paper

Default Values

Default values by product type, as summarized in Table 3-26, were obtained from EPA's State Inventory Tool.[111]

Table 3-26: Industrial Wastewater Treatment Default Values

Product	Wastewater outflow (m^3/MT)	COD/BOD (g/L)	Fraction of BOD/COD anaerobically digested	Emission factor (g CH_4/g BOD/COD)
Fruits and vegetables	9.11	5.0	0.0%	0.25
Red meat	5.30	4.1	33.0%	0.25
Poultry	12.50	4.1	25.0%	0.25
Pulp and paper	39.00	0.3	5.2%	0.60

Limitations

Key limitations of the methodology used to quantify emissions from the treatment of industrial wastewater on-site include:

- The calculator only includes default assumptions for select industries. Users are encouraged to independently estimate emissions from industrial wastewater treatment if their industry is not covered by the calculator.
- The emission estimates are calculated based on a variety of assumptions about the quantity of wastewater treated, BOD or COD production, and emission factors, which are not editable in calculator. Actual emissions will vary based on the specific characteristics of the wastewater and treatment system.

3.10 Treatment of Waste Off-Site

Emissions result from the transportation and treatment of waste that is generated during the operational phase of a project and treated at a facility off-site. Waste generated during project operation may be landfilled, combusted, composted, or recycled. The calculator quantifies emissions from the treatment of waste off-site

[111] EPA. "State Inventory Tool," 2025. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool.

based on the estimated quantity of waste generated and treatment-specific emission factors, as shown in Equation 29 and Equation 30.

Equation 29. Annual Waste Generation

$$waste\ generated_p = \sum waste\ generation\ rate_s \times unit\ multiplier \times\ waste\ disposal\ rate_p$$

where,

Waste generation rate	= Amount of waste material generated by building type, s (lbs/unit)
Unit multiplier	= Number of households/employees/visitors
Waste disposal rate	= Percent of waste material treated by waste management method, p (%)

Equation 30. Annual GHG Emissions from the Treatment of Waste Off-Site

$$annual\ GHG\ emissions = \sum waste\ generated_p \times\ emission\ factor_p$$

where,

Waste generated	= Amount of waste material generated each year by treatment type, p (tons/year)
Emissions factor	= The emissions associated with the transportation and treatment of waste by treatment type, t ($MTCO_2e$/ton)

Waste Generation Rate

The quantity of waste generated is calculated based on waste generation rates. Default waste generation rate assumptions are available in the calculator. Users may apply the default values, or they may enter their own value. The default waste generation rate assumptions were acquired from a residential waste characterization study for the City of Minneapolis,[112] CalRecycle,[113] and a waste characterization study for select industry groups,[114] as summarized in Table 3-27.

Table 3-27. Waste Disposal Rates by Building Type

Building Type	Waste Disposal	Units	Source
Residential	7.00	lb/household/day	MSW Consultants
Industrial	8.93	lb/employee/day	CalRecycle
Commercial	10.53	lb/employee/day	CalRecycle

[112] MSW Consultants. "Residential Waste Characterization & Capture Rate Study," 2022. lims.minneapolismn.gov/Download/RCAV2/30166/Minneapolis 2022 Final Sort Report.pdf.
[113] CalRecycle. "Estimated Solid Waste Generation Rates," 2025. https://www2.calrecycle.ca.gov/wastecharacterization/general/rates.
[114] Cascadia Consulting Group. "Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups," 2006. https://www2.calrecycle.ca.gov/Publications/Details/1184.

Building Type	Waste Disposal	Units	Source
Institutional	3.55	lb/employee/day	CalRecycle
Public venues and events	1.72	lb/visitors	Cascadia

Unit Multiplier

Users are required to provide data on key project characteristics that drive waste production. The project characteristics for which users may provide data include the following:

- Residential: number of households
- Industrial: number of employees
- Commercial: number of employees
- Institutional: number of employees
- Public venues and events: visitors per year

Waste Disposal Rate

The Minnesota Pollution Control Agency (MPCA) collects data on the amount of waste treated by waste management method in Minnesota.[115] The amount of waste that was landfilled and combusted by county in 2022 is summarized in Table 3-28. These values are used to determine the default waste disposal rates by management practice. Users in the calculator can modify these defaults as well as specify a recycling and composting rate for the waste generated, which are defaulted to zero.

Table 3-28. Waste Disposal Rate by County and Management Method

County	Waste Disposed in 2022 (tons)		Default Waste Disposal Rate	
	Landfilled	Combusted	Landfilled	Combusted
Aitkin	8,846	-	100%	0%
Anoka	200,756	19,548	91%	9%
Becker	9,362	11,834	44%	56%
Beltrami	11,857	8,434	58%	42%
Benton	10,891	8,130	57%	43%
Big Stone	2,841	-	100%	0%
Blue Earth	33,314	24,020	58%	42%
Brown	23,251	3,055	88%	12%

[115] MPCA. "Select Committee on Recycling and the Environment (SCORE)," 2022. https://data.pca.state.mn.us/views/SCOREreport2022/2022SCOREreport?%3Aembed=y&%3AisGuestRedirectFromVizportal=y.

County	Waste Disposed in 2022 (tons)		Default Waste Disposal Rate	
	Landfilled	Combusted	Landfilled	Combusted
Carlton	16,109	-	100%	0%
Carver	57,084	7	100%	0%
Cass	19,512	-	100%	0%
Chippewa	11,382	-	100%	0%
Chisago	34,543	-	100%	0%
Clay	32,383	6,440	83%	17%
Clearwater	2,272	3,134	42%	58%
Cook	3,180	-	100%	0%
Cottonwood	10,364	-	100%	0%
Crow Wing	45,646	-	100%	0%
Dakota	229,565	11,697	95%	5%
Dodge	956	8,702	10%	90%
Faribault	1,337	5,928	18%	82%
Fillmore	6,182	1,711	78%	22%
Freeborn	22,000	-	100%	0%
Goodhue	412	20,727	2%	98%
Grant	-	2,648	0%	100%
Hennepin	357,157	377,125	49%	51%
Houston	1,231	6,038	17%	83%
Hubbard	10,989	5,518	67%	33%
Isanti	32,430	-	100%	0%
Itasca	28,422	-	100%	0%
Jackson	4,319	3	100%	0%
Kanabec	10,355	-	100%	0%
Kandiyohi	34,158	-	100%	0%
Kittson	2,185	-	100%	0%
Koochiching	8,372	-	100%	0%
Lac qui Parle	4,787	-	100%	0%
Lake	5,791	-	100%	0%

County	Waste Disposed in 2022 (tons)		Default Waste Disposal Rate	
	Landfilled	Combusted	Landfilled	Combusted
Lake of the Woods	3,422	-	100%	0%
Le Sueur	10,614	4,637	70%	30%
Lincoln	2,991	-	100%	0%
Lyon	21,507	-	100%	0%
Mahnomen	25	1,649	1%	99%
Marshall	5,066	-	100%	0%
Martin	3,260	8,530	28%	72%
McLeod	21,599	-	100%	0%
Meeker	8,523	-	100%	0%
Mille Lacs	16,752	-	100%	0%
Morrison	23,478	-	100%	0%
Mower	24,736	3	100%	0%
Murray	4,491	-	100%	0%
Nicollet	55,129	8,555	87%	13%
Nobles	10,687	-	100%	0%
Norman	692	3,007	19%	81%
Olmsted	2,923	100,767	3%	97%
Otter Tail	10,888	21,816	33%	67%
Pennington	9,299	-	100%	0%
Pine	21,960	-	100%	0%
Pipestone	6,272	-	100%	0%
Polk	15,316	8,106	65%	35%
Pope/Douglas	7,543	27,248	22%	78%
Ramsey	68,570	238,772	22%	78%
Red Lake	1,694	-	100%	0%
Redwood/Renville	15,040	-	100%	0%
Rice	45,129	1,300	97%	3%
Rock	4,531	-	100%	0%
Roseau	10,690	-	100%	0%

County	Waste Disposed in 2022 (tons)		Default Waste Disposal Rate	
	Landfilled	Combusted	Landfilled	Combusted
Scott	72,448	-	100%	0%
Sherburne	41,698	5,314	89%	11%
Sibley	5,977	1,497	80%	20%
St. Louis - partial	53,672	-	100%	0%
Stearns	42,832	31,948	57%	43%
Steele	35,313	-	100%	0%
Stevens	4,401	1,988	69%	31%
Swift	7,405	-	100%	0%
Todd	5,879	7,105	45%	55%
Traverse	1,101	-	100%	0%
Wabasha	2,048	3,915	34%	66%
Wadena	1,421	4,910	22%	78%
Waseca	4,505	-	100%	0%
Washington	25,479	97,332	21%	79%
Watonwan	6,543	-	100%	0%
Wilkin	2,464	-	100%	0%
Winona	20,390	1,949	91%	9%
WLSSD	56,314	-	100%	0%
Wright	91,149	-	100%	0%
Yellow Medicine	4,719	-	100%	0%

Emission Factors

Emission factors associated with different treatment practices were acquired from EPA's GHG Emission Factors Hub and are shown in Table 3-29.[116] These emission factors include emissions from the decomposition and combustion of waste as well as the transportation of waste to the waste treatment facility.[117]

[116] EPA. "GHG Emission Factor Hub," 2025. https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[117] The emission factors do not include avoided emissions associated with displaced electric utility generation, landfill carbon sequestration, soil carbon storage, or avoided fertilizer application.

Table 3-29. Emission factors by Treatment Practice

Treatment Practice	Emission Factor ($MTCO_2e$/short ton)
Landfilled	0.58
Recycling	0.09
Composted	0.13
Combusted	0.43

Limitations

Key limitations of the methodology used to quantify emissions from the treatment of waste off-site include:

- The default waste generation rates are based on sources that are dated and/or may not accurately represent generation rates for the proposed project.
- Emissions from the transportation of waste that are accounted for in the emission factors are based on a default assumption regarding the distance traveled from the project site to the waste management facility, which may vary from the actual distance traveled for a specific project.
- The landfill emission factors are based on typical landfill gas collection practices and average landfill moisture conditions. Actual emissions will vary based on the characteristics of the landfill where the waste is treated.
- The emission factors reflect assumptions regarding the typical composition of municipal solid waste and organic waste. Actual emissions will vary based on the composition of the waste generated by the project. Defaults associated with the treatment of hazardous waste are not included.

3.11 Enteric Fermentation

Methane emissions result from enteric fermentation, the digestive process of ruminant livestock during feedlot operation. The calculator quantifies annual emissions from enteric fermentation based on the annual livestock population and animal-specific emission factors, as shown in Equation 31.

Equation 31. Annual GHG Emissions from Enteric Fermentation

$$annual\ GHG\ emissions_t = livestock_t \times\ emission\ factor_t\ \times\ GWP_{CH4}$$

where,

Livestock = Annual animal population by livestock type and age/production class, t
Emissions factor = Annual enteric fermentation emissions per animal by livestock type, t ($kgCH_4$/head/year)
GWP_{CH4} = The GWP for converting methane

Livestock Population

The annual average animal population by livestock type and age/production class are provided by users. The livestock types for which users may provide data include:

- Bulls
- Beef cows
- Beef heifers
- Steer stockers
- Heifer stockers
- Feedlot beef
- Beef calves
- Dairy heifers
- Dairy cows
- Dairy calves
- Swine, >55 lbs[118]
- Swine, 55-330 lbs
- Swine, 330+ lbs

Emission Factors

Emission factors for enteric fermentation, as summarized in Table 3-30, were obtained from the 1990-2022 U.S. GHG Inventory.[119] Specifically, emission factors for all cattle categories were obtained from Table A-144 for the state of Minnesota. All other livestock emissions factors were obtained from Table A-148.

Table 3-30. Emission Factors for Enteric Fermentation

Livestock Type	Emission Factor (kgCH_4/head/year)
Bulls	95.0
Beef cows	92.0
Beef heifers*	63.0
Steer stockers	56.0
Heifer stockers	58.0
Feedlot beef	33.0
Beef calves	10.0
Dairy heifers*	54.0
Dairy cows	140.0
Dairy calves	12.0
Swine, >55 lbs	1.5

[118] Weight classes for swine differ from those reported in the U.S. GHG Inventory; the classes used in the calculator are consistent with [Minnesota Administrative Rule 7020.03000 subpart 5c](#).
[119] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Livestock Type	Emission Factor ($kgCH_4$/head/year)
Swine, 55-330 lbs	1.5
Swine, 330+ lbs	1.5

*Derived by developing a weighted average by population for the emission factors for the following categories: Replacement Heifers 7-11 Months and Replacement Heifers 12-23 Months.

Limitations

Key limitations of the methodology used to quantify emissions from enteric fermentation include:

- Although the number of animals may change from year to year, users are required to provide the average annual number of livestock over the lifespan of the project. The calculator also does not adjust for lifetimes under one year or any standard annual losses to stock.
- Emission factors for enteric fermentation are derived from state averages for Minnesota, as reported in the U.S. GHG Inventory. Emissions from enteric fermentation can vary significantly among individual animals due to differences in breed, size, and age. Multiple management decisions also influence emissions from enteric fermentation, including feed quality, composition, and feeding practices. This calculator does not account for these factors.
- The method included in this calculator evaluates emissions based solely on the number of livestock in feedlot operations. It does not account for variations in animal productivity or feed efficiency, which can significantly impact emissions intensity (emissions per unit of product). This limitation may lead to over- or under-estimation of emissions for operations with particularly high or low productivity.
- Climate conditions, particularly ambient temperature and humidity, can impact enteric fermentation rates. The use of state-average emission factors may not fully capture these effects, especially in years with extreme weather events or as climate patterns shift due to climate change. As a result, the accuracy of these factors may diminish over time, potentially leading to under- or over-estimation of enteric fermentation emissions.

3.12 Manure Management

Emissions result from the process of managing livestock manure in solid or liquid systems during project operation, including direct and indirect emissions from managed manure and pasture and manure land application. The calculator quantifies annual emissions from manure management based on annual values for the livestock population, typical animal mass, volatile solids, maximum methane production capacity, methane conversion factors, nitrogen excretion, volatilization, runoff and leaching fractions, system-specific emission factors, and the portion of manure managed in each system and applied to land as a fertilizer, as shown in the equations below.

Equation 32. Annual GHG Emissions from Manure Management

$$annual\ GHG\ emissions = (CH_4\ emissions \times GWP_{CH4}) + \left((direct\ N_2O_{manure} + indirect\ N_2O_{manure} + direct\ N_2O_{land} + indirect\ N_2O_{land}) \times GWP_{N2O}\right)$$

where,

CH_4 emissions	= Annual manure management CH_4 emissions ($kgCH_4$)
Direct N_2O_{manure}	= Annual direct N_2O emissions from managed manure and pasture (kgN_2O)
Indirect N_2O_{manure}	= Annual indirect N_2O emissions from managed manure and pasture (kgN_2O)
Direct N_2O_{land}	= Annual direct N_2O emissions from manure land application (kgN_2O)
Indirect N_2O_{land}	= Annual indirect N_2O emissions from manure land application (kgN_2O)
GWP_{CH4}	= The GWP for methane
GWP_{N2O}	= The GWP for nitrous oxide

Equation 33. Annual Methane Emissions from Manure Management

$$annual\ CH_4\ emissions = \sum livestock_t \times TAM_t \times VS_t \times B0_t \times MCF_m \times 0.662$$

where,

Livestock	= Annual animal population by livestock type and age/production class, t
TAM	= Typical animal mass by type, t (kg/head)
VS	= Amount of volatile solids excreted by animal type, t (kg VS/kg animal mass/year)
B_0	= Maximum CH_4 producing capacity by type, t (m^3 CH_4/kg VS)
MCF	= Manure methane conversion factor by management system type, m
0.662	= Density of methane at 25˚C ($kgCH_4$/ m^3CH_4)

Equation 34. Amount of Nitrogen Excreted Annually

$$N\ excreted_t = livestock_t \times TAM_t \times Nex_t$$

where,

Livestock	= Annual animal population by livestock type and age/production class, t
TAM	= Typical animal mass by type, t (kg/head)
Nex	= Nitrogen excretion rate by type, t (kgN/kg animal mass/year)

Equation 35. Annual Direct Nitrous Oxide Emissions from Managed Manure and Pasture

$$direct\ N_2O_{manure} = \sum N\ excreted_t \times emissions\ factor \times \frac{44}{28}$$

where,

N excreted	= Amount of nitrogen excreted annually by type, t, as calculated by Equation 34 (kgN/year)
Emissions factor	= Direct N_2O per kg nitrogen excreted by management system type, m (kgN_2O-N/kgN)
44/28	= Conversion factor of N_2O-N to N_2O

Equation 36. Annual Indirect Nitrous Oxide Emissions from Managed Manure and Pasture

$$indirect\ N_2O_{manure} = \sum \left(N\ excreted_t \times Frac\ Vol_{t,m} \times EF_{vol} \times \frac{44}{28}\right) + \left(N\ excreted_t \times Frac\ Run_{t,m} \times EF_{run} \times \frac{44}{28}\right)$$

where,

N excreted	= Amount of nitrogen excreted annually by type, t, as calculated by Equation 34 (kgN/year)
Frac Vol	= Fraction of nitrogen lost to volatilization by animal type, t, and management system type, m (%)
Frac Run	= Fraction of nitrogen lost to runoff/leaching by animal type, t, and management system type, m (%)
EF_{vol}	= Volatilization indirect N_2O emission factor from IPCC 2019 Refinement, 0.01 (kgN_2O-N/kgN)
EF_{run}	= Leaching and runoff indirect N_2O emission factor from IPCC 2019 Refinement, 0.011 (kgN_2O-N/kgN)
44/28	= Conversion factor of N_2O-N to N_2O

Equation 37. Proportion of Nitrogen Remaining in Manure

$$N\ remaining_t = 1 - \left(emissions\ factor_m + Frac\ Vol_{t,m} + Frac\ Run_{t,m}\right)$$

where,

Emissions factor	= Direct N_2O emission factor by management system type, m (kgN_2O-N/kgN)
Frac Vol	= Fraction of nitrogen lost to volatilization by animal type, t, and management system type, m (%)
Frac Run	= Fraction of nitrogen lost to runoff/leaching by animal type, t, and management system type, m (%)

Equation 38. Annual Direct Nitrous Oxide Emissions from Manure Land Application

$$direct\ N_2O_{land} = \sum N\ excreted_t \times N\ remaining_t \times fertilizer\ applied \times emissions\ factor \times \frac{44}{28}$$

where,

N excreted	= Amount of nitrogen excreted annually by livestock type, t, as calculated by Equation 34 (kgN/year)
N remaining	= The proportion of nitrogen remaining in manure by system type, t, as calculated by Equation 37 (%)
Fertilizer applied	= Percent of manure applied to land as organic fertilizer (%)
Emissions factor	= Direct N_2O emission factor from IPCC 2019 Refinement, 0.01 (kgN_2O-N/kgN)
44/28	= Conversion factor of N_2O-N to N_2O

Equation 39. Annual Indirect Nitrous Oxide Emissions from Manure Land Application

$$\begin{aligned} indirect\ N_2O_{land} = \sum \Big\{ \Big(& \left(N\ excreted_{t,m} \times N\ remaining_t \times fertilizer\ applied \times Frac_{vol} \times EF_{vol}\right) \\ & + \left(N\ excreted_{t,m} \times N\ remaining_t \times fertilizer\ applied \times Frac_{run} \times EF_{run}\right)\Big) \times \frac{44}{28} \Big\} \end{aligned}$$

where,

N excreted	= Amount of nitrogen excreted annually, as calculated by Equation 34 (kgN/year)
N remaining	= The proportion of nitrogen remaining in manure by type, t, as calculated by Equation 37 (%)
Fertilizer applied	= Percent of manure applied to land as fertilizer (%)
$Frac_{vol}$	= Percent of nitrogen lost to volatilization when applied to soils from IPCC Guidelines, 21 (%)
$Frac_{run}$	= Percent of nitrogen lost to runoff/leaching when applied to soils from IPCC Guidelines, 24 (%)
EF_{vol}	= Volatilization emission factor from IPCC Guidelines, 0.01 (kgN_2O-N/kgN)
EF_{run}	= Leaching and runoff emission factor from IPCC Guidelines, 0.011 (kgN_2O-N/kgN)
44/28	= Conversion factor of N_2O-N to N_2O

Livestock Population

The annual animal population by livestock type and age/production class is provided by users. The livestock types for which users may provide data include:

- Bulls
- Beef cows
- Beef heifers
- Steer stockers
- Heifer stockers
- Feedlot beef
- Beef calves
- Dairy heifers
- Dairy cows
- Dairy calves
- Swine, >55 lbs[120]
- Swine, 55-330 lbs
- Swine, 330+ lbs
- Poultry, layers
- Poultry, pullets
- Poultry, chickens
- Poultry, broilers
- Turkeys

Manure Management Systems

The type of manure management system is identified by users for each livestock species and age/production class. The types of manure management systems that users may select, and their definitions are presented in Table 3-31, which are based on Table A-161 of the U.S. GHG Inventory.[121] Available manure management systems by animal type are denoted in Table 3-37 and Table 3-38 (where some factors are reported as NA because the manure management system will not be available for the relevant animal type).

Table 3-31. Definitions of Manure Management Systems

System Type	Description
Dry Lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. Dry lots are most typically found in dry climates but also are used in humid climates.

[120] Weight classes for swine differ from those reported in the U.S. GHG Inventory; the classes used in the calculator are consistent with Minnesota Administrative Rule 7020.03000 subpart 5c.
[121] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

System Type	Description
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water to facilitate handling and is stored in either tanks or earthen ponds, usually for periods less than one year.
Pasture, Range, Paddock (PRP)	The manure from pasture and range grazing animals is allowed to lie as is and is not managed. Methane emissions are accounted for under Manure Management, but the N_2O emissions from manure deposited on PRP are included under the Agricultural Soil Management category.
Solid Storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Deep Pit	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility. Typical storage periods range from 5-12 months, after which manure is removed from the pit and transferred to a treatment system or applied to land. This may also be referred to as pit storage.
Composting	Composting in windrows with regular (at least daily) turning for mixing and aeration, with or without runoff/leaching containment.
Cattle deep litter[a]	An animal housing system, based on the repeated spreading of straw or sawdust material in indoor booths. An initial layer of litter is spread for the animals to use for bedding material and to defecate in, and as the litter is soiled, new layers of litter are continuously added by the farmer.
Daily Spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. Methane and indirect N_2O emissions are accounted for under Manure Management. Direct N_2O emissions from land application are included under the Agricultural Soil Management category.
Anaerobic Lagoon	Uncovered anaerobic lagoons are designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the VS loading rate, and other operational factors. Anaerobic lagoons accumulate sludge over time, diminishing treatment capacity. Lagoons must be cleaned out once every 5 to 15 years, and the sludge is typically applied to agricultural lands. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields. Lagoons are sometimes used in combination with a solids separator, typically for dairy waste. Solids separators help control the buildup of nondegradable material such as straw or other bedding materials.
Anaerobic Digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel (complete mix or plug flow digester) or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4, which is captured and flared, used as fuel on-site, or transferred off-site for use as fuel.
Poultry with Litter	Enclosed poultry houses use bedding derived from wood shavings, rice hulls, chopped straw, peanut hulls, or other products, depending on availability. The bedding absorbs moisture and dilutes the manure produced by the birds. Litter is typically cleaned out completely once a year. These manure systems are typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl. This may also be referred to as poultry with bedding.
Poultry without Litter	In high-rise cages or scrape-out/belt systems, manure is excreted onto the floor below with no bedding to absorb moisture. The ventilation system dries the manure as it is stored. When designed and operated properly, this high-rise system is a form of passive windrow composting. This may also be referred to as poultry without bedding.

[a] Cattle deep litter is not included in Table A-161 of the U.S. GHG Inventory.

Typical Animal Mass

The typical animal mass by animal type for Minnesota were obtained from the national typical animal masses presented in Table A-156 in the U.S. GHG Inventory, as summarized in Table 3-32 below.[122]

Table 3-32. Typical Animal Mass Assumptions

Livestock Type	Typical Animal Mass (kg)
Bulls[a]	874.0
Beef cows[a]	582.5
Beef heifers[a]	351.5
Steer stockers[a]	438.0
Heifer stockers[a]	407.0
Feedlot beef[b]	422.5
Beef calves[a]	122.5
Dairy heifers[a]	407.0
Dairy cows	680.0
Dairy calves[a]	122.5
Swine, <55 lbs	13.0
Swine, 55-330 lbs	41.0
Swine, 330+ lbs	91.0
Poultry, layers	1.8
Poultry, pullets	1.8
Poultry, chickens	1.8
Poultry, broilers	0.9
Turkeys	6.8

[a] Values calculated by averaging the range reported in A-156.
[b] Value calculated by averaging feedlot stockers and feedlot heifers.

[122] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Volatile Solids

The annual volatile solids (VS) excreted by animal type were obtained from Table A-157 and Table A-158 in the U.S. GHG Inventory, using unit conversion to standardize both tables in kg VS/kg animal mass/year.[123] Maximum methane production capacity values were obtained from Table A-156 in the U.S. GHG Inventory.[124] These values are summarized in Table 3-33.

Table 3-33. Volatile Solid Production Assumptions

Livestock Type	Volatile Solids Production Rate (kgVS/kg animal mass/year)	Maximum CH_4 Production Capacity, B_0 ($m^3CH_4/kgVS$)
Bulls	1.88	0.17
Beef cows	2.73	0.17
Beef heifers	2.88	0.17
Steer stockers	2.86	0.17
Heifer stockers	2.88	0.17
Feedlot beef[a]	1.49	0.33
Beef calves	2.81	0.17
Dairy heifers	3.08	0.17
Dairy cows	4.16	0.24
Dairy calves	2.81	0.17
Swine, <55 lbs	3.21	0.48
Swine, 55-330 lbs	1.97	0.48
Swine, 330+ lbs	1.97	0.48
Poultry, layers	3.72	0.39
Poultry, pullets	3.72	0.39
Poultry, chickens	4.02	0.39
Poultry, broilers	6.21	0.36
Turkeys	3.10	0.36

[a] Value calculated by averaging feedlot steers and feedlot heifers.

[123] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[124] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Methane Conversion Factor

Methane conversion factors by manure management system were obtained from Table A-162 (for cool climates), which are based on values from the 2019 Refinement to the 2006 IPCC Guidelines,[125] and Table A-163 in the U.S. GHG Inventory, as summarized in Table 3-34. [126]

Table 3-34. Methane Conversion Factors by Manure Management System

Manure Management Systems	Methane Conversion Factor (%)
Dry lot	1.0
Liquid/slurry[a]	24.5
Pasture, range, paddock	0.5
Solid storage	2.0
Deep pit[a]	24.5
Composting[b]	0.8
Cattle deep litter	20.0
Daily spread	0.1
Anaerobic lagoon - liquid[a]	68.3
Anaerobic digester[c]	3.6
Poultry without litter	1.5
Poultry with litter	1.5

[a] For liquid systems, methane conversion factors were averaged across livestock types.
[b] Value calculated by averaging values across all types of composting systems.
[c] Methane conversion factor obtained directly from the IPCC 2019 Refinement, Table 10.17.

Nitrogen Excretion Rate

The nitrogen excretion rates by animal type were obtained from Tables A-157 and A-158 in the U.S. GHG Inventory and converted to kg N/kg animal liveweight/year, as summarized in Table 3-35 below. [127]

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[125] IPCC. “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Chapter 10: Emissions from Livestock and Manure Management (2019). https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf.
[126] EPA. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022,” 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[127] EPA. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022,” 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Table 3-35. Nitrogen Excretion Rates by Animal Type

Livestock Type	Excreted Nitrogen (kgN/kg animal liveweight/year)
Bulls	0.10
Beef cows	0.13
Beef heifers	0.14
Steer stockers	0.13
Heifer stockers	0.14
Feedlot beef[a]	0.14
Beef calves	0.16
Dairy heifers	0.17
Dairy cows	0.23
Dairy calves	0.16
Swine, <55 lbs	0.34
Swine, 55-330 lbs	0.20
Swine, 330+ lbs	0.20
Poultry, layers	0.29
Poultry, pullets	0.29
Poultry, chickens	0.40
Poultry, broilers	0.35
Turkeys	0.23

[a] Value calculated by averaging feedlot stockers and feedlot heifers.

Direct Nitrous Oxide Emissions Factor

Direct nitrous oxide emissions factors by manure management system were obtained from Table A-164 in the U.S. GHG Inventory, as summarized in Table 3-36.[128] The value for pasture, range and paddock was obtained from Table 11.1 of the 2019 Refinement to the 2006 IPCC Guidelines and represents direct N_2O emissions from unmanaged manure deposited onto pasture by grazing or free range cattle, poultry, and pigs.[129]

[128] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[129] IPCC. "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application (2019). https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf.

Table 3-36. Direct N_2O from Manure Management by Manure Management System

Manure Management Systems	Direct Emission Factor (kgN/kg excreted N)
Dry lot	0.020
Liquid/slurry	0.005
Pasture, range, paddock	0.004
Solid storage	0.010
Deep pit	0.002
Composting[a]	0.008
Cattle deep litter[b]	0.040
Daily spread	0.000
Anaerobic lagoon	0.000
Anaerobic digester	0.001
Poultry without litter	0.001
Poultry with litter	0.001

[a] Value calculated by averaging values across all types of composting systems.
[b] Value calculated by averaging values for active mix and no mix.

Volatilized Nitrogen Loss Rates

Volatilized nitrogen loss rates by manure management system were obtained from Table A-165 in the U.S. GHG Inventory, as summarized in Table 3-37. [130] The value for pasture, range and paddock was obtained from Table 11.3 of the 2019 Refinement to the 2006 IPCC Guidelines and represents indirect N_2O emissions from manure deposited by grazing animals.[131] Some factors are reported as NA because the manure management system does not occur for the relevant animal type.

Table 3-37. Volatilized Nitrogen Loss Rates

System Type	Beef Cattle	Dairy Cattle	Swine	Poultry
Dry lot	23%	15%	NA	NA
Liquid/slurry	26%	26%	26%	26%
Pasture, range, paddock	21%	21%	21%	21%

[130] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[131] IPCC. "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application (2019). https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf.

System Type	Beef Cattle	Dairy Cattle	Swine	Poultry
Solid storage	45%	27%	45%	8%
Deep pit	25%	24%	34%	NA
Composting	65%	NA	NA	65%
Cattle deep litter	25%	NA	NA	NA
Daily spread	7%	10%	NA	NA
Anaerobic lagoon	NA	43%	58%	54%
Anaerobic digester[a]	0%	0%	0%	0%
Poultry with litter	NA	NA	NA	26%
Poultry without litter	NA	NA	NA	34%

[a] Indirect emissions from anaerobic digestion are assumed to be zero (rather than NA).

Leaching and Runoff Loss Rates

Leaching and runoff loss rates by manure management system for the Midwest region were obtained from Table A-165 in the U.S. GHG Inventory, as summarized in Table 3-38.[132] The value for pasture, range and paddock was obtained from Table 11.3 of the 2019 Refinement to the 2006 IPCC Guidelines and represents indirect N_2O emissions from leaching and runoff in wet climates.[133] Some factors are reported as NA because the manure management system does not occur for the relevant animal type.

Table 3-38. Loss Rates for Leaching and Runoff

System Type	Beef Cattle	Dairy Cattle	Swine	Poultry
Dry lot	1.9%	0.9%	NA	NA
Liquid/slurry	0%	0.4%	0.4%	0.4%
Pasture, range, paddock	24%	24%	24%	24%
Solid storage	0.02%	0%	0%	0%
Deep pit	0%	0%	0%	NA
Composting	0.06%	NA	NA	0.06%
Cattle deep litter	0.035%	NA	NA	NA
Daily spread	0%	0%	NA	NA

[132] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[133] IPCC. "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application (2019). https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf.

System Type	Beef Cattle	Dairy Cattle	Swine	Poultry
Anaerobic lagoon	NA	0.4%	0.4%	0.4%
Anaerobic digester[a]	0%	0%	0%	0%
Poultry with litter	NA	NA	NA	0%
Poultry without litter	NA	NA	NA	0%

[a] Indirect emissions from anaerobic digestion are assumed to be zero (rather than NA).

Limitations

Key limitations of the methodology used to quantify emissions from manure management include:

- Although the number of animals may change from year to year, users are required to provide the average annual number of livestock over the lifespan of the project. The calculator also does not adjust for lifetimes under one year, such as for broilers, or any standard annual losses to stock.
- Emission factors for manure management are primarily derived from national averages as reported in the U.S. GHG Inventory, with limited regional specificity. Emissions from manure management can vary significantly among individual operations due to differences in manure handling systems, storage practices, and climate conditions. Multiple management decisions also influence emissions from manure management, including the type of storage, frequency of manure collection, and treatment methods employed. National values, where used, could therefore be improved if, in the future, regional values become available.
- The method included in this calculator only evaluates emissions based on the number of livestock and general manure management system types. It does not account for site-specific variations in management practices such as varying lengths of manure storage time or technological interventions that may reduce emissions. Additionally, it does not evaluate emissions on a per unit of product basis, and therefore does not reflect the production efficiency of livestock operations. A user could compare tool outputs to data on production to assess how the emissions intensity is changing over time.
- Climate conditions, particularly temperature and precipitation, significantly impact emissions from manure management systems and this is reflected in the climate specific methane conversion factor. The use of cool dry climate specific parameters has been used for the methane conversion factor.
- The methodology applied by this calculator generally aligns with the method employed by the Animal Feedlot GHG Calculator by calculating both methane and nitrous oxide emissions from manure management and the land application of manure. However, unlike the Animal Feedlot GHG Calculator, this calculator quantifies indirect N_2O emissions from manure management and direct and indirect N_2O emissions from manure deposited by grazing animals onto pasture, while it does not quantify emissions avoided from alfalfa. As a result, emission results will differ from results generated using MPCA's Animal Feedlot GHG Calculator.[134]

[134] Minnesota Pollution Control Agency. "Animal Feedlot GHG Calculator," February 2025. https://www.pca.state.mn.us/business-with-us/environmental-review.

4 Mitigation and Adaptation

4.1 Mitigation Measures

The calculator includes 146 measures that are proven to be effective at reducing GHG emissions. Measures were identified from industry, academic, and regulatory publications. Only those measures with robust and meaningful data that demonstrate an appreciable GHG reduction at the project level are included in the calculator. The measures are categorized by the emission sources identified in the calculator. While some measures may reduce emissions across more than one source, the calculator categorizes each measure according to the primary source through which emission reductions are expected.

The measures included in the calculator are diverse. Users can use the column filters to narrow the list of measures to only those emission sources applicable to their project. Once the measure list is filtered, users should carefully review the measure descriptions to determine which measures are most applicable to their project and support their GHG reduction goals. Users can then use the drop-down menu under the Select column to choose the measures they intend to implement as part of their project.

The calculator does not quantify potential GHG reductions achieved by user-selected measures. While GHG reductions are not currently quantified, selecting measures provides documentation of user actions that will be implemented to reduce GHG emissions. The list of selected measures can be used to develop a comprehensive set of mitigation strategies or guiding policies for project design and implementation. Many of the measures may also achieve “co-benefits,” or additional benefits beyond GHG reduction (e.g., water conservation, improved air quality), and may therefore be important to acknowledge in other project documentation.

Subsequent updates to the calculator may support measure quantification. Until then, users may quantify potential GHG reductions of their selected measures by using the calculator to run multiple scenarios and/or by using external resources. Table 4-1 summarizes models and calculation methods that may be leveraged for quantification support at the project level. Resources are presented in alphabetical order, and emission source(s) addressed by each resource identified. While the list of resources presented in Table 4-1 is comprehensive, additional guidance and models are continually being developed and may be used to support measure quantification.

Table 4-1. Additional Resources to Support GHG Reduction Measure Quantification

Name	Description	Emission Source(s)
AVoided Emissions and Generation Tool (AVERT)	AVERT analyzes emission impacts of energy efficiency and renewable energy policies and programs in the electric power sector.	Building energy consumption
California Emissions Estimator Model (CalEEMod)	CalEEMod quantifies emissions reductions from numerous project- and plan-level GHG reduction measures.[a]	All except Material inputs; Coal production; Natural gas and oil products; Industrial processes

Name	Description	Emission Source(s)
California's Climate Investments Quantification, Benefits, and Reporting Materials	Repository that includes quantification methods and tools for various sectors, including Transportation and Sustainable Communities, Clean Energy and Energy Efficiency, and Natural Resources and Waste Diversion.[a]	All except Material inputs; Coal production; Natural gas and oil products; Industrial processes
Clean Energy Emission Reduction (CLEER) Tool	CLEER Tool calculates emissions reduced or avoided from clean energy activities based on internationally accepted GHG estimation methodologies.	Building energy consumption
COMET-Farm	COMET-Farm can be used to estimate the impact of agricultural practices on soil carbon storage and GHG emissions. The tool can simulate changes in GHG emissions because of grazing.	Enteric fermentation; Manure management
COMET-Planner	COMET-Planner evaluates potential carbon sequestration and GHG reduction from adopting various conservation practices.	Land use change (construction/ operations)
Cool Farm	Cool Farms provides carbon accounting for agriculture, covering emissions from on-farm mobile source combustion, cropland nutrient management, livestock, manure storage and treatment, and land use change.	Land use change (operations); Enteric fermentation; Manure management
Cool Roof Calculator	Cool Roof Calculator estimates cooling and heating savings for flat roofs with non-black surfaces.	Building energy consumption
Embodied Carbon in Construction Calculator (EC3)	EC3 can be used to assess reductions in embodied carbon.	Material inputs
Fuel & Fire Tools (FFT)	FFT allows users to model the impacts of prescribed and wildland fires. They can also be used to evaluate the effectiveness of fuel treatments.	Land use change (operations)
EPA GHG Emission Factor Hub	The Emission Factor Hub provides a regularly updated and easy-to-use set of default emission factors for GHG reporting.	All (potentially)
Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET)	GREET calculates GHG emissions by lifecycle stage through the different pathway options of a product or fuel.	All (potentially)
Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity	Handbook that provides methods and defaults to quantify various GHG reduction measures.[a]	All except Material inputs; Coal production; Natural gas and oil products; Industrial processes
Handbook for Estimating Transportation Greenhouse Gases for Integration into the Planning Process	Handbook that describes the types of analyses that may be conducted in the context of statewide transportation planning and provides an overview of primary GHG estimation methods.	On-road vehicles

Name	Description	Emission Source(s)
HFCVille	HFCVille identifies where lower GWP substances and alternative technologies are readily available to replace high-GWP HFC use.	HFC leakage
Impact Estimator for Buildings	Impact Estimator for Buildings evaluates whole buildings using LCA methodology. The estimator integrates most lifecycle stages and can evaluate implications of design choices.	Material inputs; Building energy consumption
Infrastructure Carbon Estimator (ICE)	ICE evaluates energy and emission impacts of transportation alternatives and quantifies direct and indirect emissions from construction and operation activities.	Material inputs; Construction waste; On-road vehicles
i-Tree Tools	i-Tree is a software suite that provides urban and rural forestry analysis and benefits assessment tools.	Land use change (construction/ operations)
LCA Pave Tool	LCA Pave Tool estimates emissions impacts from pavement materials.	Material inputs
Minnesota Infrastructure Carbon Estimator (MICE)	MICE evaluates energy and emission impacts of transportation alternatives in Minnesota and quantifies direct and indirect emissions from construction and operation activities.	On-road vehicles
One Click LCA	One Click LCA provides software to support construction professionals reduce carbon, costs, and material use.	Material inputs; Building energy consumption
OpenLCA	OpenLCA provides a variety of impact assessment methods that allow users to quantify and evaluate the environmental impacts associated with a product.	Material inputs
Quantifying Greenhouse Gas Emissions from Transit	Report that provides a method for quantifying GHG reductions from mode shift achieved by transit policies.	On-road vehicles
Transit Greenhouse Gas Emissions Estimator v2.0	The Transit GHG Emissions Estimator is a Microsoft Excel-based tool that allows users to estimate the GHG emissions generated from a project across selected transit modes.	On-road vehicles
US Environmentally-Extended Input-Output (USEEIO) Models	USEEIO is a suite of models that provide emission factors for the production or consumption of goods and services.	Material inputs
Waste Reduction Model (WARM)	WARM provides high-level estimates of GHG emissions from solid waste reuse, recycling, composting, incineration, anaerobic digestion, and landfilling.	Material inputs; Construction waste; Treatment of waste off-site

[a] Resource was originally developed for application in California. While some emission factors and defaults may not be appropriate to projects in Minnesota, the underlying quantification methods may be universally applicable.

4.2 Adaptation Strategies

There are numerous ways that climate change is altering the climate in Minnesota. The calculator includes 54 strategies that are known to be effective in adapting to these changing climate conditions. The strategies address the key climate trends identified by the Minnesota Department of Natural Resources.[135] These climate trends, as defined in the calculator, are summarized in Table 4-2. Users should refer to the EAW Climate Guidance for additional information and resources to identify which climate trends are relevant to their project.[136]

Table 4-2. Climate Trends Included in the Climate Calculator

Climate Trend	Definition
Heavier, more damaging rain	Increased frequency and intensity of rainfall events over the next several decades, which can lead to more flooding.
Average annual precipitation increasing	Increased yearly rainfall over the next several decades.
Average annual temperature increasing	Increased yearly average temperatures over the next several decades.
Increasing risk of extreme heat and heatwaves	More frequent and higher extreme heat days and prolonged periods of excessively hot weather over the next several decades (e.g., three days of extreme heat, rather than just one).
Early thawing (cold weather warming)	Earlier onset of warmer temperatures in spring, leading to earlier melting of snow and ice over the next several decades.
Increasing risk of drought	Higher likelihood of prolonged periods of low precipitation over the next several decades.

In addition to identifying which climate trends are relevant to the project, users also must select applicable project characteristics to narrow the list of viable strategies. The project characteristics that are mapped to each strategy within the calculator are summarized in Table 4-3. Strategies may map to more than climate trend and/or project characteristic. Once the strategy list is filtered to the applicable climate trend(s) and project characteristic(s), users should carefully review each strategy to determine which ones they intend to implement. Users can use the drop-down menu under the Select column to choose the strategies. The list of selected strategies can then be used to develop a comprehensive set of adaptation actions or guiding policies for project design and implementation.

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135 Minnesota Department of Natural Resources. "Climate Trends." Accessed April 21, 2025. https://www.dnr.state.mn.us/climate/climate_change_info/climate-trends.html.

136 Minnesota Environmental Quality Board. "Environmental assessment worksheet guidance," 2024. https://www.eqb.state.mn.us/sites/eqb/files/2024_eaw_climate_guidance_2.pdf.

Table 4-3. Project Characteristic Definitions

Project Characteristic	Definition
Hazardous waste	Involve the handling, storage, treatment, or disposal of materials that pose a risk due to their toxic, corrosive, flammable, or reactive properties. Hazardous waste may include nuclear fuels and nuclear waste.
Agriculture	Involve the cultivation of crops or expansion of cropland.
Livestock	Involve the management of animals, such as cattle, sheep, goats, pigs, and poultry (e.g., animal feedlots).
Critical infrastructure	Involve the development, maintenance, or enhancement of essential systems and assets, including electrical systems, mineral mining infrastructure, resource processing facilities, and other key infrastructure.
Waste management	Involve the collection, transportation, processing, recycling, or disposal of waste materials.
New or upgraded buildings	Involve the construction of new buildings or the renovation of existing structures, such as industrial, commercial, or institutional facilities; residential development; and storage facilities.
Subsurface infrastructure	Involve the installation, maintenance, or upgrade of underground systems such as water and sewer lines, electrical conduits, and telecommunications cables.
Water management	Involve the collection, transportation, processing, recycling, or disposal of water resources, including those related to water appropriation and impoundments and wastewater systems.
Construction	Involve development activities such as building, renovating, or improving structures, such as buildings, bridges, and roads.
Increased impervious surface	Involve the addition of surfaces that do not allow water to penetrate, such as roads, parking lots, and buildings.
New, expanded, or rebuilt transportation route	Involve the creation, widening, or reconstruction of transportation routes, such as roads, highways, railways, and bridges.

The adaptation strategies included in the calculator were developed by reviewing a suite of existing plans and reports, as summarized in Table 4-4. Once the initial list was developed, the identified strategies were then combined and refined. The list of strategies is not intended to be fully comprehensive or exclusive, and project developers are encouraged to look at other sources and include other relevant strategies that apply. Additionally, there are other climate trends, such as high winds and wildfires, that are less severe but may increase in impact. While adaptation strategies exist to address these climate trends, they are not currently included in the calculator. Furthermore, many adaptation strategies may also achieve “co-benefits,” or additional benefits beyond climate adaptation (e.g., improved water quality, increased ecosystem services), and may therefore be important to acknowledge in other project documentation.

Table 4-4. Adaptation Strategy Resources

Resource	Additional Details
Nationwide resources	
EPA's Climate Change Adaptation Resource Center (ARC-X)	Includes a searchable list of adaptation strategies.
Arscht-Rock Heat Action Platform	Includes policy cards on various urban heat island mitigation strategies.
Fernleaf Actions Database	Includes toolbox of community adaptation strategies.
NIBS Natural Hazard Mitigation Saves	Includes typical cost-benefit analyses for several adaptation strategies (e.g., elevate road, reconstruct bridge).
The 21st Century Development Matrix	A visualization of five degrees of performance across seven performance areas – Place, Water, Energy, Health + Happiness, Materials, Equity, Beauty.
Minnesota resources	
MN EAW Guidance	Provides climate-related information and relevant guidance for answering EAW Item 7.
Resilient Adaptation of Sustainable Buildings	Provides strategies specific to the resilience sector.
Center for Sustainable Building Research Case Studies	Provides strategies specific to the resilience sector.
State and local climate plans	
Resilience and Durability to Extreme Weather in the H-GAC Region Pilot Program Report	Provides detailed strategies, specifically in the Adaptation Strategies section and Appendix E.
Heat Resilience Solutions for Boston	Provides heat-specific adaptation strategies.
DCTC Plan On It - From Flooding to Drought and Back Again	Focusing on stormwater management, has community level measures homeowners and organizations can implement.
City of Santa Cruz Climate Action Plan 2030	Provides list of strategies for Santa Cruz, California.
California Climate Adaptation Strategy	Provides list of strategies for the state of California.
West Palm Beach Rethink Paradise: Sustainability Action Plan	Provides list of strategies for West Palm Beach, Florida.
City of Seattle Preparing for a Changing Climate	Provides sector-specific actions for Seattle, Washington.
North Carolina Regional Resilience Assessment	Includes adaptation actions for North Carolina.
Planning for Climate Resilience, City of Asheville, North Carolina	Provides a comprehensive list of resilience strategies for Asheville, North Carolina.
Flagstaff Climate Action and Adaptation Plan	Includes adaptation actions for Flagstaff, Arizona.
City of Charleston, South Carolina All Hazards Vulnerability and Risk Assessment	Includes adaptation actions for Charleston, South Carolina.
Climate Ready Boston, Climate Resilience Initiatives	Provides list of resilience strategies for Boston, Massachusetts.

Resource	Additional Details
Sector-specific resources	
Summary of impact of increased heat on railways.	Provides railway-specific strategies.
FHWA resources on increasing pavement resilience	Provides pavement-specific strategies.
Summary of how to raise cattle in a higher heat climate	Provides cattle-specific strategies.
EPA climate change related resources and actions for water utilities	Provides water utility-specific strategies.
EPA Guide for Solid Waste Management Best Practices in response to climate change	Provides solid waste-specific strategies.
Maryland DOT MTA Adaptation and Resilience Toolbox	Provides transportation-specific strategies.

5 Limitations and Future Improvements

5.1 Limitations

The Minnesota Climate Calculator is intended to be used to develop a reasonable estimate of GHG emissions from development projects in Minnesota. The results of the calculator are based on user inputs and various assumptions, as documented above in Sections 2 and 3. Actual project emissions are expected to vary based on project-specific conditions and measured activity data. Limitations associated with the methodologies and assumptions applied by the calculator are discussed by emissions source in Sections 2 and 3. In addition to source-specific limitations, the calculator does not support quantification of emissions for all project categories and may not estimate all sources of GHG emissions that are applicable to the project, as described in Section 1.3. Furthermore, the calculator does not quantify emission offsets or (in most cases) mitigation measures. In some cases, these limitations are the result of intentional decisions regarding the design and scope of the calculator. In other cases, these limitations are due to resource constraints and the intention to build on and expand the calculator in the future. A summary of key calculator limitations is provided below.

- **Emission Source Exclusions:** Emission sources that are not currently quantified in the calculator include operational material inputs and transportation of material inputs; SF_6 emissions from electrical transmission and distribution equipment; employee commuting during project operation; operational maintenance activities; changes in off-road vehicle, aircraft, or watercraft usage during project operation; and consumption of products generated. These emission sources were deprioritized due to resource constraints and other factors such as difficulty in defining activities, expected magnitude of emissions, applicability across project types, and feasibility of accurate quantification. Users of the calculator are encouraged to assess and disclose emissions from sources not covered by the calculator in their assessment of GHG emissions impact, to the extent possible.

- **Highway Projects:** This calculator is not intended to estimate emissions for projects falling under subpart 22 (Highway projects). Emissions from highway projects should be estimated using the MICE Tool.[137]

- **Feedlot Projects:** MPCA also has a calculator, the Animal Feedlot GHG Calculator, available to support quantification of emissions from feedlots.[138] The Climate Calculator generally aligns with the method employed by the Animal Feedlot GHG Calculator by calculating both methane and nitrous oxide emissions from manure management and the land application of manure. However, unlike the Animal Feedlot GHG Calculator, this calculator quantifies indirect N_2O emissions from manure management and direct and indirect N_2O emissions from manure deposited by grazing animals onto pasture, while it does not quantify emissions avoided from alfalfa. It also allows users to specify the portion of manure applied to land as a fertilizer. Furthermore, this calculator quantifies lifetime emissions, rather than emissions

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[137] Minnesota Department of Transportation. "Minnesota Infrastructure Carbon Estimator (MICE) Tool," 2025. https://www.dot.state.mn.us/project-development/subject-guidance/greenhouse-gas-analysis/process.html.

[138] Minnesota Pollution Control Agency. "Animal Feedlot GHG Calculator," February 2025. https://www.pca.state.mn.us/business-with-us/environmental-review.

for a single year, and does not adjust animal populations for aging, lifetimes shorter than one year, or loss of stock. Users should input population averages for the project lifetime that account for these factors.

- **Offsets:** Emission offsets refer to emissions that are outside the scope of the project boundary but are avoided as a result of project activities. For example, if landfill gas is collected at a landfill and then sold to another entity and used in the place of conventional natural gas, the emissions avoided by not combusting conventional natural gas are considered an offset. In general, offsets are not currently included as part of the quantification methodologies within the calculator.

- **Double Counting:** Effort has been made to avoid the double counting of emissions across emission sources. However, users should assess the GHG emissions calculations by reviewing the included emission methodologies to determine if their specific project and the included emission sources have any overlap.

- **Mitigation Quantification:** The calculator does not quantify potential GHG reductions achieved by user-selected measures. Future updates to the calculator may support measure quantification. Until then, users may quantify potential GHG reductions of their selected measures by using the calculator to run multiple scenarios and/or by using external resources, as discussed in Section 4.1.

5.2 Future Improvements

Development of this calculator is considered a first step to making the process of answering EAW items 7 and 18 more efficient, effective, and consistent. Future updates to the calculator are expected to further refine and tailor the methodologies and assumptions for quantifying emissions for projects in Minnesota, expand the scope of the emission sources quantified, and expand the analytical capabilities and data visualizations within the calculator. Priority areas for refinement or expansion include the following:

1. **Revise Methodologies for Existing Emission Sources.** The methodologies developed for the emission sources included in the calculator considered data availability and tradeoffs between accuracy and complexity. Simplified approaches were adopted to make the calculator easy to use but at the same time may limit the ability for users to tailor the information to reflect the specific circumstances of their project. Based on user feedback, updates should be made to existing methodologies to allow for better flexibility in what data are provided. For example, for emission sources such as construction equipment and building energy use, the calculator could be modified to allow for direct entry of energy consumed rather than depending on activity data. The inclusion of offsets may also be considered to account for emission reduction benefits that are otherwise considered outside the project quantification boundary.

2. **Update and Expand Default Assumptions.** Default assumptions were developed to reduce the burden on users to provide data. In some cases, default assumptions in the calculator may be overridden or adjusted by the user. The quality and specificity of the default assumptions are dependent on data availability. Updates to default assumptions should be considered where new or better (e.g., Minnesota-specific) data are identified and where it is particularly challenging for users to provide data. For example, development of emission factors for an expanded list of material inputs or industrial processes may be considered, along with the development of assumptions for building subcategories. State-

specific waste composition data could also be used to tailor the emission factors associated with the treatment of mixed MSW. Targeted studies may also be considered to develop new default assumptions on material inputs or construction equipment use.

3. **Incorporate Additional Emission Sources.** As described in the Limitations section above, some emission sources were excluded from the initial version of the calculator due to a variety of factors. As feasible, the calculator should be expanded to include the ability to quantify emissions from additional emission sources. New emission sources should be prioritized based on user feedback. For example, expansion of the calculator may be considered to quantify the use of off-road equipment and heavy-duty vehicles for maintenance and/or deliveries.

4. **Quantify Mitigation Measures.** The calculator is currently designed to assess the expected GHG emissions impact of a proposed project. The calculator includes some flexibility to adjust the calculations to reflect mitigation measures (e.g., installation of on-site renewables, implementation of technologies and practices that minimize natural gas leakage) but does not comprehensively allow users to quantify the impact of mitigation actions. To further support users in answering item #18 of the EAW, the calculator should be expanded to allow for quantification of mitigation measures. This update may involve the creation of a new module within the calculator that quantifies individual measures or reworking of the calculator structure to allow users to quantify a baseline and mitigation scenario. It may not be possible to quantify reductions from all identified mitigation measures. Further scoping is required to identify the best approach for incorporating mitigation quantification into the calculator.

5. **Expand Data Access and Visualization.** The calculator was developed in Microsoft® Excel® and includes several features that allow users to digest and share calculator outputs. Specifically, the calculator includes built in charts and a summary report that synthesizes data inputs and results. Expansion of these features should be considered to further support access to and analysis of the outputs. For example, EQB may consider creating a dashboard in Tableau or Power BI that draws on data outputs from the calculator. As other aspects of the calculator are refined and/or expanded, the charts and summary tables should also be modified to support data digestion and EAW completion.

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Appendix B. Acronyms

BOD	Biological oxygen demand
C&D	Construction and demolition
CBECS	Commercial Buildings Energy Consumption Survey
CFS	Commodity Flow Survey
CLEER	Clean Energy Emission Reduction
COD	Chemical oxygen demand
EAW	Environmental Assessment Worksheet
EF	Emission factor
eGRID	Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPD	Environmental Product Declarations
EQB	Environmental Quality Board
GDP	Gross Domestic Product
GREET	Gases, Regulated Emissions, and Energy use in Technologies
GHG	Greenhouse gas
GWP	Global warming potential
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle analysis
MECS	Manufacturing Energy Consumption Survey
MICE	Minnesota Infrastructure Carbon Estimator
MISO	Midcontinent Independent System Operator
MOVES	MOtor Vehicle Emission Simulator
MPCA	Minnesota Pollution Control Agency

MSW	Municipal solid waste
MT	Metric tons
NAICS	North American Industry Classification System
NAIMA	North American Insulation Manufacturing Association
NRMCA	National Ready Mixed Concrete Association
PRP	Pasture, Range, Paddock
RECS	Residential Energy Consumption Survey
RGU	Responsible governmental units
RSI	R-value Systeme International
SCORE	Select Committee on Recycling and the Environment
T&D	Transmission and distribution
USEEIO	US Environmentally-Extended Input-Output
VMT	Vehicle miles traveled
WARM	Waste Reduction Model

Appendix C. Electricity Grid Emission Factors

Emissions result from the generation of electricity. Emission factors, inclusive of upstream emissions associated with the production, transmission, and distribution of fuels used for electricity generation, were derived based on current and future assumptions regarding the grid fuel mix. Emission factors were generated to represent the average fuel mix across the region and for select electricity providers within Minnesota (i.e., Xcel Energy, Minnesota Power, Great River Energy, and Otter Tail Energy Company). The emission factors by energy provider and year are summarized in Table C-1. The methodology used to derive these values is documented in the subsequent sections.

Table C-1. Electricity Emission Factors

Electricity Provider	Emission Factor ($kgCO_2e/MMBtu$)[a]					
	2025	2030	2035	2040	2045	2050
Regional Average	116.62	42.63	21.32	-	-	-
Xcel Energy	69.75	19.84	12.97	-	-	-
Minnesota Power	162.74	49.69	16.88	-	-	-
Great River Energy	161.81	91.92	33.76	-	-	-
Otter Tail Power Company	141.40	91.44	45.66	-	-	-

[a] Values shown are based on AR5 global warming potentials.

Regional Average

The lifecycle electricity emission factors for the region were derived from EPA's Emissions & Generation Resource Integrated Database (eGRID)[139] and GREET1 2024.[140] The emission factor for electricity output in Minnesota for 2023 were obtained from eGRID (see Table C-2). The emission factor for upstream emissions associated with the production, transmission, and distribution of fuels used for electricity generation were obtained from GREET1 2024 for 2025 and 2030 based on the fuel mix for the Midcontinent Independent System Operator (MISO) area (see Table C-3 and Table C-4).[141] The emission factors for electricity output for 2025 and 2030 were separately calculated by projecting forward the 2023 generation-stage eGRID emission factor using the growth rate for the regional projections from GREET1 2024 (see Table C-5). The emission factors for each lifecycle stage for each year were then summed to derive the average electricity emission factor for Minnesota. The tables below summarize the data used to derive the emission factors, as obtained from eGRID and GREET1 2024.

[139] EPA. "Emissions & Generation Resource Integrated Database (eGRID)." 2025. https://www.epa.gov/egrid.
[140] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[141] The projections are based on the AEO 2023 reference case scenario, using 2023 data as the baseline. The projected generation mix for 2025 that is used in this analysis, therefore, may differ from the actual generation mix reported by MISO.

Table C-2. Minnesota Combustion Electricity Emissions from eGRID, 2023 (lb/MWh)

CO_2	CH_4	N_20
747.38	0.073	0.01

Table C-3. GREET1 2024 Fuel Mix Assumptions

Energy Source	2025	2030
Residual oil	0.2%	0.1%
Natural gas	10.7%	6.8%
Coal	35.3%	11.3%
Nuclear power	10.6%	9.7%
Biomass	0.8%	0.7%
Other[a]	42.4%	71.3%

[a] Includes hydroelectric, wind, and solar PV.

Table C-4. GREET1 2024 Upstream Emissions from Electricity Generation

Year	$kgCO_2e$/MMBtu[a]
2025	9.21
2030	3.82

[a] Values shown are based on AR5 global warming potentials.

Table C-5. GREET1 2024 Electricity Combustion Emissions, MISO Region

Year	gCO_2e/MMBtu	% of 2023
2023	123,443.35	100.0%
2025	125,942.88	102.0%
2030	45,477.97	36.8%

The life cycle emission factors for Minnesota for 2025 and 2030 are calculated by first summing the emissions from the upstream and generation stages and multiplying the total by the assumed transmission and distribution (T&D) loss rate of 4.86 percent from GREET1 2024.[142] This amount was added to the sum of the emissions from the upstream and generation stages to calculate the full lifecycle emission factors. For the years after 2030, emissions are linearly projected to reach zero by 2040, in accordance with Minnesota's requirement that by 2040 all utilities in the state generate 100% of their electricity from carbon-free technologies.[143]

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[142] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

[143] Minnesota Legislature. "Minnesota Statutes, Section 216B.1691 – Renewable Energy Objectives." 2024. https://www.revisor.mn.gov/statutes/cite/216b.1691.

Xcel Energy

The lifecycle electricity emission factors for Xcel Energy were derived based on the utility's actual and projected energy mix through 2035, as provided by Xcel Energy and consistent with their approved *Upper Midwest Integrated Resource Plan for 2024-2040*.[144] Although Xcel is projected to continue to use natural gas beyond 2040, it is assumed that by 2040, all electricity provided to customers in Minnesota will be generated using carbon-free energy sources, consistent with the state's requirement. The assumed generation mix for Xcel Energy is summarized in Table C-6. GREET1 2024 was then used to derive lifecycle emission factors associated with energy production and generation based on the assumed energy mix. [145]

Table C-6. Electric Generation Mix Assumptions for Xcel Energy

Energy Source	2025	2030	2035	2040
Natural gas	12.0%	11.6%	7.6%	0.0%
Coal	15.0%	0.0%	0.0%	0.0%
Nuclear power	27.0%	25.7%	22.1%	21.1%
Biomass	0.7%	0.5%	0.3%	0.1%
Other [a]	45.3%	62.2%	70.1%	78.9%

[a] Includes hydroelectric, wind, and solar PV.

Minnesota Power

The lifecycle electricity emission factors for Minnesota Power were derived based on information from the utility's *2025-2039 Integrated Resource Plan* that indicates that renewables account for 50% of the current energy mix and will reach 80% by 2030 and 90% by 2035.[146] In addition, the utility plans to achieve a coal-free energy supply by 2035. The assumed generation mix for Minnesota Power is summarized below in Table C-7, which also assumes the utility will comply with the state's requirement to generate 100% of their electricity from carbon-free technologies by 2040. GREET1 2024 was then used to derive lifecycle emission factors associated with energy production and generation based on the assumed energy mix. [147]

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[144] Xcel Energy. "Upper Midwest Integrated Resource Plan for 2024-2040." 2025. [Xcel Energy IRP 2024 / Public Utilities Commission]

[145] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

[146] Minnesota Public Utilities Commission. "2025-2039 Integrated Resource Plan." 2025. https://www.edockets.state.mn.us/documents/%7BA0446195-0000-C339-B88F-8CE00FEBADAA%7D/download.

[147] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Table C-7. Electric Generation Mix Assumptions for Minnesota Power

Energy Source	2025	2030	2035	2040
Natural gas	1.0%	10.0%	10.0%	0.0%
Coal	49.0%	10.0%	0.0%	0.0%
Others[a]	50.0%	80.0%	90.0%	100.0%

[a] Includes hydroelectric, wind, and solar PV.

Great River Energy

The lifecycle electricity emission factors for Great River Energy were derived based on information available from the cooperative for 2024[148] and grid mix projections for 2037 from the cooperative's *2023-2037 Integrated Resource Plan*.[149] Estimates for 2024 and 2037 were linearly interpolated to derive estimates for 2025, 2030, and 2035. The assumed generation mix for Great River Energy is summarized below in Table C-8, which also assumes the utility will comply with the state's requirement to generate 100% of their electricity from carbon-free technologies by 2040. GREET1 2024 was then used to derive lifecycle emission factors associated with energy production and generation based on the assumed energy mix. [150]

Table C-8. Electric Generation Mix Assumptions for Great River Energy

Energy Source	2024	2025	2030	2035	2037	2040
Residual oil	0.1%	0.3%	1.4%	2.3%	2.5%	0.0%
Natural gas	5.3%	5.2%	4.4%	3.7%	3.5%	0.0%
Coal	49.9%	46.3%	24.2%	5.8%	2.2%	0.0%
Nuclear power	3.3%	3.1%	2.1%	1.3%	1.1%	0.0%
Biomass	0.2%	0.2%	0.2%	0.1%	0.1%	0.0%
Others[a]	41.1%	45.0%	67.8%	86.8%	90.6%	100.0%

[a] Includes hydroelectric, wind, and solar PV.

Otter Tail Power Company

The lifecycle electricity emission factors for Otter Tail Power Company were derived based on energy delivery mix data from the utility's *ESG Report 2023*.[151] The assumed generation mix for Otter Tail Power Company is summarized below in Table C-9, which also assumes the utility will comply with the state's requirement to generate 100% of their electricity from carbon-free technologies by 2040. GREET1 2024

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[148] Great River Energy. "Electricity Sources." 2025. https://greatriverenergy.com/electricity-sources/.
[149] Great River Energy. "2023–2037 Integrated Resource Plan One-Pager." 2023. https://greatriverenergy.com/wp-content/uploads/2023/04/2023-37-IRP-One-pager-FINAL.pdf.
[150] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.
[151] Otter Tail Power Company. "Environmental, Social, and Governance (ESG) Report 2023." 2024. https://www.otpsustainability.com/media/edfeocny/2023-esg-report.pdf.

was then used to derive lifecycle emission factors associated with energy production and generation based on the assumed energy mix. [152]

Table C-9. Electric Generation Mix Assumptions for Otter Tail Power Company

Energy Source	2025	2030	2035	2040
Residual oil	3.3%	2.5%	1.3%	0.0%
Natural gas	8.7%	4.7%	2.3%	0.0%
Coal	34.9%	22.6%	11.3%	0.0%
Nuclear power	3.2%	3.1%	1.6%	0.0%
Biomass	0.2%	0.2%	0.1%	0.0%
Others[a]	49.7%	66.8%	83.4%	100.0%

[a] Includes hydroelectric, wind, and solar PV.

[152] Argonne National Laboratory. "GREET 1 2024 Excel-based Fuel-Cycle Model," 2025. https://greet.anl.gov/greet_excel_model.models.

Appendix D. User's Manual

The Minnesota Climate Calculator is an Excel-based calculator that estimates greenhouse gas (GHG) emissions from development projects in Minnesota based on user inputs, default assumptions, and emission factors. The Excel-based calculator has dynamic functionality for users to select their project type and input details for each applicable emissions source and phase of the project. For select fields, users can decide whether to use default assumptions and emission factors or override them and provide their own inputs. Based on these selections and inputs, the calculator quantifies the cumulative and annualized GHG emissions from each emissions source and summarizes the results in tables and charts that can be used to respond to answer item 18 of the Environmental Assessment Worksheet (EAW). The calculator also provides qualitative information on mitigation measures and adaptation strategies. The remainder of this user manual is organized as follows:

- Section 1: Getting Started
- Section 2: Calculator Structure
- Section 3: Using the Climate Calculator
- Section 4: Calculator Inputs
- Section 5: Emission Outputs
- Section 6: Mitigation and Adaptation

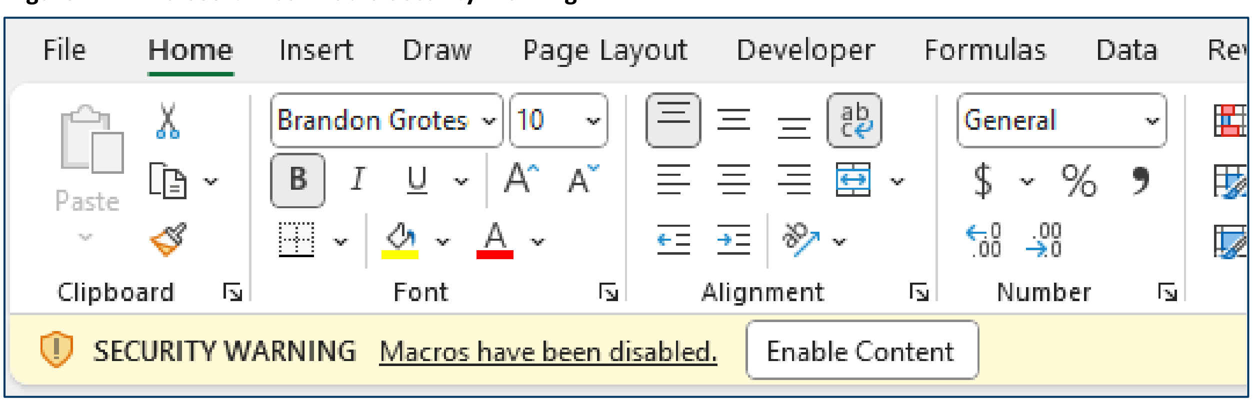
1. Getting Started

The calculator was developed using Microsoft® Excel® for Microsoft 365. While the module should function properly using older versions of Excel, it works best with Excel for Microsoft 365 or later on IBM-PC compatible computers. If a user is using another version of Excel, instructions for opening the module or adjusting settings may vary.

Microsoft Excel Security

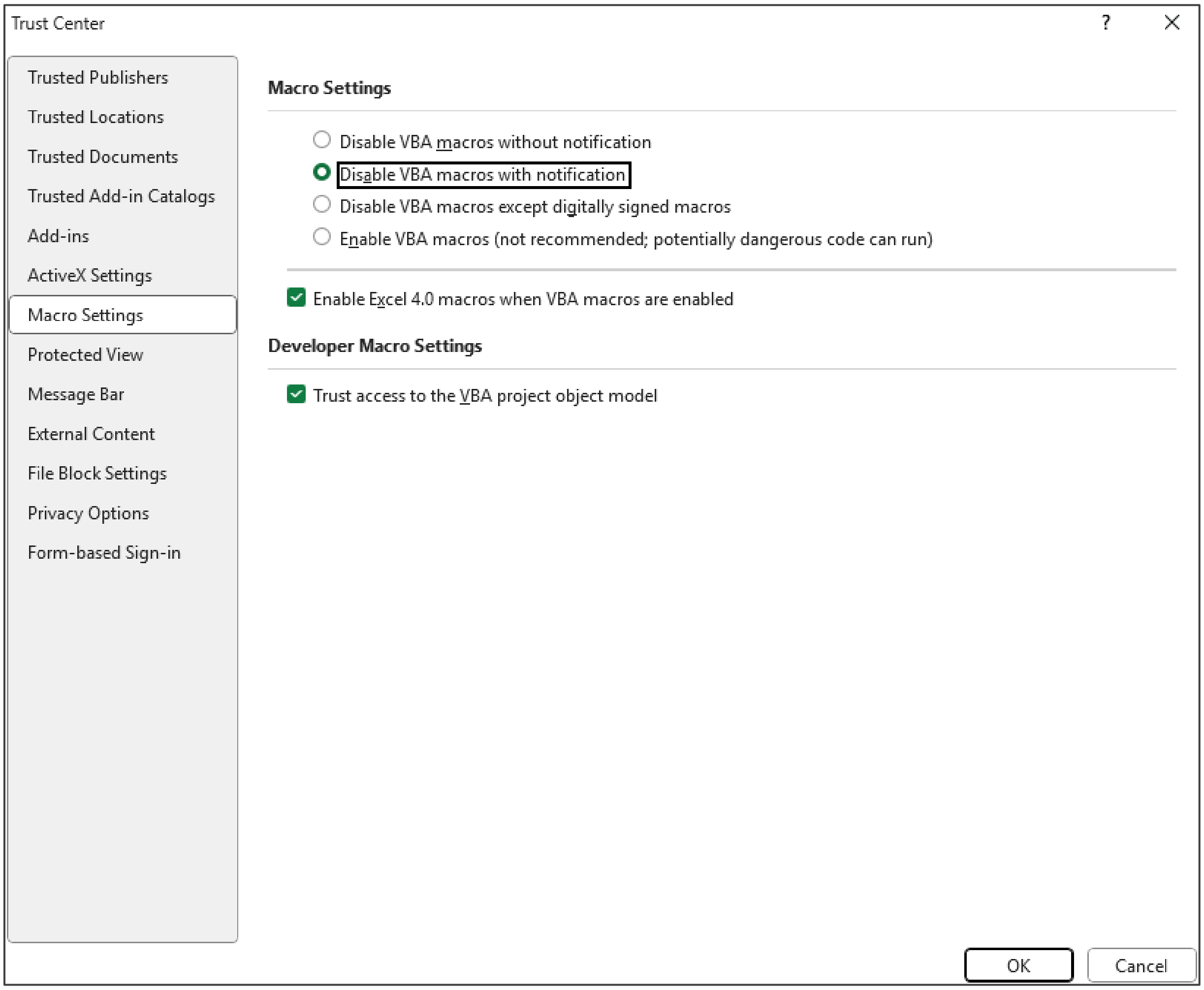
If Excel's default security settings are on, a Security Warning may appear when opening the calculator, indicating that macros are disabled. To enable macros, either click "Enable Content" as shown in Figure D-1 or click "Options" in the security message, select "Enable this content," then close the welcome message box.

Figure D-1. Microsoft Excel Macro Security Warning



If the Security Warning does not appear, users may need to adjust macro security settings. Exit the spreadsheet, re-launch Excel, and open the calculator. Click the Excel icon, select “Excel Options,” then “Trust Center.” Click “Trust Center Settings,” then “Macro Settings,” and choose “Disable all macros with notification.” Before re-opening the module, right-click the file, select properties, and mark “Unblock” under the “General” tab. Open the module again and enable macros as described above. See Figure D-2 for an example of this setting.

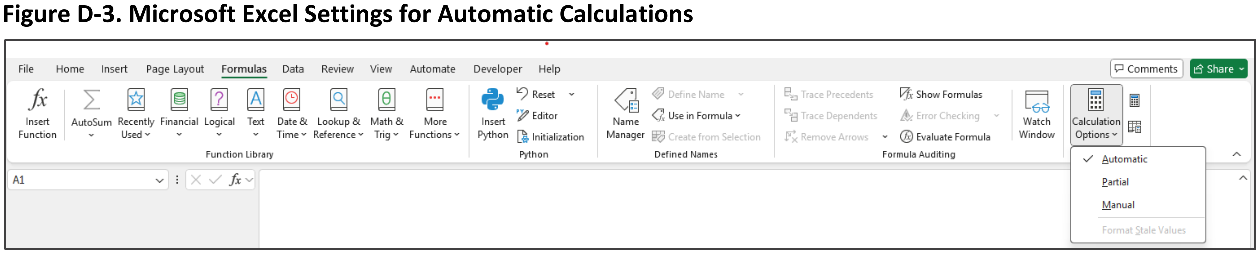
Figure D-2. Microsoft Excel Security Settings for Macros



Microsoft Excel Settings

For the calculator to function properly, Excel must be set to automatic calculation. In the Formulas ribbon, select “Calculation Options” and make sure that the box next to the “Automatic” option is checked from the menu. See Figure D-3 for an example of this setting.

Figure D-3. Microsoft Excel Settings for Automatic Calculations



2. Calculator Structure

The organization of the calculator is summarized in Table D-1.

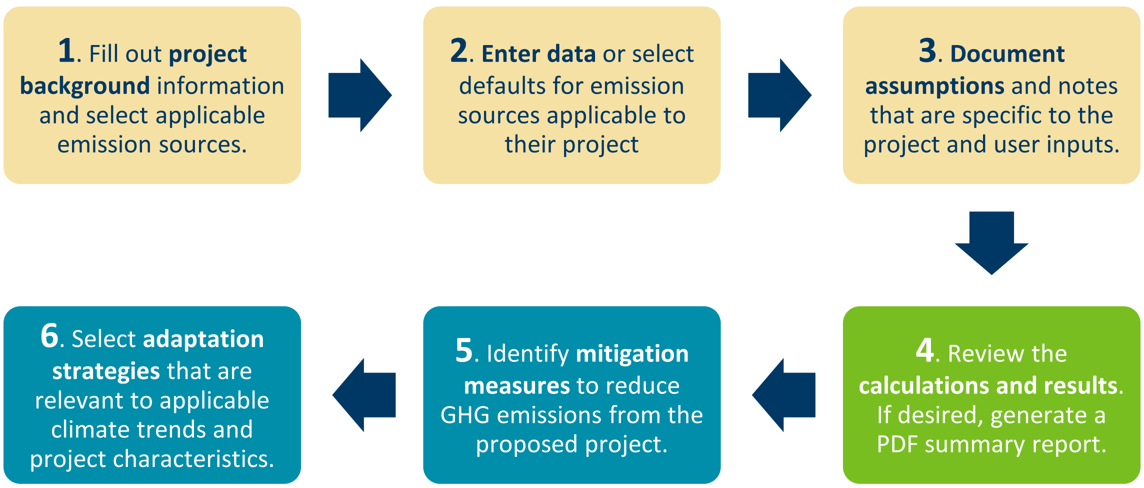
Table D-1. Climate Calculator Structure

Tab Name	Contents
Introduction	Summarizes the purpose, scope, and limitations of the calculator. Includes the version number and release date.
User Guide	Includes instructional steps on how to use the calculator, a cell legend, and a table of contents describing the details of each tab.
Project Background	Prompts users to enter basic information about their project, including the project name, category, location, construction start date and duration, the year when the project is expected to be fully operational, the project lifespan, project acreage, building area, and electricity provider. Allows the user to select the preferred unit in which to present results. Based on the project category selected, the calculator specifies which emission sources may apply and give users the option to select and unselect emission sources to quantify.
User Inputs	Prompts users to enter the activity data needed to quantify emissions from the selected emission sources, organized by project phase. Users also have the option to view and override, as desired, select default assumptions and emission factors.
Notes	Allows users to document assumptions, data sources, notes for reviewers, special circumstances or other helpful information specific to their project, organized by project phase and emissions source.
Construction	Shows the calculations for quantifying emissions from each applicable emissions source during the construction phase of the project, drawing on user inputs, assumptions, constants, and emission factors.
Operation	Shows the calculations for quantifying emissions from each applicable emissions source during the operational phase of the project, drawing on user inputs, assumptions, constants, and emission factors.
Results	Provides a summary of cumulative and annualized project-related lifetime emissions by emissions source and project phase.
Charts	Graphically summarizes cumulative and annualized GHG emissions by source.
Mitigation	Identifies potential mitigation measures to reduce GHG emissions, organized by the primary source through which emission reductions are expected.
Adaptation	Identifies potential adaptation strategies, organized by climate trend and project characteristics.
Assumptions	Summarizes assumptions, including both activity data and emission factors, that are used in the calculations.
Constants	Lists constants and conversion factors used in the calculations.
Other (Variable Names)	Additional white tabs that document raw data inputs and the interim calculations used to derive the assumptions.

3. Using the Climate Calculator

The general process for using the calculator is summarized by the six steps outline in Figure D-4. Instructions and guidance are embedded throughout the calculator to help guide users through this process. Instructional or informational language is found at the top of each tab and/or section and provided in pop-up text boxes for select cells. Additional features of the calculator that support data accuracy, completeness, and usability are discussed further in the remainder of this section.

Figure D-4. Overview of the Process for Using the Climate Calculator



Formatting: Formatting is used throughout the calculator to help users understand where to enter data and what the data in each cell represents. The cell legend used in the calculator is shown in Table D-2.

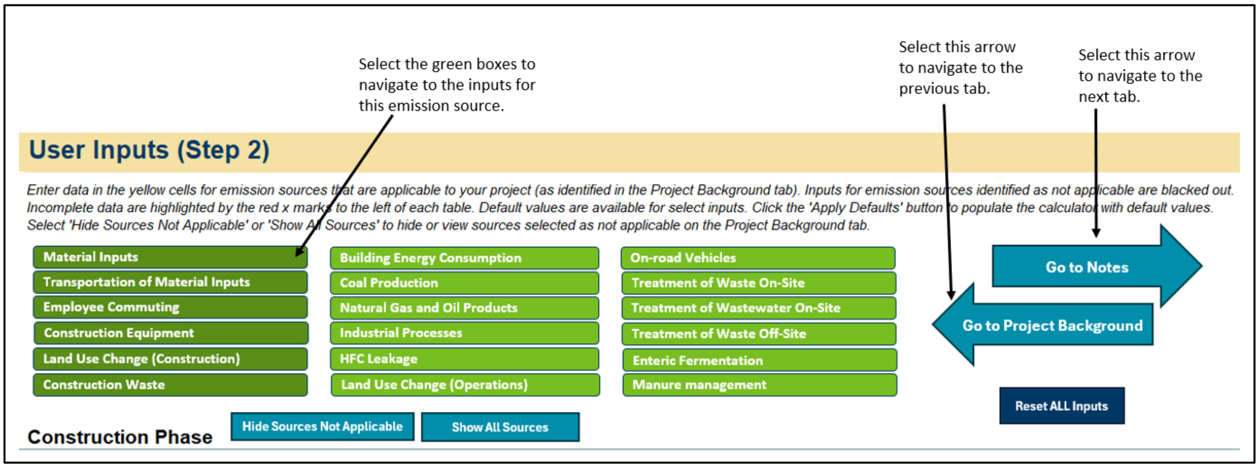
Table D-2. Climate Calculator Cell Legend

Legend	Criteria
	Yellow cells are **data input fields**.
	Blue cells are **headings** and are **not editable**.
	White cells are **lists or constants** and are **not editable**.
	Green cells are **calculated fields** and are **not editable**.
	Light green cells are **calculated fields** for interim calculations and are **not editable**.
	Gray cells are **assumptions** and are **not editable**.
	Black cells are for **emissions sources that are not applicable** and are not calculated.

Navigation: As shown in Figure D-5, the calculator is organized into informational tabs (shaded in dark blue) input tabs (shaded in yellow), calculation tabs (shaded in green), mitigation and adaptation tabs (shaded in blue), and assumptions and constants tabs (shaded in light blue). Users can navigate through the sections of the calculator by selecting the navigation arrows at the top of each tab or clicking directly on the tab name at the bottom of Excel. Users can navigate to the top of each tab by selecting the return to top buttons at the bottom of tabs. On the User Inputs, Construction, and Operation tabs, users can select the green boxes at the top to navigate to specific sections of a tab. An example of the navigation features on the User Inputs tab is shown in Figure D-6.

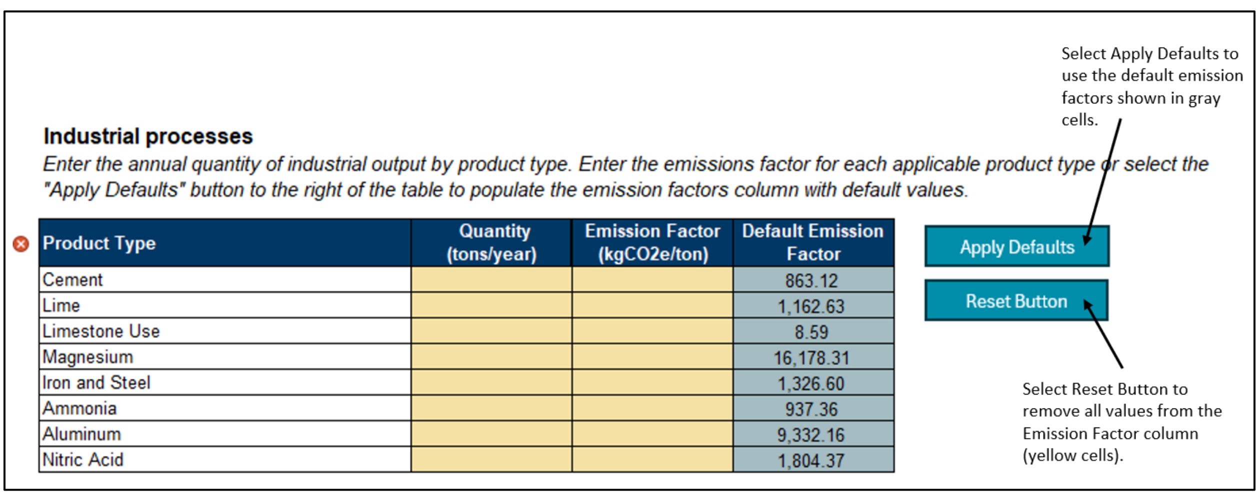
Figure D-5. Tab Organization and Coloring

Figure D-6. Navigation Features on the User Inputs Tab



Applying Defaults: Default assumptions are available for select user inputs. Default data are displayed in gray cells and link to values summarized on the Assumptions tab. For inputs where default data are available, an “Apply Defaults” button is included next to these inputs to allow users to easily populate the calculator with default values. A ‘Reset ALL Inputs’ button is also included to remove all inputs, both those that are defaults and user-provided inputs, from each emission source. Note that the “Reset” button will clear all user inputs from the input fields, even manually entered or edited values. An example of the default and reset buttons on the User Inputs tab is shown in Figure D-7.

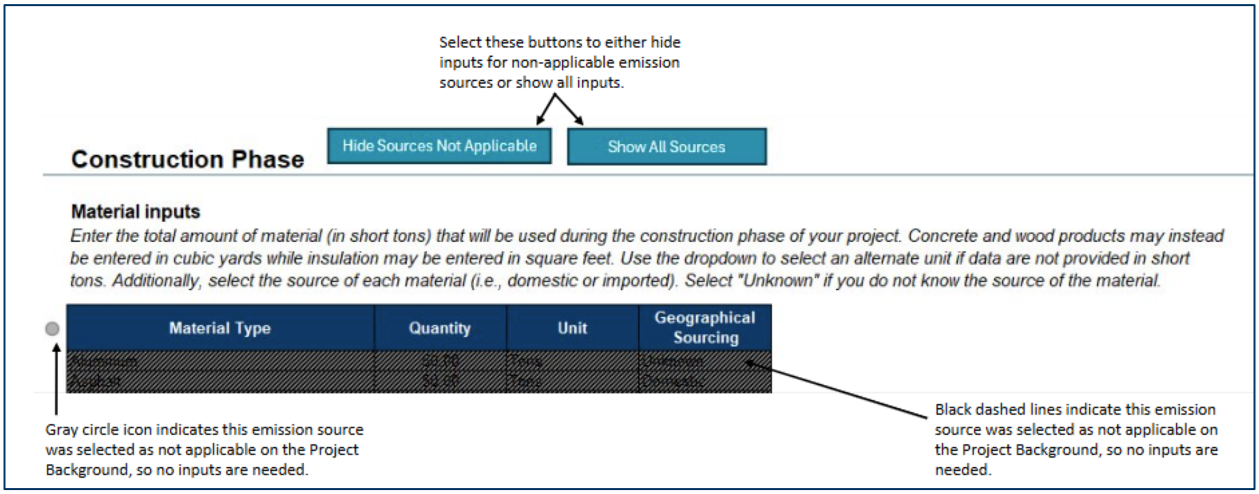
Figure D-7. Example of Applying Defaults and Reset Buttons for an Emission Source on the User Inputs Tab



Product Type	Quantity (tons/year)	Emission Factor (kgCO2e/ton)	Default Emission Factor
Cement			863.12
Lime			1,162.63
Limestone Use			8.59
Magnesium			16,178.31
Iron and Steel			1,326.60
Ammonia			937.36
Aluminum			9,332.16
Nitric Acid			1,804.37

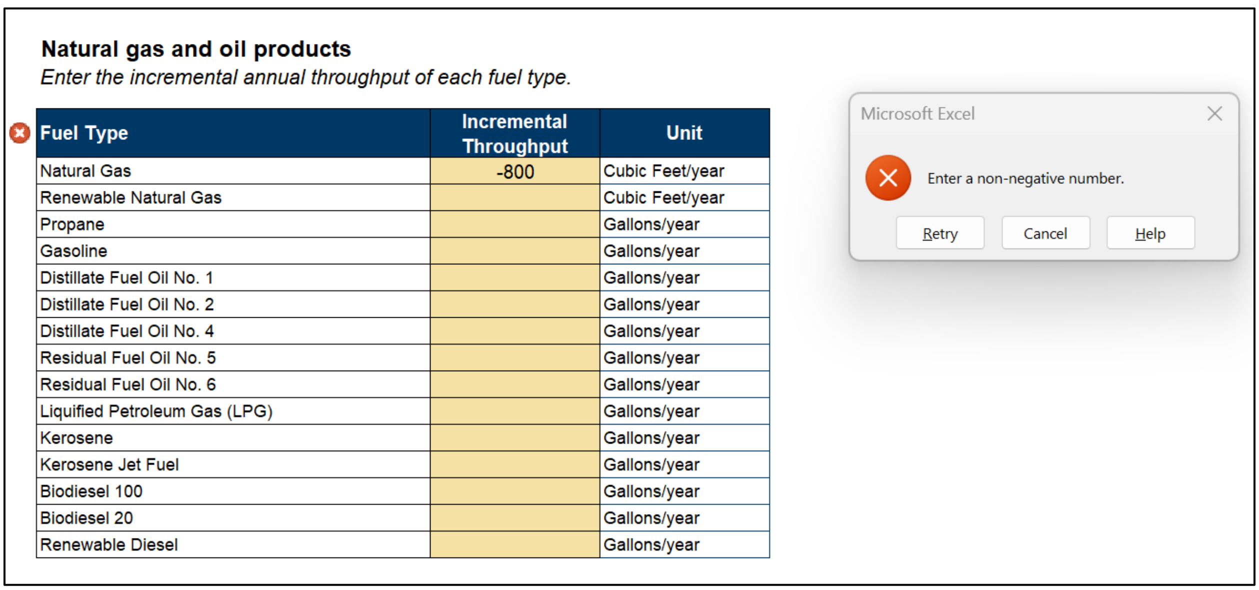
Shading and Hiding: Gray shading with black dashed lines are used throughout the calculator when values are not applicable based on prior selections made by the user. On the User Inputs tab, users may choose to hide all these rows for sources that are identified as not applicable by selecting the “Hide Sources Not Applicable” button at the top of the tab. Rows for non-applicable sources are automatically hidden in the Results and Charts tabs. See Figure D-8 for an example of these features.

Figure D-8. Example of Shading and Hiding for Not Applicable Emissions Sources



Data Validations: Data validations are built into user input fields to help ensure data quality and accuracy. Validations include value ranges, drop-down lists, and formatting restrictions. A pop-up message will appear if you try to enter a nonvalid value into a user input field. An example of a data validation pop-up message is shown in Figure D-9.

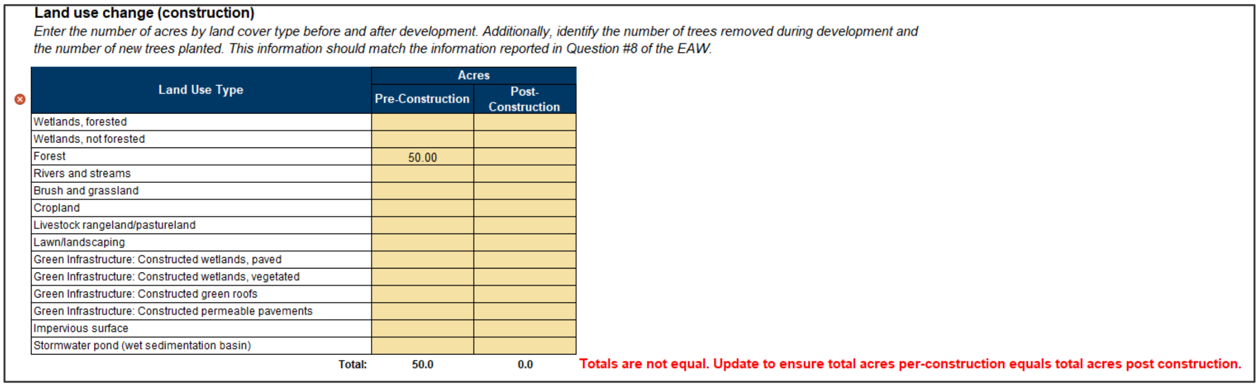
Figure D-9. Example of Data Validation on the User Inputs Tab



Fuel Type	Incremental Throughput	Unit
Natural Gas	-800	Cubic Feet/year
Renewable Natural Gas		Cubic Feet/year
Propane		Gallons/year
Gasoline		Gallons/year
Distillate Fuel Oil No. 1		Gallons/year
Distillate Fuel Oil No. 2		Gallons/year
Distillate Fuel Oil No. 4		Gallons/year
Residual Fuel Oil No. 5		Gallons/year
Residual Fuel Oil No. 6		Gallons/year
Liquified Petroleum Gas (LPG)		Gallons/year
Kerosene		Gallons/year
Kerosene Jet Fuel		Gallons/year
Biodiesel 100		Gallons/year
Biodiesel 20		Gallons/year
Renewable Diesel		Gallons/year

Data Checks: Data checks are used to alert users to incomplete or incorrectly entered data. Checker icons are included next to each required field or table. A red "x" icon will appear next to a field if it is left blank, and a green check icon will appear if the field has been populated. Checkers are not included for fields where inputs are optional. Red text will also display if inputs are entered incorrectly (see Figure D-10). Furthermore, if all inputs are not provided on the Project Background tab, a pop-up message will be displayed when users navigate to the User Inputs tab. Similarly, if not all user inputs are provided for emissions sources selected as applicable, a pop-up message and red error text will also appear when users navigate to the Results tab (see Figure D-11).

Figure D-10. Example of Error Checkers for Land Use Change (Construction) User Inputs



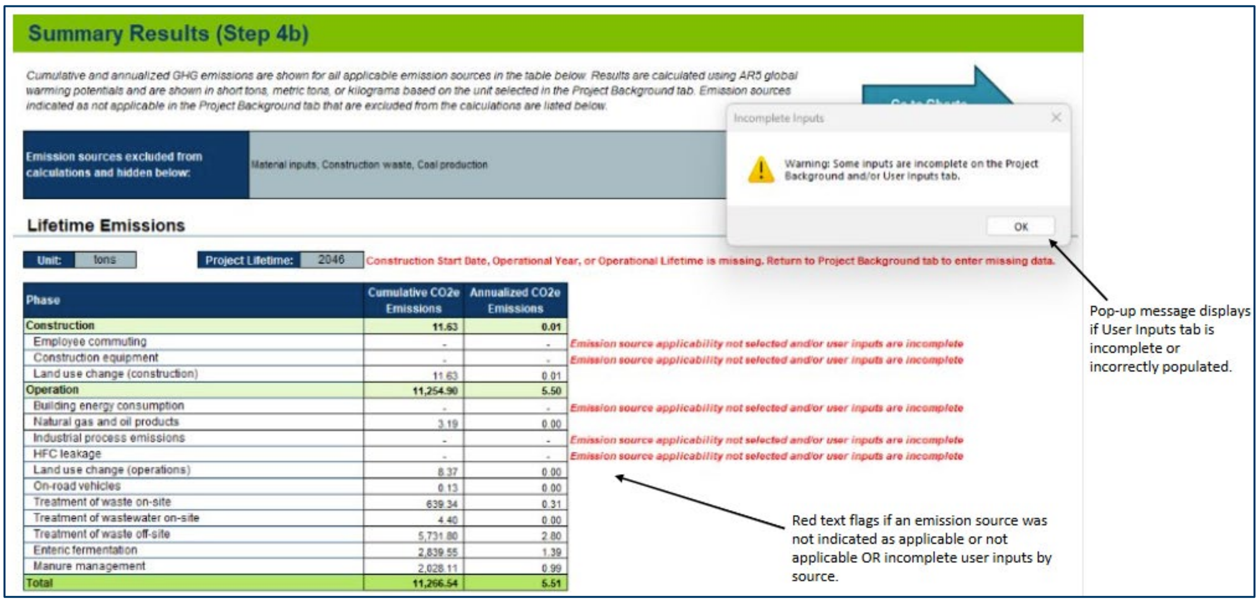
Land use change (construction)

Enter the number of acres by land cover type before and after development. Additionally, identify the number of trees removed during development and the number of new trees planted. This information should match the information reported in Question #8 of the EAW.

Land Use Type	Acres	
	Pre-Construction	Post-Construction
Wetlands, forested		
Wetlands, not forested		
Forest	50.00	
Rivers and streams		
Brush and grassland		
Cropland		
Livestock rangeland/pastureland		
Lawn/landscaping		
Green Infrastructure: Constructed wetlands, paved		
Green Infrastructure: Constructed wetlands, vegetated		
Green Infrastructure: Constructed green roofs		
Green Infrastructure: Constructed permeable pavements		
Impervious surface		
Stormwater pond (wet sedimentation basin)		
Total:	50.0	0.0

Totals are not equal. Update to ensure total acres per-construction equals total acres post construction.

Figure D-11. Example of Data Validation on the Results Tab



Summary Results (Step 4b)

Cumulative and annualized GHG emissions are shown for all applicable emission sources in the table below. Results are calculated using AR5 global warming potentials and are shown in short tons, metric tons, or kilograms based on the unit selected in the Project Background tab. Emission sources indicated as not applicable in the Project Background tab that are excluded from the calculations are listed below.

Emission sources excluded from calculations and hidden below:	Material inputs, Construction waste, Coal production

Incomplete Inputs

Warning: Some inputs are incomplete on the Project Background and/or User Inputs tab.

OK

Lifetime Emissions

Unit: tons Project Lifetime: 2046 Construction Start Date, Operational Year, or Operational Lifetime is missing. Return to Project Background tab to enter missing data.

Phase	Cumulative CO2e Emissions	Annualized CO2e Emissions	
Construction	11.63	0.01	
Employee commuting	-	-	*Emission source applicability not selected and/or user inputs are incomplete*
Construction equipment	-	-	*Emission source applicability not selected and/or user inputs are incomplete*
Land use change (construction)	11.63	0.01	
Operation	11,254.90	5.50	
Building energy consumption	-	-	*Emission source applicability not selected and/or user inputs are incomplete*
Natural gas and oil products	3.19	0.00	
Industrial process emissions	-	-	*Emission source applicability not selected and/or user inputs are incomplete*
HFC leakage	-	-	*Emission source applicability not selected and/or user inputs are incomplete*
Land use change (operations)	8.37	0.00	
On-road vehicles	0.13	0.00	
Treatment of waste on-site	639.34	0.31	
Treatment of wastewater on-site	4.40	0.00	
Treatment of waste off-site	5,731.80	2.80	
Enteric fermentation	2,839.55	1.39	
Manure management	2,028.11	0.99	
Total	11,266.54	5.51	

Pop-up message displays if User Inputs tab is incomplete or incorrectly populated.

Red text flags if an emission source was not indicated as applicable or not applicable OR incomplete user inputs by source.

4. Calculator Inputs

Users of the calculator are required to enter data into the Project Background and User Inputs tabs. Detailed guidance on when and what to enter in each field are provided by tab and subsection below.

Project Background Tab

Project Information: Users are required to provide information on the type, timeframe, and size of their proposed project as well as energy source information, as available. Results will not calculate if certain fields are left blank, as highlighted by red x marks. Project information inputs, including information on the field type, data validations, availability of default assumptions, and use within the calculator, are detailed in Table D-3.

Table D-3. Project Information User Inputs on the Project Background Tab

Input	Input Type	Data validation	Default Assumption	Description/Use
Project Name	Text	NA	NA	This input is optional.
Project Category (primary)	Drop-down selection	Must match value from drop-down list. Checker indicates if cell is left blank.	NA	Used for default emission source applicability.
Project Category (secondary)	Drop-down selection	Must match value from drop-down list.	NA	Used for default emission source applicability.
Location (County)	Drop-down selection	Must match value from drop-down list. Checker indicates if cell is left blank.	NA	Location where the project will be built. Used for default treatment of waste off-site assumptions.
Construction Start Date	mm/dd/yyyy	Validation for date format. Checker indicates if cell is left blank.	NA	The anticipated start date of project construction. Used to calculate project lifetime and cumulative emissions. Used to determine the annually variable emission factors for calculating emissions from the transportation of material inputs and construction electricity consumption.
Operational Year	yyyy	Validation for date format. Checker indicates if cell is left blank.	NA	The year in which the project is expected to become operational. Used to calculate project lifetime and cumulative emissions. Used to determine the annually variable emission factors for calculating emissions from on-road vehicles and operational electricity consumption.

Input	Input Type	Data validation	Default Assumption	Description/Use
Operational Lifetime (Years)	Whole number	Validation for number between 1 and 60. Checker indicates if cell is left blank.	NA	The anticipated operational lifetime of the project. Used to calculate project lifetime and cumulative emissions.
Building Construction Project	Drop-down selection	Must match value from drop-down list.	Calculator is defaulted to Yes.	A building construction project refers to the construction of a building like an office or house. In contrast, a linear construction project describes a project where construction progresses along a continuous line, like a road, pipeline, or railway. Determines if construction stage duration inputs are needed and the applicability of the default assumptions.
Construction Stage Durations (Days)	Whole number	Must be a whole number greater than 0. Checker indicates if all cells are left blank.	Defaults vary based on project acreage and are only applicable to building construction projects due to source data.	Duration of each construction stage. Used for employee commuting and construction equipment calculations.
Total Project Acreage	Decimal number	Must be a decimal number greater than 0. Checker indicates if cell is left blank.	NA	Area of land that is disturbed during project construction or operation. Used to calculate construction stage duration defaults.
Area by building type (sq ft)	Decimal number	Must be a decimal number greater than 0. Checker indicates if all cells are left blank for building construction projects.	NA	Building area constructed by building type. Used to calculate emissions from building energy consumption and HFC leakage.
Electricity Provider	Drop-down selection	Must match value from drop-down list.	Calculator is defaulted to Grid Average.	Used to determine the electricity emission factors for building energy consumption calculations.

Input	Input Type	Data validation	Default Assumption	Description/Use
Portion of Building Electricity Consumption to be Generated On-Site via Renewables or Supplied through the Purchase of Renewable Energy Credits (RECs)	Percent	Data validation for percent between 0 and 100.	Calculator is defaulted to 0.	Identifies the portion of building electricity consumption provided by renewable sources via direct purchase or on-site generation. Value may not be greater than 100%. Used to calculate electricity emissions from building energy consumption.
Portion of Building Natural Gas Consumption to be Supplied from Renewable Sources	Percent	Data validation for percent between 0 and 100.	Calculator is defaulted to 0.	Identifies the portion of building natural gas consumption provided by renewable sources via direct purchase or on-site generation. Used to calculate natural gas emissions from building energy consumption.

Calculator Calculations Preferences: Users can specify their preferred unit in which to present emissions in the Results tab. The drop-down list allows users to select from the following options:

- Tons (short tons)
- MT (metric tons)
- Kg (kilograms)

Applicable Emission Sources: Information on whether an emissions source is potentially applicable to your project will automatically populate based on the primary and secondary project category selected in the Project Information section. Users can apply default selections by clicking the “Apply Defaults” or choose which emission sources to include by selecting “Yes” or “No” in the drop-down menu next to each emissions source. A selection must be made for each emissions source. If “No” is selected, fields applicable to that emissions source will be shaded gray with black dashed lines and/or hidden in subsequent tabs of the calculator and no emissions from that source will be included in the results.

User Inputs Tab

On the User Inputs tab, fields that are not applicable to the selected project type will be shaded gray with black dashed lines to align with the selections on the Project Background tab. Users can hide all inputs for emissions sources that are not appliable to their project by selecting the “Hide Sources Not Applicable” button at the top of this tab. User input cells are shaded yellow so it is clear which cells require data. Default assumptions and emission factors are provided in gray and can be populated by selecting the “Apply Defaults” buttons next to each emission source user input table. A “Reset ALL Inputs” button is included if users would like to clear all user inputs from this tab. Checker icons throughout the tab are color coded as follows:

- A **gray circle** icon if the emission source is excluded from the calculations
- A **red x** icon if the emission source is applicable but required data inputs are missing
- A **green check** icon if the emission source is applicable and all required inputs are provided

Material Inputs: If material inputs and transportation of material inputs are applicable to the project, a user is required to enter the inputs described in Table D-4.

Table D-4. User Inputs for Material Inputs

Input	Input Type	Data validation	Default Assumptions	Description/Use
Quantity	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0. For individual materials, users can leave the quantity blank or 0.	NA	Total amount of material that will be used during construction. These quantities are also used to calculate default construction waste material quantities.
Unit	Drop-down selection	Must match value from drop-down list.	Calculator is defaulted to tons.	Identifies the unit of measure for the provided material quantity.
Geographical Sourcing	Drop-down selection	Must match value from drop-down list.	Calculator is defaulted to "Unknown", except for Asphalt and Concrete, which are only sourced domestically.	Identifies the source of the material input. Select "Unknown" if you do not know the source of the material. Used to determine the distance traveled by mode for the transportation of material inputs.

Employee Commuting: If employee commuting is applicable to the project, a user is required to enter the inputs described in Table D-5.

Table D-5. User Inputs for Employee Commuting

Input	Input Type	Data validation	Default Assumptions	Description/Use
Daily Average Number of Employees Commuting	Whole number	Must be a whole number equal to or greater than 0. Red checker appears if sum of all values equals 0. For individual construction stages, users can leave cell blank or 0.	NA	Average number of employees that will commute to the construction site during each phase of construction.
Average One-Way Commute Length	Decimal number	Must be a decimal number greater than 0. Value must be populated or red checker will appear.	Yes	Average one-way commuter distance in miles.
Percent of Employees by Transportation Mode	Percent	Must be between 0 and 100 for each mode. Total across modes must sum to 100%. Red checker and text will appear if total does not equal 100%.	Yes	Percent of employees that commute by each transportation mode.

Construction Equipment: If construction equipment is applicable to the project, a user is required to enter the inputs described in Table D-6.

Table D-6. User Inputs for Construction Equipment

Input	Input Type	Data validation	Default Assumptions	Description/Use
Fuel type by equipment type	Drop-down selection	Must match value from drop-down list	Calculator is defaulted to diesel.	Determines the emission factor used for calculating emissions from construction equipment.
Number of Hours per Day by Construction Stage for each equipment type	Decimal number	Must be a decimal number equal to or greater than 0. Users only need to enter values for equipment types and construction stages relevant to their project.	Yes. Defaults are only applicable to building construction projects and values are dependent on the user-provided project acreage.	Total number of hours each equipment type is used per day by construction phase. Total hours should account for multiple pieces of equipment being used each day.

Note: If the user does not want to use the calculator defaults and does not know what specific construction equipment they will use or for how long, the user may alternatively enter estimated construction equipment fuel consumption in the natural gas and oil products emission source section of the calculator to estimate emissions from construction equipment. The calculation of construction emissions using this approach should be done in a separate version of the calculator so that cumulative emissions, which are derived by multiplying annual emissions from natural gas and oil products by the operational lifetime, are not inflated.

Land Use Change (Construction): If land use change during construction is applicable to the project, a user is required to enter the inputs described in Table D-7. This information should match the information reported in Item #8 of the EAW.

Table D-7. User Inputs for Land Use Change During Construction

Input	Input Type	Data validation	Default Assumptions	Description/Use
Pre-construction acreage by land use type	Decimal number	Must be a decimal number equal to or greater than 0. Red checkers will appear if total pre-construction acreage does not equal post-construction acreage.	NA	Number of acres by land cover type prior to construction.
Post-construction acreage by land use type	Decimal number	Must be a decimal number equal to or greater than 0. Red checkers will appear if total post-construction acreage does not equal pre-construction acreage.	NA	Number of acres by land cover type after construction.
Number of mature trees removed	Whole number	Must be a whole number equal to or greater than 0. This input is optional.	NA	Number of trees removed during construction, not including trees removed as part of forest conversion.

Input	Input Type	Data validation	Default Assumptions	Description/Use
Number of new trees planted	Whole number	Must be a whole number equal to or greater than 0. This input is optional.	NA	Number of new trees planted after development, not including trees planted as part of reforestation.

Construction Waste: If construction waste is applicable to the project, a user is required to enter the inputs described Table D-8.

Table D-8. User Inputs for Construction Waste

Input	Input Type	Data validation	Default Assumptions	Description/Use
Quantity of materials by material type	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all values equals 0.	Yes. Based on inputs entered under the Material Inputs section. Calculated by multiplying the user-provided material quantities by the assumed loss rate of each material type. No default available for mixed C&D waste.	Total amount of waste generated during construction in short tons. Users may also enter a quantity for mixed C&D waste generated to account for other waste not covered by material-specific values.

Building Energy Consumption: If building energy consumption is applicable to the project, a user is required to enter the inputs described in Table D- 9.

Table D-9. User Inputs for Building Energy Consumption

Input	Input Type	Data validation	Default Assumptions	Description/Use
Energy intensity by building type	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if no values are added for building types with areas greater than 0.	Yes. No defaults are available for Other Building Area.*	The annual amount of energy consumed (in Btu) on average by fuel source per building square foot.

* For industrial buildings, industry-specific default values are also calculated and may be used in place of the default provided.

Coal Production: If coal production is applicable to the project, a user is required to enter the inputs described in Table D-10.

Table D-10. User Inputs for Coal Production

Input	Input Type	Data validation	Default Assumptions	Description/Use
Incremental production by coal type	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0. For individual coal types, users can leave the quantity blank or 0.	NA	Incremental amount of coal by type that is delivered and combusted as a result of the project in tons per year.

Natural Gas and Oil Products: If natural gas and oil products are applicable to the project, a user is required to enter the inputs described in Table D-11.

Table D-11. User Inputs for Natural Gas and Oil Products

Input	Input Type	Data validation	Default Assumptions	Description/Use
Incremental throughput by fuel type	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0. For individual fuel types, users can leave the quantity blank or 0.	NA	Incremental amount of each fuel type in cubic feet or gallons per year, depending on the fuel, that is delivered and combusted as a result of the project.
Percent reduction in leakage and venting emissions for natural gas	Percent	Must be between 0 and 75%. No checkers as this input is optional.	Yes. Calculator is defaulted to 0.	If mitigation strategies are to be adopted to reduce natural gas leakage and venting, users may enter the anticipated percent reduction relative to the default emissions. This value is used to calculate the adjusted leakage and venting emissions.

Industrial Processes: If industrial processes are applicable to the project, a user is required to enter the inputs described in Table D-12.

Table D-12. User Inputs for Industrial Processes

Input	Input Type	Data validation	Default Assumptions	Description/Use
Quantity of industrial outputs by product type	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0. For individual products, users can leave the quantity blank or 0.	NA	Annual quantity of industrial output by product type in tons per year.

Input	Input Type	Data validation	Default Assumptions	Description/Use
Emission factors for each applicable product type	Decimal number	Must be a decimal number greater than 0. Red checkers will appear if no value is provided for product types with a quantity greater than 0.	Yes	Emissions (in $kgCO_2e$) associated with the production of one ton of output.

HFC Leakage: If HFC leakage is applicable to the project, a user is required to enter the inputs described in Table D-13.

Table D-13. User Inputs for HFC Leakage

Input	Input Type	Data validation	Default Assumptions	Description/Use
Percent of building area utilized by building type	Percent	Must be between 0 and 100% for applicable building types. Red checkers will appear if no input is provided for building types with an area greater than 0.	Yes. Default is 100% for all building types.	Portion of the building area by building type that utilizes air conditioning and/or refrigeration equipment. Building area based on the building square footage data entered in the Project Background tab.

Land Use Change (Operation): If land use change during operation is applicable to the project, a user is required to enter the inputs described in Table D-14.

Table D-14. User Inputs for Land Use Change During Operations

Input	Input Type	Data validation	Default Assumptions	Description/Use
Post-operation acres by land use type	Decimal number	Must be a decimal number equal to or greater than 0. Red checkers will appear if total post-operation acreage does not equal post-construction acreage.	NA	Number of acres by land cover type after project operation.

On-Road Vehicles: If on-road vehicles are applicable to the project, a user is required to enter the inputs described in Table D-15.

Table D-15. User Inputs for On-Road Vehicles

Input	Input Type	Data validation	Default Assumptions	Description/Use
Additional VMT by speed bin	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0. For individual speed bins, users can leave the quantity blank or 0.	NA	Additional VMT each year as a result of the project. Users may enter additional VMT for the fleet average and by speed bin, if known.

Treatment of Waste On-Site: If treatment of waste on-site is applicable to the project, a user is required to enter the inputs described in Table D-16.

Table D-16. User Inputs for Treatment of Waste On-Site

Input	Input Type	Data validation	Default Assumptions	Description/Use
Waste Treatment Practice	Drop-down selection	Must match value from drop-down list. Red checker will appear if no practices are selected.	NA	The type of waste treatment practice used by the project. Up to three practices may be selected.
Quantity of Waste Treated	Decimal number	Must be a decimal number greater than 0. Red checkers will appear if no quantities are provided and if a selected waste treatment practice is missing a quantity input.	NA	Amount of waste the project is anticipated to treat on-site in short tons per year.

Treatment of Wastewater On-Site: If treatment of wastewater on-site is applicable to the project, a user is required to enter the inputs described in Table D-17. Only inputs for municipal wastewater treatment of industrial wastewater treatment is required.

Table D-17. User Inputs for Treatment of Wastewater On-Site

Input	Input Type	Data validation	Default Assumptions	Description/Use
Population served by treatment plant	Whole number	Must be a whole number equal to or greater than 0. Red checker will appear if this cell and the production quantity is left blank or 0.	NA	Population served by the municipal wastewater treatment plant.
Product type	Drop-down selection	Must match value from drop-down list. Red checker will appear if no product type is selected and the population served is left blank or 0.	NA	Product type for industrial wastewater. Only one type may be selected.
Production	Decimal number	Must be a decimal number equal to or greater than 0. Red checker will appear if no production value is entered and the population served is left blank or 0.	NA	Anticipated production output of the industrial wastewater plant for the selected product type in metric tons per year.

Treatment of Waste Off-Site: If treatment of waste off-site is applicable to the project, a user is required to enter the inputs described in Table D-18.

Table D-18. User Inputs for Waste Off-Site

Input	Input Type	Data validation	Default Assumptions	Description/Use
Quantity of activity	Whole number	Must be a whole number equal to or greater than 0. Red checker appears if the sum of all inputs equals 0.	NA	Number of households, commercial, industrial, or institutional employees, and visitors per year at public venues.
Waste generation rate by activity	Decimal number	Must be a decimal number equal to or greater than 0. Red checker appears if no values are added for activities with quantities greater than 0.	Yes	Waste generation rate in pounds per household per day, employee per day, or pounds per visitor, depending on the activity.
Percent of waste by waste treatment practice	Percent	Must be between 0 and 100%. Total across practices must sum to 100%. Red checker and text will appear if total does not equal 100%.	Yes. Defaults based on the county in which the project is located, as entered on the Project Background tab.	Percent of waste that is managed by each type of waste treatment practice.

Enteric Fermentation and Manure Management: If enteric fermentation and manure management are applicable to the project, a user is required to enter the inputs described in Table D-19.

Table D-19. User Inputs for Enteric Fermentation and Manure Management

Input	Input Type	Data validation	Default Assumptions	Description/Use
Percent of manure applied or sold for application to agricultural soils (pasture or cropland) as fertilizer	Percent	Must be between 0 and 100%. Red checker will appear if no value is entered.	NA	Used to calculate annual direct and indirect nitrous oxide emissions from land application.
Population of animals	Whole number	Must be a whole number equal to or greater than 0. Population must be provided for at least one animal. Red checker appears if the sum of all values equals 0.	NA	Average annual number of animals across the operational lifetime of the project that will be managed during feedlot operation as a result of the project.
Percentage of applicable manure management system by livestock type	Percent	Must be between 0 and 100%. Values by livestock type must sum to 100% for each animal type. Red checker and text will appear if total does not equal 100%.	NA. Values can only be entered for applicable manure management systems for each livestock type.	Portion of manure that will be treated by each management system.

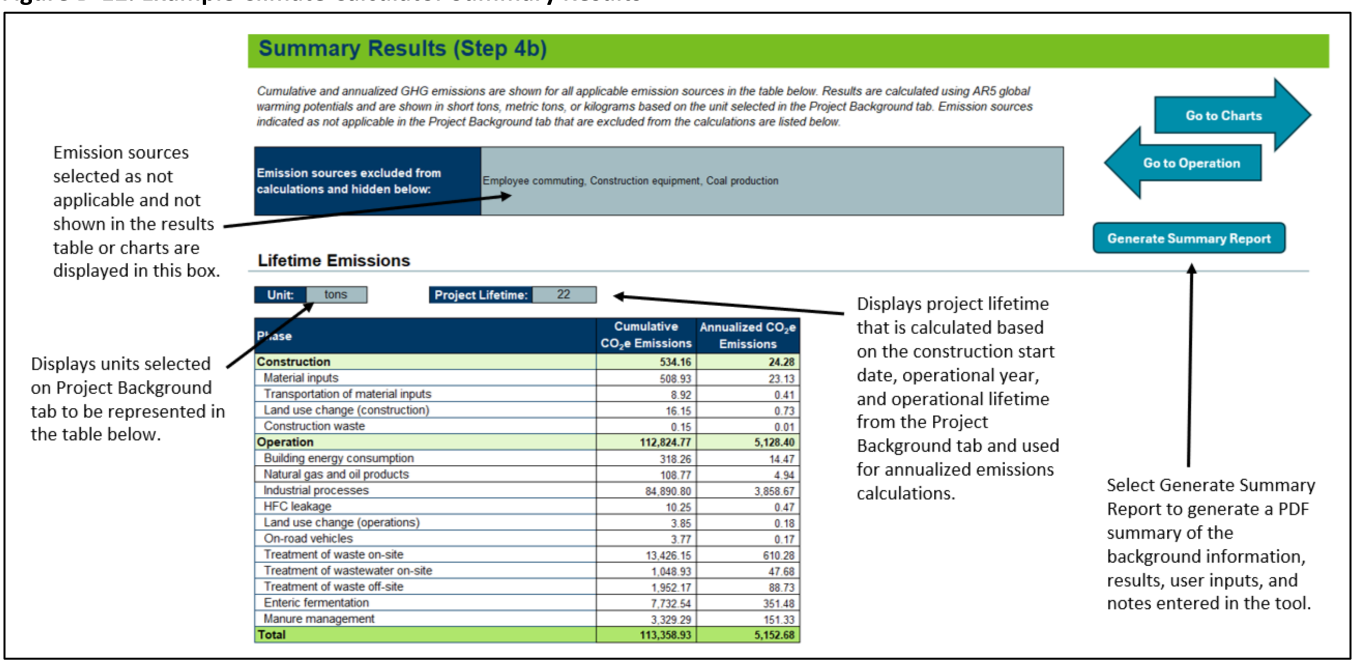
5. Emission Outputs

Based on the inputs entered by users and the assumptions embedded into the calculator, the calculator quantifies GHG emissions across the lifetime of the proposed project. The calculations by emissions source are detailed in the Construction and Operation tabs. The emissions in these tabs are presented in kilograms of carbon dioxide equivalent (kgCO_2e). Construction emissions and annual operational emissions are then aggregated and presented as cumulative and annualized emissions by emission source and project phase on the Results tab. Definitions of key terms include the following:

- **Cumulative Emissions:** Cumulative emissions are calculated as the sum of construction emissions and operational emissions across operational lifespan of the project.
- **Annualized Emissions:** Annualized emissions are calculated by dividing cumulative emissions, which include both construction and operational emissions, by the project lifetime.
- **Project Lifetime:** The project lifetime includes both the construction and operational phases of the project and is derived based on the construction start date, operational year, and operational lifetime.

Results are shown in short tons, metric tons, or kilograms based on the unit selected in the Project Background tab. **Users may use the lifetime emissions quantified by the calculator to answer Item 18 in the EAW.** Emission sources that are indicated as not applicable in the Project Background tab are excluded from calculations and noted in a box at the top of the tab. Rows for these not applicable sources are automatically hidden and excluded from the table and charts. Users can also select the "Generate Summary Report" button to print a PDF summary report. Figure D-12 provides an overview of the Results tab and these features.

Figure D-12. Example Climate Calculator Summary Results



Summary Report: This report includes a summary of the background information provided by users, the cumulative and annualized emissions by source and project phase, user inputs for each emissions source, and any notes entered on the Notes tab. NA is used to denote emissions that were not quantified and/or activity was identified as not applicable by the user. An example excerpt of this report is provided in Figure D-13. Users may amend this report to their EAW as part of their report to Item 18.

Figure D-13. Example Summary Report Excerpt

Minnesota Climate Calculator: Project Summary Report

Date Prepared: 4/29/2025

The results shown below were generated using the Minnesota Climate Calculator. The emissions quantified account for the full greenhouse gas impact of a potential project throughout the construction and operational phases of the project. This includes emissions from project activities that occur on-site as well as emissions that occur upstream and downstream of the project. The results are based on user inputs and assumptions; actual project emissions may vary.

Background Information

Project Name	Test Report
Project Category (primary)	Subp. 8, Transfer facilities
Project Category (secondary)	
Location (County)	Benton
Construction Start Date	1/1/2026
Operational Year	2027
Operational Lifetime (Years)	10

Electricity Provider	Grid Average
Portion of Building Electricity Consumption to be Generated On-Site via Renewables or Supplied through the Purchase of Renewable Energy Credits (RECs)	0%
Portion of Building Natural Gas Consumption to be Supplied from Renewable Sources	0%

Building Construction Project?	Yes

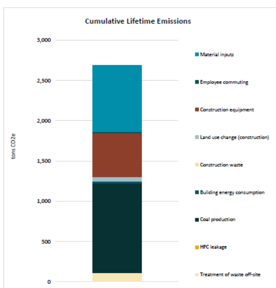
Construction Stage	Duration (Days)
Demolition	20
Site Preparation	10
Grading	20
Building Construction	230
Architectural Coatings	20
Paving and Landscaping	20

Summary Results

Project Lifetime	11
Unit	tons

Phase	CO2e Emissions	
	Cumulative	Annualized
Construction		
Material inputs	825.75	75.07
Transportation of material inputs	18.22	1.66
Employee commuting	15.74	1.43
Construction equipment	548.21	49.84
Land use change (construction)	50.82	4.62
Construction waste	0.83	0.08
Operation		
Building energy consumption	26.86	2.44
Coal production	1,109.34	100.85
Natural gas and oil products	NA	NA
Industrial process emissions	NA	NA
HFC leakage	3.39	0.31
Land use change (operations)	NA	NA
On-road vehicles	NA	NA
Treatment of waste on-site	NA	NA
Treatment of wastewater on-site	NA	NA
Treatment of waste off-site	109.28	9.93
Enteric fermentation	NA	NA
Manure management	NA	NA
Total	2,708.45	246.22

Note: NA indicates that emissions were not quantified and/or are not applicable.



Minnesota Climate Calculator: Project Summary Report 1 of 5

User Inputs

Note: NA indicates that emissions were not quantified and/or activity is not applicable.

Material Inputs

Material Type	Quantity	Unit	Geographical Sourcing
Aluminum	50.00	Tons	Unknown
Asphalt	0.00	Tons	Domestic
Brick	50.00	Tons	Unknown
Concrete	100.00	Tons	Domestic
Glass	50.00	Tons	Unknown
Insulation (residential)	50.00	Tons	Unknown
Insulation (commercial)	50.00	Tons	Unknown
Steel	50.00	Tons	Unknown
Wood Products	50.00	Tons	Unknown

Employee Commuting

Construction Stage	Daily Average Number of Employees Commuting
Demolition	5
Site Preparation	5
Grading	5
Building Construction	5
Architectural Coatings	5
Paving and Landscaping	5

Transportation Mode	Percent of Employees
Single Occupancy Vehicle	82%
Carpool	11%
Motorcycle	0%
Bus	2%
Transit Rail	2%
Bike/Walk	3%

Average One-Way Commute Length (miles)	13.2

Construction Equipment

Equipment Type	Fuel Type	Number of Hours per Day by Construction Stage					
		Demolition	Site Preparation	Grading	Building Construction	Architectural Coatings	Paving and Landscaping
Air Compressors	Diesel	0	0	0	0	6	0
Cement and Mortar Mixers	Diesel	0	0	0	0	0	0
Concrete/Industrial Saws	Diesel	8	0	0	0	0	0
Cranes	Diesel	0	0	0	7	0	0
Excavators	Diesel	24	0	16	0	0	0
Forklifts	Diesel	0	0	0	24	0	0
Generator Sets	Diesel	0	0	0	8	0	0
Graders	Diesel	0	0	8	0	0	0
Pavers	Diesel	0	0	0	0	0	16
Paving Equipment	Diesel	0	0	0	0	0	16
Rollers	Diesel	0	0	0	0	0	16
Rubber Tired Dozers	Diesel	16	24	8	0	0	0
Scrapers	Diesel	0	0	16	0	0	0
Tractors/Loaders/Backhoes	Diesel	0	32	16	21	0	0
Welders	Diesel	0	0	0	8	0	0

Land Use Change

Land Use Type	Acres		
	Pre-Construction	Post-Construction	Post-Operation
Wetlands, forested	0.00	0.00	NA
Wetlands, not forested	0.00	0.00	NA
Forest	50.00	0.00	NA
Rivers and streams	0.00	0.00	NA
Brush and grassland	0.00	0.00	NA
Cropland	0.00	0.00	NA
Livestock rangeland/pastureland	0.00	0.00	NA
Lawn/landscaping	500.00	100.00	NA
Green Infrastructure: Constructed wetlands, paved	0.00	0.00	NA
Green Infrastructure: Constructed wetlands, vegetated	0.00	0.00	NA
Green Infrastructure: Constructed green roofs	0.00	0.00	NA
Green Infrastructure: Constructed permeable pavements	0.00	0.00	NA
Impervious surface	0.00	450.00	NA
Stormwater pond (wet sedimentation basin)	0.00	0.00	NA

Minnesota Climate Calculator: Project Summary Report 2 of 5

Emissions Equivalencies: Emissions equivalencies for cumulative and annualized emissions are shown underneath the results table, derived using equivalency factors from EPA's Greenhouse Gas Equivalency Calculator.[153] For cumulative emissions results, equivalencies are shown for miles driven by an average gasoline-powered passenger vehicle, gallons of gasoline consumed, and tons of waste recycled instead of landfilled. For annualized emissions results, equivalencies are shown for gasoline-powered passenger vehicles driven for one year, home energy use for one year, and acres of U.S. forests in one year. Users may also follow the link provided to convert emissions results into additional equivalencies.

Charts: Results are also displayed graphically on the Charts tab. Lifetime emissions are represented as stacked bar charts, to show cumulative and annualized lifetime emissions by emission source. Emissions by project phase are represented as clustered column charts. Non-applicable emission sources are automatically hidden from view in the charts.

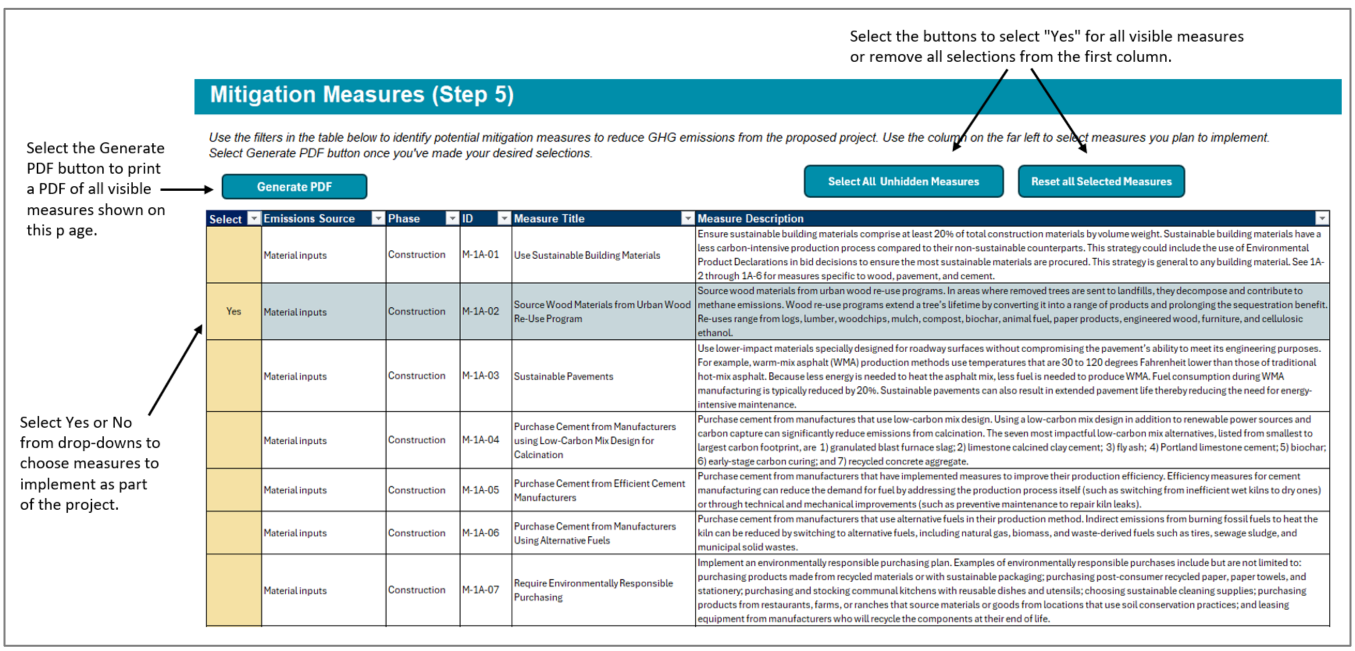
[153] EPA. "Greenhouse Gas Equivalencies Calculator – Calculations and References," 2024. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-calculations-and-references.

6. Mitigation and Adaptation

Mitigation Tab

The Mitigation tab identifies potential mitigation measures that may be used to reduce GHG emissions from the proposed project. A unique identifier (e.g., M-1A-1) is assigned to each identified mitigation measure in the calculator. While some measures may reduce emissions across more than one source, the calculator categorizes each measure according to the primary source through which emission reductions are expected. Users can use the column filters to narrow the list of measures to only those emission sources applicable to their project. Once the measure list is filtered, users should carefully review the measure descriptions to determine which measures are most applicable to their project and support their GHG reduction goals. Users can then use the drop-down menu under the Select column to choose the measures they intend to implement as part of their project. Users can also select the ‘Select All Unhidden Measures’ button to select “Yes” for all visible measures. Rows are shaded gray when a measured is selected. The ‘Reset all Selected Measures’ button can be used to remove all selections from the first column. The ‘Generate PDF’ button can be used to print a PDF of all visible measures. Figure D-14 highlights the features of the mitigation tab.

Figure D-14. Example Mitigation Measure

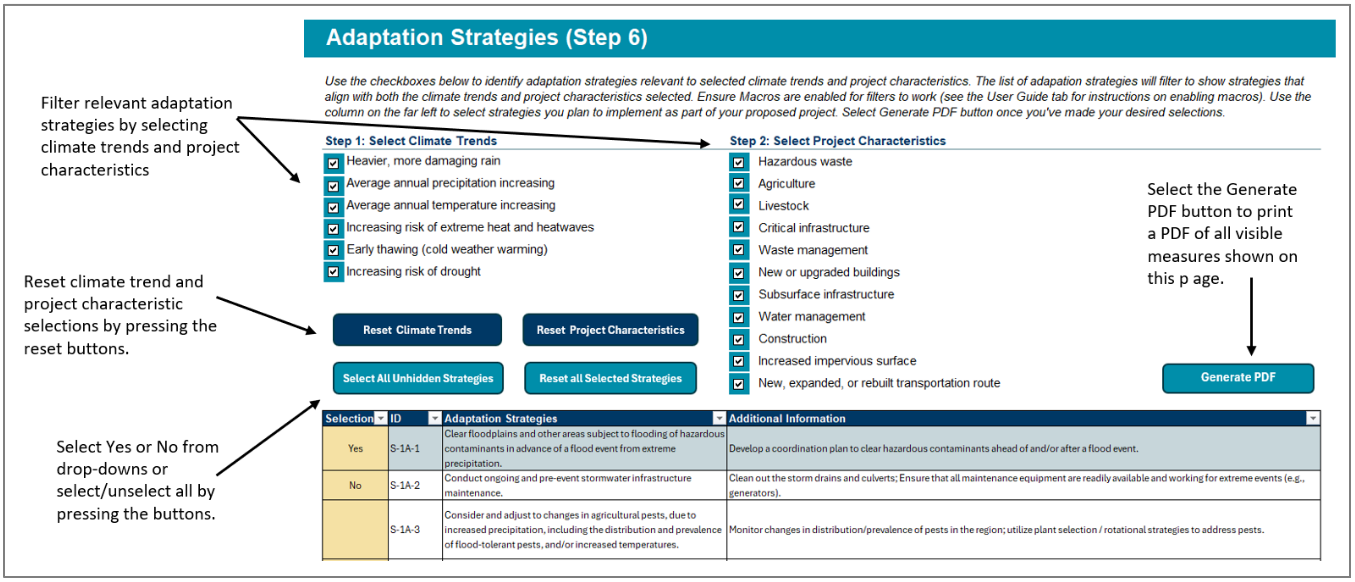


Select	Emissions Source	Phase	ID	Measure Title	Measure Description
	Material inputs	Construction	M-1A-01	Use Sustainable Building Materials	Ensure sustainable building materials comprise at least 20% of total construction materials by volume weight. Sustainable building materials have a less carbon-intensive production process compared to their non-sustainable counterparts. This strategy could include the use of Environmental Product Declarations in bid decisions to ensure the most sustainable materials are procured. This strategy is general to any building material. See 1A-2 through 1A-6 for measures specific to wood, pavement, and cement.
Yes	Material inputs	Construction	M-1A-02	Source Wood Materials from Urban Wood Re-Use Program	Source wood materials from urban wood re-use programs. In areas where removed trees are sent to landfills, they decompose and contribute to methane emissions. Wood re-use programs extend a tree’s lifetime by converting it into a range of products and prolonging the sequestration benefit. Re-uses range from logs, lumber, woodchips, mulch, compost, biochar, animal fuel, paper products, engineered wood, furniture, and cellulosic ethanol.
	Material inputs	Construction	M-1A-03	Sustainable Pavements	Use lower-impact materials specially designed for roadway surfaces without compromising the pavement’s ability to meet its engineering purposes. For example, warm-mix asphalt (WMA) production methods use temperatures that are 30 to 120 degrees Fahrenheit lower than those of traditional hot-mix asphalt. Because less energy is needed to heat the asphalt mix, less fuel is needed to produce WMA. Fuel consumption during WMA manufacturing is typically reduced by 20%. Sustainable pavements can also result in extended pavement life thereby reducing the need for energy-intensive maintenance.
	Material inputs	Construction	M-1A-04	Purchase Cement from Manufacturers using Low-Carbon Mix Design for Calcination	Purchase cement from manufactures that use low-carbon mix design. Using a low-carbon mix design in addition to renewable power sources and carbon capture can significantly reduce emissions from calcination. The seven most impactful low-carbon mix alternatives, listed from smallest to largest carbon footprint, are 1) granulated blast furnace slag; 2) limestone calcined clay cement; 3) fly ash; 4) Portland limestone cement; 5) biochar; 6) early-stage carbon curing; and 7) recycled concrete aggregate.
	Material inputs	Construction	M-1A-05	Purchase Cement from Efficient Cement Manufacturers	Purchase cement from manufacturers that have implemented measures to improve their production efficiency. Efficiency measures for cement manufacturing can reduce the demand for fuel by addressing the production process itself (such as switching from inefficient wet kilns to dry ones) or through technical and mechanical improvements (such as preventive maintenance to repair kiln leaks).
	Material inputs	Construction	M-1A-06	Purchase Cement from Manufacturers Using Alternative Fuels	Purchase cement from manufacturers that use alternative fuels in their production method. Indirect emissions from burning fossil fuels to heat the kiln can be reduced by switching to alternative fuels, including natural gas, biomass, and waste-derived fuels such as tires, sewage sludge, and municipal solid wastes.
	Material inputs	Construction	M-1A-07	Require Environmentally Responsible Purchasing	Implement an environmentally responsible purchasing plan. Examples of environmentally responsible purchases include but are not limited to: purchasing products made from recycled materials or with sustainable packaging; purchasing post-consumer recycled paper, paper towels, and stationery; purchasing and stocking communal kitchens with reusable dishes and utensils; choosing sustainable cleaning supplies; purchasing products from restaurants, farms, or ranches that source materials or goods from locations that use soil conservation practices; and leasing equipment from manufacturers who will recycle the components at their end of life.

Adaptation Tab

The Adaptation tab identifies adaptation strategies that can be applied by project developers to adapt to changing climate conditions. A unique identifier (e.g., S-1A-1) is assigned to each identified adaptation strategy in the calculator. The strategies are mapped to a defined list of climate trends and project characteristics. Strategies may map to more than climate trend and/or project characteristic. Users can filter relevant adaptation strategies by selecting or unselecting relevant climate trends and project characteristics in the check boxes under Steps 1 and 2. The table automatically filters based on these selections. Users can then use the drop-down menu under the Select column to choose the strategies they intend to implement as part of their project. Users can also select the ‘Select All Unhidden Strategies’ button to select “Yes” for all visible strategies. Rows are shaded gray when a strategy is selected. The ‘Reset all Selected Strategies’ button can be used to remove all selections from the first column. The ‘Reset Climate Trends’ and ‘Reset Project Characteristics’ buttons may also be used to select all climate trends and project characteristics in the check boxes under Steps 1 and 2. The ‘Generate PDF’ button may be selected to print a PDF of all visible strategies. Figure D-15 highlights the features of the adaptation tab.

Figure D-15. Example Adaptation Strategies



Appendix E. Calculator Maintenance Guide

Many of the data sources that the calculator relies on to inform assumptions are regularly updated to reflect the best and most recently available information. To ensure assumptions in the calculator reflect changing and evolving trends, it is recommended that the calculator is reviewed and updated annually. At a minimum, the sources listed in Table E-1 should be reviewed and the latest available data incorporated into the calculator.

Table E-1. Sources to Review Annually for Potential Updates

Source	Impacted Assumptions
Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET)	Material inputs; Employee commuting; Construction equipment; Electricity; Building energy consumption, Coal production, Natural gas and oil products; Industrial processes
Embodied Carbon in Construction Calculator (EC3)	Material inputs; Industrial processes
Emissions & Generation Resource Integrated Database (eGRID)	Electricity emission factors
EPA GHG Emission Factor Hub	All except land use change
EPA Greenhouse Gas Equivalencies Calculator	Emissions equivalencies
EPA State Inventory Tool (SIT)	Treatment of wastewater on-site
EPA Local Greenhouse Gas Inventory Tool	Employee commuting
EIA Residential Energy Consumption Survey (RECS)	Building energy consumption
EIA Commercial Buildings Energy Consumption Survey (CBECS)	Building energy consumption
EIA Manufacturing Energy Consumption Survey (MECS)	Building energy consumption
Minnesota Infrastructure Carbon Estimator (MICE)	On-road vehicles
U.S. Inventory of Greenhouse Gas Emissions	Employee commuting; Enteric fermentation; Manure management

Source data are documented in the calculator in white hardcoded cells in the white supporting data tabs. Data in these tabs are used to derive the assumptions that are used in the calculations. If source data are updated, update the hardcoded cells in the white tabs. Trace dependents when updating data to ensure formulas flow through correctly and there are no impacts on calculator functionality. Adhere to best practices by documenting updates made by noting the source below data tables and updating the version number and date of the calculator. A revision history table may also be incorporated into the calculator to track changes over time.

TIP: Adding new rows or categories to tables in the calculator could create errors with linking, formulas, or macros. Trace formulas and check macros before adding new information into the calculator.