MINNESOTA
ENVIRONMENTAL QUALITY BOARD

# Revised Environmental Assessment Worksheet (EAW) Guidance

Developing a carbon footprint and incorporating climate adaptation and resilience

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# Section 1 – Developing a carbon footprint

In 2007, the Minnesota Legislature passed into law the Next Generation Energy Act (Minn. Stat. § 216H) that requires the tracking of specific greenhouse gas emissions (GHG). The statute also includes Statewide GHG emission reduction goals, from a 2005 baseline.

In order to support Minnesotans in their efforts to mitigate the impacts of climate change, and to adapt to changes already occurring, it is important that environmental documents required by the Minnesota Environmental Policy Act (MEPA) include usable information about potential effects of a proposed project on climate change.

Estimation of GHG emissions is useful to the public and decision makers to understand whether proposed projects are contributing to, or detracting from, achieving progress in meeting state and local GHG reduction goals as well as providing important information needed to effectively mitigate climate change.

The purpose of this guidance is to help project proposers and responsible governmental units (RGU) develop a carbon footprint in response to item 18 of the revised Environmental Assessment Worksheet (EAW) Form. This guidance supports an RGU as they develop the required climate related information on the EAW but does not limit the use of other reliable and relevant guidance for quantifying and assessing GHG emissions. An RGU has discretion for identifying what information is needed and how much information is required to respond to item 18 on the EAW Form; based on the nature and location of the project.

## What is a carbon footprint?

A carbon footprint includes greenhouse gas emissions from fuel directly, such as by providing heat to a building or fuel in a car. It also includes greenhouse gases that come from producing the goods or services, including emissions from power plants that make electricity, factories that make products, and landfills. At a minimum, a proposed project's carbon footprint includes, but is not limited to, identification and assessment of:

- Sources of GHG emissions associated with the proposed project
- Types of GHGs emitted
- Amount of GHG emissions from those sources
- Reduction of GHG emissions from planned mitigation

# Steps to assemble a carbon footprint

## Step 1: Identify sources of GHG emissions

In the carbon footprint specific to item 18 of the EAW Form, GHG emission sources include all project sources of GHGs by source type and operational and construction phases. Emissions are categorized as either direct or indirect. Direct emissions are emissions released directly from properties owned or under the control of the project proposer (Scope 1). This includes, for example, the use of mobile equipment during construction. Indirect emissions are known as Scope 2 or 3 emissions. Scope 2 emissions are emissions associated with the offsite generation of purchased electricity and/or steam. For the purposes of responding to item 18 of the EAW Form, Scope 3 emissions are from the offsite provision of waste management services, including land disposal (landfilling), recycling, and solid waste composting.

The USEPA annually prepares a detailed analysis of GHG emissions by source type. A list of these sources is shown in Table 1, by greenhouse gas emitted. GHG sources that are known in Minnesota are assessed biennially by the Minnesota Pollution Control Agency (MPCA). Sources that depend on specific mineral deposits not found in Minnesota have been excluded from the list. Environmental Review documents should identify and describe any of the GHG sources shown in Table 1 that are potentially associated with, and may result in, GHG emissions from the proposed project.

Table 1. Sources of Greenhouse Gases

| Source Type | Gas |
|---|---|
| Stationary fossil fuel combustion | $CO_2$, $CH_4$, $N_2O$ |
| Mobile source fossil fuel combustion | $CO_2$, $CH_4$, $N_2O$ |
| Biomass and biofuels fuels combustion | $CH_4$, $N_2O$ |
| Purchased electricity or steam (emitted offsite at generation) | $CO_2$, $CH_4$, $N_2O$ |
| Nonfuel use of fossil fuels[a] | $CO_2$ |
| Natural gas transmission/distribution | $CH_4$, $CO_2$, $N_2O$ |
| Petroleum refining | $CO_2$, $CH_4$ |
| Electricity transmission & distribution | $SF_6$ |
| Ammonia, nitric acid, caprolactam, adipic acid manufacture | $CO_2$, $N_2O$ |
| Cement, lime, glass manufacture | $CO_2$ |
| Copper/nickel mining/processing | $CO_2$ |
| Fire suppression | PFCs |

[a] Lubricants, waxes

| Source Type | Gas |
|---|---|
| Industrial solvent use (electronics, precision cleaning) | PFCs, HFCs |
| Petrochemicals, other chemical manufacture[b] | $CO_2$, $CH_4$ |
| Metallurgy | $CO_2$ |
| Polyurethane, polystyrene, phenolic, polyolefin foam manufacture | HFC-134a, HFC-152a, HFC-245fa |
| Refrigeration and cooling | HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a |
| Secondary lead production | $CO_2$ |
| Semiconductor manufacture | PFCs, $SF_6$, HFC-134a |
| Silicon carbon consumption as abrasives in manufacturing | $CO_2$ |
| Taconite and DRI pellet production, steel production | $CO_2$, $CH_4$ |
| Titanium dioxide production | $CO_2$ |
| Waste incineration | $CO_2$[c], $CH_4$, $N_2O$ |
| Solid waste landfilling | $CH_4$ |
| Solid waste composting | $N_2O$, $CH_4$ |
| Biosolids land application | $N_2O$ |
| Wastewater treatment | $N_2O$, $CH_4$ |
| Effluent nitrogen discharges | $N_2O$ |
| Feedlot manure storage/land application | $CH_4$, $N_2O$ |
| Feedlot livestock | $CH_4$ |
| Soil nutrient management | $N_2O$, $CO_2$ |
| Wetland drainage | $CO_2$, $CH_4$, $N_2O$ |
| Grassland conversion to cultivation or pasture | $CO_2$, $CH_4$ |
| Forest harvesting | $CO_2$, $N_2O$ |
| Atmospheric GHG Removal | Gas |
| Solid waste landfilling | biogenic $CO_2$ |
| Wood products manufacture | biogenic $CO_2$ |

[b] Adhesives, binders, chemical intermediates, fillers, humectants, paint and coating additives, reagent catalysts, resins, sealants, solvents, surface treatment agents

[c] $CO_2$ from combustion of petrochemical part of solid and hazardous waste

## Step 2: Identify types of GHGs emitted

The GHGs most commonly included in project GHG reporting are:

- carbon dioxide ($CO_2$)
- nitrous oxide ($N_2O$)
- methane ($CH_4$)
- sulfur hexafluoride ($SF_6$)
- two families of gases known as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)

In response to item 18 of the EAW Form for a project's carbon footprint, we recommend that typical reporting be limited to emission of these gases. State-level reporting of GHG emissions to the Minnesota Legislature under the Next Generation Energy Act is limited to this set of gases. Other GHGs and their precursors, not commonly reported in GHG inventories, but may be relevant to consider, include:

- chlorofluorocarbons (CFCs)
- hydrchlorofluorocarbons (HCFCs)
- hydrofluoroethers (HFEs)
- sulfuryl fluoride ($SO_2F_2$)
- ozone
- various idiocarbons and chlorocarbons

For more information on these GHG gases, see Section 2: Sources and Sinks of Greenhouse Gases in the MPCA's Greenhouse Gas Emissions in Minnesota: 1970-2006 report.

## Step 3: How to report GHG emissions

GHG emissions should be reported in $CO_2$-equivalent short tons (English units). GHG emissions are converted to $CO_2$-equivalent units by multiplying nominal estimated emissions, in short tons, by its global warming potential (GWP). A GWP is a factor that converts emissions of any one GHG to its equivalent in tons of emitted $CO_2$.

It is conventional in emissions reporting, whether at the national, state or facility level, to use the 2007 version of the GWPs developed by the Intergovernmental Panel on Climate Change. These are shown in Table 2 by gas.

Table 2. Greenhouse Gas Global Warming Potentials[d]

| Greenhouse Gas | Chemical Formula | Global Warming Potential |
|---|---|---|
| Carbon dioxide | $CO_2$ | 1 |
| Methane | $CH_4$ | 25 |
| Nitrous oxide | $N_2O$ | 298 |
| Sulfur hexafluoride | $SF_6$ | 22,800 |
| Nitrogen trifluoride | $NF_3$ | 17,200 |
| Hydrofluorocarbons | | |
| HFC-23 | $CHF_3$ | 14,800 |
| HFC-32 | $CH_2F_2$ | 675 |
| HFC-125 | $C_2HF_5$ | 3,500 |
| HFC-134a | $CH_2FCF_3$ | 1,430 |
| HFC-143a | $C_2H_3F_3$ | 4,470 |
| HFC-152a | $CH_3CHF_2$ | 124 |
| HFC-227ea | $C_3HF_7$ | 3,220 |
| HFC-236fa | $C_3H_2F_6$ | 9,810 |
| HFC-245fa | $C_3H_3F_5$ | 1,030 |
| HFC-365mfc | $C_4H_5F_5$ | 794 |
| HFC-4310mee | $CF_3CFHCFHCF_2CF_3$ | 1,640 |
| Perfluorocarbons | | |
| PFC-14 (Perfluoromethane) | $CF_4$ | 7,390 |
| PFC-116 (Perfluoroethane) | $C_2F_6$ | 12,200 |
| PFC-218 (Perfluoropropane) | $C_3F_8$ | 8,830 |
| PFC-31-10 (Perfluorobutane) | $C_4F_{10}$ | 8,860 |
| PFC-51-14 (Perfluorohexane, FC-72) | $C_6F_{14}$ | 9,300 |

[d] Source: EPA, Inventory of US Sources and Sinks of Greenhouse Gases, Table ES-1, Federal Register, CFR part 98, Mandatory Greenhouse Gas Reporting, Table A-1, with additions

Projected GHG emissions should be developed on an average annual basis and include the proposer's best estimate of average annual emissions over the proposed life / design service life of the project. As noted above, the estimates should include emissions from the operating phase of the project plus emissions from project construction. To include construction emissions in the footprint, emissions should be annualized by dividing total construction GHG releases to the atmosphere by project life.

In the project GHG accounting, the project proposer should report GHG emissions by source type and project phase (i.e., construction, operations), and also bring emissions to a project total. We recommend that emissions be reported using the reporting framework and categories shown in Table 3 which additionally breaks out emissions from type and subtype of emission and gas.

Table 3. Emission Categories for Project Carbon Footprint

| Category | Scope | Project phase | Type of emission | Emissions Sub-type | Emitant |
|---|---|---|---|---|---|
| Direct emissions | Scope 1-emissions | Operations | combustion | stationary; area; mobile | $CO_2$,[e] $N_2O$, $CH_4$ |
| | Scope 1-emissions | Operations | non-combustion process[f] | stationary[g] | $CO_2$,[e] $CH_4$, $N_2O$, HFCs, PFCs, other fully fluorinated GHGs |
| | Scope 1-emissions | Construction | combustion | mobile | $CO_2$,[e] $N_2O$, $CH_4$ |
| | Scope 1-emissions | Construction | land-use | area | $CO_2$,[e] $N_2O$, $CH_4$ |
| Indirect Emissions | Scope 2-emissions | Operations | off-site electricity/steam production | grid-based | $CO_2$, $CH_4$, $N_2O$[e] |
| | Scope 3-emissions | Operations | off-site waste management | stationary; area | $CO_2$,[e] $CH_4$ |
| Atmospheric Removals of GHGs | Scope 1-sinks | Construction/ operations | land-use | area | $CO_2$ removals to terrestrial storage |

*Total Emissions plus Sinks = Direct Emissions + Indirect Emissions + Sinks*

$CO_2$ removals from the atmosphere through afforestation and other forms of terrestrial carbon sequestration may be included in the carbon footprint, though this is not required. Carbon removals from the atmosphere act to offset emissions of $CO_2$ to the atmosphere. Given the atmosphere's continued retention of $CO_2$ after

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[e] Fossil $CO_2$; see discussion in subsection 'Treatment of Emitted Biomass $CO_2$' below

[f] Noncombustion industrial process emissions are often chemical in nature, but can involve evaporative or other noncombustion processes

[g] Process emissions usually are from stationary sources. If they derive from area or mobile sources, they should be reported as area or mobile noncombustion process emissions

emission, to fully offset a ton of emitted $CO_2$, carbon removed from the atmosphere through terrestrial sequestration must remain in terrestrial storage for about 50 years. For projects with shorter lifetimes, terrestrial carbon sequestration may only partially offset $CO_2$ emissions from combustion.

### *Treatment of Emitted Biomass $CO_2$*

If resulting from permanent land-use change, biogenic $CO_2$ emissions should be included in the proposed facility's carbon footprint. Permanent land-use changes may include:

- forestland converted to cropland, pastureland, or urban uses
- grassland converted to cropland, pastureland, or urban uses
- all wetlands conversions

Beyond emissions from permanent land use change, other emissions of $CO_2$ from biomass sources or ecosystem or animal respiration generally are not included in project accounting. We recommend that this convention be followed. Unless released to the atmosphere as a result of permanent land use change, $CO_2$ emitted to the atmosphere from biomass combustion or ecosystem or animal respiration, is often rapidly removed from the atmosphere through subsequent photosynthesis and returned to storage in living biomass and soils. Table 4 includes a list of common biogenic sources of $CO_2$ for which carbon neutrality may be assumed in carbon footprint development.

Table 4. Common Biomass $CO_2$ Sources[h]

| Type | State | Source |
|---|---|---|
| Common Biomass Fuels | Solid fuels | sawdust, hogged bark, wastewood, other papermill and sawmill residuals, biogenic part of mixed municipal solid waste (MMSW) or refuse-derived fuel (RDF),[i] paper mill sludge, wastewater treatment sludge, urban tree removal wastes, residential firewood, dedicated whole tree or perennial grasses for bioenergy |
| Common Biomass Fuels | Liquid fuels | ethanol, biodiesel |
| Common Biomass Fuels | Gaseous fuels | landfill gas (LFG), digester gas, biomethane for pipeline uses |
| Other common Biogenic Sources of $CO_2$ Emissions | | MMSW composting, garden/yard waste composting, municipal wastewater and industrial treatment, biosolids land application, industrial grain fermentation, manure storage, grain storage, prescribed burning of grassland/brushland, residential recreational burning, cropland cultivation, forest harvest residuals (slash) |

[h] This listing should not be considered to be exhaustive, but rather broadly indicative of biomass fuels and biogenic $CO_2$ sources that, in carbon footprint development, should be treated as carbon neutral

[i] As noted in Table 1, emissions of fossil $CO_2$ from the combustion of the fossil fuel (petrochemical) part of MMSW and RDF should be included as an integral part of the carbon footprint. Emissions of $CH_4$ and $N_2O$ from waste combustion also should be included.

Table 5 summarizes the recommended reporting requirements under this guidance. They do not include requirements related to documentation of data sources, assumptions made, or methods used. At its discretion, the RGU may wish to establish requirements for documentation of information sources that are used in carbon footprint development.

### Table 5. Summary of Recommended Reporting Elements for Carbon Footprint

| Reporting element | Detail |
|---|---|
| Units to report in: | $CO_2$-equivalent ($CO_2$-e) short tons |
| Greenhouse gas (GHG) emissions to report: | $CO_2$, $CH_4$, $N_2O$, SF6, HFCs, PFCs (see Table 2 above) |
| How to calculate $CO_2$-e tons: | nominal tons * global warming potential (GWP) |
| Version of IPCC gwps to use in calculating $CO_2$-e emissions: | 2007 Fourth IPCC Assessment version |
| What to report: | Total project emissions and emissions disaggregated by source and project phase and totaled |
| Averaging period for emissions estimate: | One-year, e.g., average annual emissions |
| Project phases over which to report emissions: | Operating phase, construction phase |
| How to include construction emissions in annual totals: | Annualize by spreading construction emissions over project projected life or design service life |
| Types of emissions to report | Stationary, mobile, and area sources, including land-use |
| Specific sources to report | See Table 1 above |
| Project boundaries for emissions estimation: | • All sources within project fence-line or under contractual control of project proposer<br>• Emissions from purchased electricity/steam<br>• Off-site emissions from purchased waste disposal services |
| How to treat emissions of $CO_2$ from wood burning, and the combustion of other solid, liquid or gaseous biofuels: | Exclude all $CO_2$ emissions from biomass sources except those from permanent forest clearing, or wetlands or grasslands conversion to other uses |
| Treatment of sequestration removals of atmospheric $CO_2$: | Recommended but optional |

## Step 4: How to quantify GHGs emitted

Simplified methods to quantify GHG emissions from a wide variety of sources have been developed by the Intergovernmental Panel on Climate Change (IPCC).[j] These are in addition to more demanding, higher level methods also developed by the IPCC. The simplified IPCC methods usually take the form of linear equations involving emission factors and activity factors. EPA's Center for Corporate Climate Leadership (CCCL) provides easy-to-use default emission factors for creating GHG inventories on the GHG Emission Factors Hub.

Simplified example formulas and references are listed below for each scope and emission type outlined in Table 3 above.

### *Scope 1 combustion emissions*

For stationary combustion sources, emissions of $CO_2$ from fossil fuel production are typically calculated using the equation:

*tons $CO_2$ = fuel use in physical units * MMBtu per physical fuel unit * tons of $CO_2$/MMbtu of fuel use*

while emissions of $N_2O$ from fuel of stationary sources use would be calculated similarly, albeit with the addition of GWP as an additional term, so:

*tons $CO_2$-e = fuel use in physical units * MMBtu per physical fuel unit * tons of $N_2O$/MMBtu of fuel use * GWP*

For mobile combustion sources, emissions of $CO_2$ from fossil fuel combustion are calculated using the equation:

*tons $CO_2$ = fuel use in physical units *$CO_2$ Emission Factor (kg $CO_2$/physical unit of fuel use) * Conversion of kg to tons*

while for $CH_4$ and $N_2O$, the equation is:

*tons $CO_2$-e = Vehicle Miles Traveled * $CH_4$/$N_2O$ Emission Factor (g/mile) * Conversion of g to tons * GWP*

### *Scope 1 non-combustion emissions*

Scope 1 non-combustion emissions may vary depending on the project type. Table 6, below, provides some pre-existing tools that may be helpful in calculating emissions from non-combustion sources. Furthermore, Attachment 2 provides references to other methodological sources that can be used for calculating emissions from non-combustion sources.

### *Scope 1 land use emissions*

Simplified formulas used for emissions from land use changes use carbon flux estimates from Chapter 6: Land Use, Land-Use Change, and Forestry in the EPA's *Inventory of Sources and Sinks of Greenhouse Gases.*[k] The simplified formula is:

*tons $CO_2$-e = Emission Factor Based on Land Type Carbon Flux (tons $CO_2$e/area) * area of land use change*

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[j] Intergovernmental Panel on Climate Change (IPCC), 2006 IPCC Guidelines for National Greenhouse Gas Inventories; IPCC, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands; IPCC, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[k] EPA's Inventory of Sources and Sinks of Greenhouse Gases

where the emission factor is calculated as:

*Emission Factor Based on Land Type Carbon Flux (tons $CO_2e$/area) = net $CO_2$ flux from land conversion* [k] ** total area of land use change in U.S.*[l]

In including terrestrial carbon sequestration (TCS) in project accounting we recommend that the offsets value of TCS for projects with lifetimes of 50 years or more be assessed at full value, while projects with lifetimes of 20 years and 25 to 49 years be assessed at 40% and 75% offsets values,[m] respectively. In practice, offsets value may be calculated by multiplying total tons of $CO_2$ removed from the atmosphere by 1, 0.75 or 0.4, depending on project lifetime.

### *Scope 2 off-site electricity/steam/heat emissions*

The simplified formula for calculating GHG emissions from off-site purchased electricity is:

*tons $CO_2$-e = purchased electricity (MWh) * Emission Factor * GWP*

Regional emission factors published by the EPA's Emission & Generation Resource Integrated Database (eGRID) for off-site electrical generation can be found in Table 6 of EPA's CCCL GHG Emission Factor Hub.[n]

For off-site purchased steam and heat, the formula is:

*tons $CO_2$-e = purchased steam/heat (MMBtu) * Emission Factor * GWP*

Emission Factors can be found in Table 7 of EPA's CCCL GHG Emission Factor Hub.[n]

### *Scope 3 off-site waste management emissions*

Similar to the equations used for Scope 2, the simplified formula for calculating GHG emissions from waste generation is:

*tons $CO_2$-e = mass of waste material (tons) * Emission Factor * GWP*

Emission Factors can be found in Table 9 of EPA's CCCL GHG Emission Factor Hub.[n]



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[l] Section 6.1. Ibid.

[m] 40% offsets valuation is the valuation at 20-years of continuous storage, while 75% is the valuation at 40 years of continuous storage. For the schedule of atmospheric $CO_2$ retention upon emission of $CO_2$ from combustion, see: F. Joos, et al., "Carbon Dioxide and climate Impulse Response Functions for the Computation of Greenhouse Gas Metrics: A Multi-Model Analysis," Atmospheric Chemistry and Physics 13 (2013): 2,793-2,825. At 100-years, the usual integration period for analysis, for a one-ton emission of $CO_2$, the atmosphere retains roughly 50 ton-years of emissions. For comparison, one ton of $CO_2$ continuously stored in soils and biomass for 50 years would result in similar degree of offsetting storage, about 50 ton-years of storage. At 20 and 40 years, $CO_2$ storage in soils and biomass resulting from one ton stored, assuming no leakage, would be would be 38 and 76 ton-years, respectively. Offsets value is derived by dividing, for one ton of $CO_2$ storage, total tons-years of terrestrial storage by total 100-year ton-years of atmospheric retention resulting from a 1 ton emission of $CO_2$.

[n] EPA's CCCL GHG Emission Factor Hub.

As noted, more highly developed methods exist of greater complexity. A more complete list of methodological sources that might be consulted is included in Attachment 2. For specific sources, these may provide an additional avenue of approach to the estimation of emissions.

A number of pre-existing tools also are available. These may prove helpful in calculating emissions from one or more GHG emission sources. Table 6 includes a list of some of the more helpful tools now available. These may be used by project proposers to estimate emissions from individual or multiple GHG sources.

### Table 6. Pre-existing Tools for Estimating GHG Emissions from Different Sources

| Tool Name | GHG sources covered |
|---|---|
| SGEC Tool | Stationary source combustion, mobile source combustion, biomass and biofuels combustion, refrigerant and cooling, fire suppression, electricity and steam purchases, off-site solid waste management |
| MPCA feedlot tool | Feedlot livestock, manure storage and treatment, manure land application |
| Minnesota Infrastructure Carbon Estimator (MICE) | Highway mobile combustion sources, highway construction |
| Federal HFC Emissions Accounting Tool | Refrigeration and space cooling |
| Clear Path: Local Government Action Climate Tool | Stationary source combustion, mobile source combustion, electricity purchases, solid waste management, biosolids land application, natural gas distribution and services |
| Cool Farm Tool | On-farm mobile source combustion, cropland nutrient management, livestock, manure storage and treatment, land use change |
| COMET-Planner | Conservation and nutrient management practices in crop production and grazing |
| EPA Waste Reduction Model (WARM) | Solid waste recycling, composting, incineration and landfilling |

In carbon footprint development, project proposers should provide sufficient background technical information to enable the reader to replicate the emissions calculations. Once calculated for each project GHG source, usually in nominal tons of emissions, emissions should be converted to $CO_2$-equivalent short tons and aggregated to a project total. For tools that estimate emissions in metric units, a conversion factor of 1.102 can be used to convert from metric tons to short tons.

## Step 5: How to identify and assess mitigation

Environmental review documents should include complete descriptions, quantification and a detailed assessment of the planned mitigation activity. Included below, are some commonly used measures to mitigate GHG emissions at the project-level.

*Common Mitigation Measures for Greenhouse Gas Reduction*

- Energy end-use efficient appliances and equipment
- Energy efficient lighting
- Energy efficient building shells
- Waste heat utilization
- Petroleum-to-natural gas and coal-to-natural gas fuel substitution
- Alternative mobile fuels
- Biogas production and use
- Enhanced use of biomass-based waste fuels
- Grid-based wind and solar power purchases
- On-site solar PV installations
- Off-site community solar gardens
- Electric vehicles
- HFC substitution to lower or zero GWP-refrigerants in cooling and refrigeration equipment
- HFC substitution in other applications
- Enhanced HFC recycling in cooling and refrigerant equipment
- Enhanced materials recycling
- Improved materials and nutrient use efficiency
- On-site terrestrial biogenic carbon sequestration
- Purchased off-site sequestration credits
- Best practices in cropland and other land-use management
- Other run-off control for nutrients and sediments
- Wetland mitigation

As in the case of the project carbon footprint, in quantifying potential emission reductions or emission offsets, project proposers should provide sufficient background technical information to enable the reader to replicate the calculations.

# Section 2 – Climate adaptation and resilience

*How climate change may influence environmental effects and potential adaptations to reduce risk and increase resilience*

The purpose of this guidance is to help project proposers and responsible governmental units (RGU) respond to the specific climate related questions of the EAW Form. This guidance supports the development of climate-related information but does not limit the use of other reliable and relevant guidance for discussing how current Minnesota climate trends and anticipated climate change may interact with a project and its development. This document provides item-by-item guidance for responding to proposed questions on the EAW form related to how climate change may influence environmental effects and potential adaptations to reduce risk and increase resilience.

## EAW Item 7a: Climate Trends

Establish a description of climate change specific to the most representative geographic unit or location of the project using readily available information. Look at historical climate trends data for conditions at the start of the project, and projected (future) climate data for conditions during the life of the project.

The primary existing and projected (future) climate change trends in Minnesota to explore using location-specific data include:

- Warmer
- Wetter
- Cold weather warming
- More damaging rains

Additional projected (future) climate change trends in Minnesota to explore using location-specific data include:

- Increasing risk of heat waves
- Increasing risk of drought

This description of current Minnesota climate trends and how climate change is anticipated to affect the general location of the project during the life of the project will be used in answering subsequent climate related questions in the EAW. The extent and scale of readily available information may vary depending on when the EAW is completed and the nature and location of the project. Provide references to the resources used to establish this description in EAW Item 5, and include any data or information gaps that are discovered.

The following Minnesota sources are recommended to help determine location-specific current climate trends and (future) climate projections. National sources with Minnesota-specific data / information also are provided to supplement available Minnesota sources:

- Minnesota Climate Trends website: Good overview of general climate trends in Minnesota. The Climate Trends map linked from the webpage above contains the same historical data – but not the projected (future) data – that is included in the Minnesota Climate Explorer map (next bullet).

- Minnesota Climate Explorer map: Use this map tool to identify current Minnesota climate trends (historical up to the present) and projected future conditions (2040-2059 and 2080-2099) in the general location of the project. Step 1: select the Historical or Projected (Future) tab in the gray bar at the top. Step 2: select a geographic unit (watershed, county, etc.) appropriate to where the project is located. Step 3: select a specific area or two adjacent areas. Step 4: select a climate variable (precipitation, temperature, etc.). Step 5: for the Historical tab select a time frame and what you want to view in the four corresponding fields; for the Projected (Future) tab select a portion of the year to analyze and what you want to view in the two corresponding fields. Additionally for the Historical tab be sure to scroll down to the "Additional Options" to toggle on "Show trend for these years" and pick whatever Start and End dates are desired for the trend line within the 1895 to current year timeframe. Step 6 in either tab: click PLOT DATA. Scroll down for results.

  Look at annual data, and also look at individual months relevant to the project (for example, related to construction schedules, operational issues, waste disposal needs, etc.).

  The Historical tab shows a trend line and actual data set. The Projected tab provides the mean value and error bar for each climate model included in the data set for that slice of time. The Model Mean (blue bar on the far left for each slice of time) shows the average of all the other models.
- Flood Factor: Identify flood potential by entering the zip code or the name of the city for the project location. Read the Summary, then click on Flood Risk Explorer (left menu bar). Move the map around to find the project site and then click the + sign to zoom in and see the site details. Above the map, select the year of projection (this year, in 15 years, in 30 years), then select a projected flood risk (for adaptation purposes look at results for 0.2% also called a "500-year storm" and 1% or "100-year storm"). Look at the map with each selection to see the potential depth of flooding projected for the site.

  Click on Environmental Changes (left menu bar), then click on Learn more about the environmental factors increasing flood risk. On the new page, scroll down to Extreme rain events are increasing, then select year of projection to see on the map the change in extreme rain events over time in Minnesota and the contiguous U.S. compared to the 1980-2010 average.

  For additional context, check out "The First National Flood Risk Assessment" report, especially page 78-80 for Minnesota-specific information on flood risk potential.
- Heat Vulnerability in Minnesota Tool: Select the study area (Minnesota, HSEM Regions, Counties), then select the spatial resolution (Counties, Cities & Townships, Block Groups), then select variables for Sensitivity and for Exposure. Zoom in on the maps to locate your project site. See more resources about specific climate change in Minnesota on the Climate & Health website.
- Climate Vulnerability Assessment Regional Risks and Opportunities for the Twin Cities Region: This website includes tools, resources and mitigation actions for regional climate hazards including Extreme Heat (Story Map and Extreme Heat Map Tool) and Localized Flooding (Story Map and Localized Flood Map Screening Tool). This data is a more localized comprehensive resource for the seven-county region (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties) governed under the Metropolitan Council.
- Most recent National Climate Assessment (NCA4 or more recent), especially Chapter 21: Midwest or more current version if available: See also NCA4 Chapter 28: Reducing risks through adaptation actions. Maps for observed and projected changes in temperature and precipitation are available in Chapters 6 and 7 of NCA4.

- National Oceanic and Atmospheric Administration (NOAA) Climate.gov: A source of timely and authoritative scientific data and information about climate.

It is important to note that readily available data may or may not (depending on project location) include projections for future years showing the type of intense precipitation events Minnesota currently experiences, and which are anticipated to increase.

In responding to this item, the following are helpful explanations of terms:

- General location of the project: the specific project location plus its environs, including the nearby and encompassing local governmental jurisdictions, and the major watershed it affects.
- Life of the project: (options relevant to different project types)
  - Proposed life: the period of time the project is proposed to last, such as for mining projects.
  - Design service life: the period of use as intended by the designer after which it may need to be replaced, but before this period has elapsed should remain fit for purpose, such as for projects that are primarily buildings and structures.
  - For project definition and interpretation consistency, consider using the same project life assumptions as the greenhouse gas emissions calculations.
- Default: the anticipated impact of climate change on the proposed project over the next 30 years, such as for conservation or restoration projects that may continue indefinitely into the future if properly maintained.
- Vulnerability: a function of exposure to climate hazards and associated impacts, sensitivity to these hazards, and capacity of a system or community to adapt or cope with the adverse effects. A hazard has the potential to disrupt or damage a project or system.
- Risk: the probability of a climate hazard exploiting a vulnerability and the magnitude of associated impacts and consequences. Significant risks share both a likelihood of occurrence and degree of impact to the project or system if they occur.

## EAW Item 7b: Project Interaction with Climate Trends

Using the description of the climate trends in the project vicinity (Item 7a), to the best extent practicable; describe how the project's proposed activities will interact with those climate trends. Future climate trends are uncertain. Identify the risk of long-term impacts climate trends might pose to the proposed activities throughout the project life, considering the range of possible future conditions. Identify climate change hazards, threats and the proposed activities' vulnerabilities to them. Identify the risk of key project assumptions and design parameters becoming outdated or insufficiently defined if future climate observations align with impactful trends and projections.

### Project Design

Aspects or features to consider that may amplify or interact with how climate change is anticipated to affect the design of the project include, but are not limited to:

- Changes to land cover, such as impervious surfaces:

  - During intense rainfall events, increases in the amount of impervious surface on a site (from table in Q7) may result in more localized flooding in the immediate area of the project, in addition to other stormwater effects, especially when vegetative buffers are absent.
  - Dark roofing materials absorb heat during the day and radiate it at night, which increases the urban heat island (UHI) effect and amplifies the warming temperatures of climate change
  - Impermeable pavement (concrete or asphalt) without the benefit of vegetative cover absorbs heat during the day and radiates it at night, increasing surface temperatures and UHI effect in the area. Information about the UHI effect including definitions, risks and strategies is available on EPA's Heat Island Effect webpage. In-depth information about mitigation strategies using green infrastructure practices is available on EPA's Heat Island Consumption webpage. Specifically for the Twin Cities metropolitan area, see Metropolitan Council's Keeping Our Cool: Extreme Heat in the Twin Cities Region, including an Extreme Heat Map Tool.
- Construction materials, site design, etc.

## Land use

Open space is any natural space, public or private, that is used primarily for passive recreation (active recreation facilities are parks and recreational facilities), animal habitat and/or for maintaining ecological services and/or rural character, or for other uses. Open space may or may not be protected by federal, state, or local entities. Examples could include woodlands, prairie, groundwater recharge areas, or greenways.

Aspects or features to consider that may amplify or interact with how climate change is anticipated to affect land use. Examples include, but are not limited to:

- Tree loss eliminates many climate resilience benefits, leading to more intense stormwater runoff, increased urban heat island effect and loss of shade for protection during extreme heat, potential reduction in air quality, and more. Information about benefit-cost considerations of tree canopy in the urban landscape is available in the EPA's "Reducing Urban Heat Islands: Compendium of Strategies".
- Increased heat and longer growing seasons can either increase or reduce crop production, causing producers to modify land use and cropland management to adapt. Longer growing season allows for additional pest and weed growth, requiring application of pesticides and herbicides, which may impact local plant and animal communities.
- Cropland and rangeland productivity is reduced by prolonged extreme flooding, topsoil loss, drought, or groundwater depletion.
- Prolonged groundwater rise can result in the expansion of wetlands, ponds, and lakes, resulting in habitat loss.
- The removal of wetlands and other low-lying areas eliminates the ability for the land to retain and absorb stormwater, leading to more intense stormwater runoff, nutrient loading, and more effects. See stormwater guidance below for related information.
- Extreme storm events erode topsoil, which results in decreased crop productivity and nutrients washed into natural waterbodies.
- Heat stress can kill vegetation, leaving soils open to erosion.
- Landslides can occur on steep slopes where soils are saturated.

- Increased freeze/thaw results in increased icing of roadways, trails, sidewalks, and parking lots, resulting in the need for increased salting. Chlorides degrade lake water quality and impact aquatic life. Chlorides also degrade soil and can kill landscape plantings.

Critical facilities are facilities necessary to a community's public health and safety, those that store or produce highly volatile, toxic or water-reactive materials, and those that house occupants that may be insufficiently mobile to avoid loss of life or injury. Examples of critical facilities include hospitals, correctional facilities, schools, daycare facilities, nursing homes, fire and police stations, wastewater treatment facilities, public electric utilities, water plants, fuel storage facilities, and waste handling and storage facilities.

Discuss the compatibility with land use, planning, and zoning as it relates primarily to development and the projected climate changes for the project location.

## Contamination/hazardous materials/wastes

Warmer, wetter weather with more frequent extreme rainfall events and localized flooding could pose operational concerns that which may result in either more frequent or more severe environmental effects. Examples include:

- More leaching from disposed wastes of contaminants into the groundwater.
- More erosion of exposed soil and other earthen materials.
- Increase in contact water volumes that may require collection and treatment.
- More erosion on the working face of waste storage or containment.
- More moisture added to the waste material or debris which will in turn increase methane gas production and add to greenhouse gasses.
- Lack of capacity for holding and managing the leachate, stormwater, and wastewater volume generated because the systems was designed based on smaller precipitation events.
- Increased stormwater sediments or solids that need proper disposal.
- Leachate and contact water require treatment, so increases in leachate provide additional potential for environmental effects on water quality; options for treatment may be affected by additional limitations on land application due to changing precipitation and temperature patterns, and on limitations at wastewater treatment plants due to treatment system capacity strained by heavy rain events.
- More extreme heat and humidity makes environmental effects such as odors more likely and may increase their severity.
- Increased freeze/thaw cycles and more "unseasonal" weather makes operational issues which may result in environmental effects – such as frost heave of cover materials – more likely and may increase the severity of the environmental effects.
- Floodwaters can mobilize contamination and transport pathogens and environmental contaminants that are dangerous to people and livestock.
- Decreased air quality due to temperature inversions, wildfires, and atmospheric reactions driven by heat. Poor air quality stresses people, livestock and wildlife.

Changes in Minnesota's climate include rainfall events of greater intensity and more localized flooding, more frequent freeze/thaw cycles, lack of snow cover, extreme heat, etc. may damage infrastructure and create situations that result in accidental spills and releases. Include in the spill prevention plan contingency plans for extreme rainfall events and localized flooding, excessive heat, repeated freeze/thaw, and other anticipated consequences of climate change as relevant.

## EAW Item 8: Cover types

Minnesota is facing wetter weather conditions, more intense precipitation events, and an increase in average temperatures due to climate change. The result will be an increase in stormwater runoff, especially in areas with more extreme land cover changes (e.g., changes from natural vegetated areas to from impervious surfaces like parking lots, roofs, and sidewalks. One adaptation tool is green infrastructure. Green infrastructure is an approach to manage wet weather impacts in a way that mimics, restores and maintains natural hydrology. The fundamental concept behind green infrastructure is to retain precipitation where it falls. Green infrastructure includes a wide array of practices that manage stormwater and reduce stormwater runoff, but also provide other benefits including carbon sequestration, wildlife habitat, recreation, and increased property values. Green infrastructure practices can reduce adverse impacts of climate change when designed, constructed and maintained properly.

To determine the acreage for the "green infrastructure" category, calculate the acreage of each green infrastructure practice to be installed for the project, based on the surface area (length multiplied by width) of the footprint for that practice (not the area that drains into the practice). Make sure not to double count any of the green infrastructure acreage in the "lawn/landscaping" category, nor in the "stormwater pond (wet sedimentation basin)" category, nor in the "impervious surface" category (for green roofs).

The practices included in the "green infrastructure" category are described below:

- **Constructed infiltration systems** – Examples of infiltration systems include, but are not limited to:
  - Raingardens use soil (typically engineered media or mixed soil) and native vegetation (including those that attract pollinators) to capture runoff and remove pollutants. Both the media and underlying soil typically have high infiltration rates that allow captured water to infiltrate. More information is available on the Minnesota Pollution Control Agency's: Green Infrastructure benefits of bioretention webpage.
  - Bioswales are vegetated channels used primarily to transport runoff and filter sediment from the runoff. Although their primary effect is on removing pollutants associated with sediment, they can be designed to infiltrate water. More information is available on the Minnesota Pollution Control Agency's Overview for filtration webpage.
- **Constructed tree trenches and tree boxes** – Tree trenches and tree boxes are engineered structural practices that behave like a raingarden. Water is captured and delivered to a storage area (engineered media), where the water can infiltrate and be taken up by trees. More information is available on the Minnesota Pollution Control Agency's Green Infrastructure benefits of tree trenches and tree boxes webpage
- **Constructed wetlands** - Stormwater wetlands differ from stormwater ponds (wet sedimentation basins) by their variety of water depths and associated vegetative complex. Stormwater wetlands are constructed stormwater management practices, not natural wetlands (including wetland restoration/enhancement/creation for compensatory mitigation required under state and/or federal

requirements). More information is available on the Minnesota Pollution Control Agency's Green Infrastructure benefits of constructed wetlands webpage.

- **Constructed green roofs** – Green roofs consist of a series of layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs provide both volume and rate control, thus decreasing the stormwater volume being delivered to downstream Best Management Practices (BMPs). Green roofs also provide filtering of suspended solids and pollutants associated with those solids. More information is available on the Minnesota Pollution Control Agency's Green roofs webpage.

  **Constructed permeable pavements** – Permeable pavements allow stormwater runoff to filter through surface voids into an underlying stone reservoir for temporary storage and/or infiltration. The most commonly used permeable pavement surfaces are pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP). More information is available on the Minnesota Pollution Control Agency's Permeable pavement webpage.
- **Other** – Implementing natural systems that promote infiltration of rainfall where it falls, mimic predevelopment hydrology and provide ecosystem services may include a variety of unique, project-specific measures, such as:
  - riparian habitat
  - shoreline restorations
  - stream restorations
  - aquatic bench restoration
  - upland native plant community restorations
  - soil loosening
  - soil compost amendments and soil life enhancements
  - some types of on-site rainwater reuse

Percent tree canopy (cover) for a given area can be estimated utilizing GIS or, if that is not available, another tool option is i-Tree Canopy, which also provides an estimate of the benefits of those existing trees. Tree size and maturity will vary based on species, but research cited by EPA in Reducing Urban Heat Islands: Compendium of Strategies Trees and Vegetation (McPherson, E.G. 2002. Green Plants or Power Plants? Center for Urban Forest Research. Davis, CA) has found that after 15 years, an average tree usually has matured enough to provide the full range of benefits. Cities and counties often have tree inventories which estimate the age of trees and can be a useful resource. In general, a mature tree is one that can take care of itself without aid (e.g., stakes, water). They typically have a well-developed tree canopy, are even-aged stands capable of sexual reproduction (i.e., fruits, flowers, nuts, cones) and have attained most of their potential height growth. For tree and forestry definitions, please refer to: USDA's Forest Service Glossary.

## EAW Item 12: Water resources

This section asks for a qualitative overview of how effects from project activities on water resources may be affected by, unaffected by, or mitigated due to current climate trends and anticipated climate change, including the following as relevant to the specific environmental effects and the general location of the project:

- rainfall frequency, intensity, and amount
- higher daytime temperatures and winter low temperatures affecting surface and waterbody temperatures

- increases in extreme heat affecting surface and waterbody temperatures
- increases in extended drought and/or periods of flooding
- increases in the frequency of freeze-thaw cycles; later ice in and earlier ice out; longer growing season

One way that climate change may influence the environmental effects is by amplifying their effect. For example, when discharges of warm water are added to surface water already warmer than historical norms due to higher nighttime lows and more daytime heat and humidity, makes the water even less hospitable for native aquatic species and decreases the likelihood of successful adaptation. Similarly, additional runoff adds contaminants to surface waters already more polluted by increased extreme precipitation and flooding from climate change.

## Wastewater

The intent of this question is to characterize potential climate-driven elements that may influence long-term wastewater disposal and to provide ideas on possible minimization/mitigation measures for these potential effects on wastewater.

Possible mitigations for septic system installation and ongoing use related to anticipated changes in Minnesota's climate include, but are not limited to:

- Increase the amount of insulation to address repeated freeze-thaw cycles, reduced snowfall, and unseasonable snow melt.
- Self-impose larger setbacks for SSTS within the development from wetlands, rivers and lakes to reduce risk of flooding from extreme precipitation events, unless compliance with an established regulatory flood elevation is required.
- Set up a regular septage pumping schedule with the maintainer so that pumping does not need to be demanded during wet times.
- Spread out the schedule for septage pumping service over multiple months or years for a project with many septic systems.
- Keep in mind that some fields are available for land application of septage only during certain times of the year. Scheduling in as much flexibility for the maintainer as possible is the best mitigation to protect against changing precipitation patterns and increasing concerns about air and water quality.

## Stormwater

The intent of this question is to characterize the effect of the project on the amounts and the composition of stormwater runoff from the site and the techniques planned to minimize adverse impacts from stormwater quantity and quality.

Discuss the changes in land cover caused by the project and the effects on existing site surface hydrology. These may include a change in land cover such as loss of tree canopy or other vegetative cover, wetland losses, and an increase in impervious surfaces.

Discuss the effects of the cumulative increase in impervious surfaces in the immediate watershed of the project location and its effect on downstream waterbodies within the project watershed along with efforts to mitigate these effects. Examples of potential stormwater impacts may include increases in receiving water flows and base flow, increase in downstream flood risk, channel erosion, thermal changes to trout streams and/or an increase or change in the generation of pollutants in runoff.

Discuss how additional stormwater flows resulting from more frequent and intense rainfall, increases in runoff from winter snowmelts, and the impacts of warmer temperatures may intensify the effects on water quality and quantity. Examples include:

- Climate change trends toward more frequent and intense extreme precipitation, riverine flooding, localized flash flooding at streams, stormwater management facilities and in upland areas lacking overflow and conveyance capacity.
- Increased frequency and intensity of freeze/thaw cycles due to winter warming increases deicing chemical, salt and sand application, eventually being carried by runoff to downstream water bodies if unmanaged.
- Extreme storm events erode topsoil, which results in decreased crop productivity and nutrients washed into natural waterbodies.
- Floodwaters can mobilize pollutants, add pathogens and environmental contaminants dangerous to people and livestock.
- Stormwater management features become overwhelmed and have reduced effectiveness for controlling the rate of runoff or pollutant capture. Increased sediment and contaminants enter natural waterbodies.
- Warming leads to increased algal blooms and pathogen growth, which can be detrimental for humans, wildlife, and aquatic communities.
- Climate change trends may result in local and regional surface-water/groundwater interactions. Prolonged groundwater rise can result in the expansion of wetlands, ponds, and lakes, resulting in habitat loss or impacts to cropland, rangeland. Fluctuating water levels in wetlands from very wet to very dry periods are amplified through climate change. Wetland plants and animal life cycles are interrupted, and their survival may become threatened.

Describe specific erosion and sedimentation control BMPs during and after construction, including additional BMPs needed to protect surface waters. For projects resulting in one (1) or more acres of new impervious surfaces, identify methods of permanent stormwater management, including a volume reduction practice (required by the MPCA stormwater permit, if applicable to a project). Volume reduction includes infiltration, harvest and reuse, or other green infrastructure practices (see Green Infrastructure Practices Guidance for EAW Item 8) designed to restore or maintain the natural hydrology of the site, promote groundwater recharge, and decrease discharges and potential impacts to area waters. These measures also help to address and adapt to more frequent and increased precipitation and runoff resulting from climate change.

## Water appropriation

The intent of this question is to evaluate the long-term sustainability of water appropriations needed for a project and requires evaluation of the following items:

- How proposed water use is resilient: This addresses how the water use demand can be met with diversified sources of water to reduce short-term and long-terms risks. Has the demand for water use been reduced through conservation and efficiency? Can some supply be met through water recycling and reuse, rainwater and stormwater harvesting, and/or other methods?
- Contingency plans for diminished water supply: A DNR permit for water appropriations requires a contingency plan that describes feasible alternatives the applicant will use if appropriations are

restricted in times of short water supply. Please provide a response that describes at least one alternative, including the option of ceasing water appropriations.

- Climate change trends may result in local and regional surface-water/groundwater interactions that create long-term uncertainty related to surface water and groundwater levels. This may create risk of conditions that reduce or inhibit surface-water and groundwater supply availability, quality and quantity.

*EAW Item 14: Fish, wildlife, plant communities, and sensitive ecological resources*

The 2015-2025 Minnesota Wildlife Action Plan (MNWAP) took a habitat and landscape approach to address climate change. Chapter 1 describes the landscape approach via the Wildlife Action Network (WAN), and Chapter 3 identifies target habitat/ecosystems most sensitive to climate change.

The WAN includes concepts such as, providing movement corridors along climate gradients and building-out protected habitat to provide ecotonal shifts. See also scientific references in the WAN (p. 36). In addition to the MNWAP, there are several sources of information on climate change, summarized briefly below:

- Audubon's 2019 MN Climate Change report: "Survival by Degrees: 389 bird species on the brink": The webpage shows Audubon's report for Minnesota species. It breaks Minnesota bird species into high, moderate, low vulnerability, and stable species. You can then click on an individual species and get more details – it also allows you to adjust the warming scenario and chose a season (summer or winter) to see how those conditions are expected to impact that species.
- **USGS climate adaptation centers** develop data and tools to address the informational needs of natural and cultural resource managers. Topics include the impacts of climate change on fish, wildlife, and ecosystems (see list of projects).

Aspects or features to consider that may amplify or interact with how climate change is anticipated to affect fish, wildlife, plant communities and sensitive ecological resources. Examples include:

- Warming winters leads to increased survival of invasive species and tree-destructive insects which can result in extensive tree death such as eastern larch beetle, pine bark beetle, eastern spruce budworm.
- Increased survival of terrestrial and aquatic invasive species may alter ecosystem functions. New invasive species encroach because they can survive through warmer winters. Additional expense is incurred for their control and pesticide use increases. Shift of species (especially plants) resulting in extinction of some plant species from Minnesota areas and the introduction of invasive species.
- Warming leads to increased algal blooms and pathogen growth, which can be detrimental for humans, wildlife, and aquatic communities.
- Longer growing season allows for additional weed growth, requiring control.
- Lack of snow stresses some vegetation and wildlife species because of lack of cover and protection from cold.
- Trend of earlier ice-out on lakes affects fish spawning.
- Warming waters are shifting the fish species components of natural waterbodies from cool water species such as walleye to warm-water species such as small mouth bass in some regions.

# Attachment 1. Default fuel heat content and stationary source emission factors

Table 7. Solid fossil fuels, mixed fuels, and peat

| Fuel type | Heat Content (MMBtu per short ton) | $CO_2$ Factor (lb $CO_2$/MMBtu) | $CH_4$ Factor (lb $CH_4$/MMBtu) | $N_2O$ Factor (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Anthracite coal | 25.09 | 228.59 | 0.0243 | 0.0035 |
| Bituminous coal | 24.93 | 205.65 | 0.0243 | 0.0035 |
| Subbituminous coal | 17.25 | 214.22 | 0.0243 | 0.0035 |
| Lignite | 14.21 | 215.43 | 0.0243 | 0.0035 |
| Coal coke | 24.80 | 250.60 | 0.0243 | 0.0035 |
| Municipal solid waste | 9.95 | 199.96 | 0.0705 | 0.0093 |
| Petroleum coke | 30.00 | 225.77 | 0.0705 | 0.0093 |
| Plastics | 38.00 | 165.35 | 0.0705 | 0.0093 |
| Tire-derived fuel | 28.00 | 189.53 | 0.0705 | 0.0093 |
| Peat | 8.00 | 246.56 | 0.0705 | 0.0093 |

Table 8. Gaseous fossil fuels

| Fuel type | Heat content (MMBtu/MMcf) | $CO_2$ Factor (lb $CO_2$/MMBtu) | $CH_4$ Factor (lb $CH_4$/MMBtu) | $N_2O$ Factor (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Natural gas | 1,026 | 116.98 | 0.0022 | 0.0002 |
| Refinery gas | 1,388 | 130.07 | 0.0066 | 0.0013 |
| Coke oven gas | 599 | 103.29 | 0.0011 | 0.0002 |
| Blast furnace gas | 92 | 604.77 | 0.0000 | 0.0002 |

Table 9. Fossil fuel liquid fuels: crude oil and refined petroleum products

| Fuel type | Heat Content (MMBtu per short ton) | $CO_2$ Factor (lb $CO_2$/MMBtu) | $CH_4$ Factor (lb $CH_4$/MMBtu) | $N_2O$ Factor (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Crude oil | 0.138 | 164.33 | 0.0066 | 0.0013 |
| Asphalt and road oil | 0.158 | 166.14 | 0.0066 | 0.0013 |
| Aviation gasoline | 0.120 | 152.67 | 0.0066 | 0.0013 |
| Butane | 0.103 | 142.79 | 0.0066 | 0.0013 |
| Distillate fuel oil #1 | 0.139 | 161.49 | 0.0066 | 0.0013 |

| Fuel type | **Heat Content** (MMBtu per short ton) | **$CO_2$ Factor** (lb $CO_2$/MMBtu) | **$CH_4$ Factor** (lb $CH_4$/MMBtu) | **$N_2O$ Factor** (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Distillate fuel oil #2 | 0.138 | 163.05 | 0.0066 | 0.0013 |
| Distillate fuel oil #4 | 0.146 | 165.43 | 0.0066 | 0.0013 |
| Ethane | 0.068 | 131.84 | 0.0066 | 0.0013 |
| Heavy gas oils | 0.148 | 165.17 | 0.0066 | 0.0013 |
| Isobutane | 0.990 | 143.17 | 0.0066 | 0.0013 |
| Jet fuel – kerosene type | 0.135 | 159.22 | 0.0066 | 0.0013 |
| Kerosene | 0.135 | 165.79 | 0.0066 | 0.0013 |
| Liquefied petroleum gases (LPG) | 0.092 | 136.05 | 0.0066 | 0.0013 |
| Lubricants | 0.144 | 163.74 | 0.0066 | 0.0013 |
| Motor gasoline | 0.125 | 174.65 | 0.0066 | 0.0013 |
| Naphtha <401 deg F) | 0.125 | 149.96 | 0.0066 | 0.0013 |
| Natural gasoline | 0.110 | 151.85 | 0.0066 | 0.0013 |
| Oil oil >4091 deg F | 0.139 | 168.03 | 0.0066 | 0.0013 |
| Pentanes plus | 0.110 | 154.37 | 0.0066 | 0.0013 |
| Petrochemical feedstocks | 0.125 | 156.57 | 0.0066 | 0.0013 |
| Petroleum coke | 0.143 | 225.77 | 0.0066 | 0.0013 |
| Propane | 0.091 | 138.60 | 0.0066 | 0.0013 |
| Residual fuel oil #5 | 0.140 | 160.78 | 0.0066 | 0.0013 |
| Residual fuel oil #6 | 0.150 | 165.57 | 0.0066 | 0.0013 |
| Special naphtha | 0.125 | 159.48 | 0.0066 | 0.0013 |
| Unfinished oil | 0.139 | 164.33 | 0.0066 | 0.0013 |
| E10 [o] | 0.126 | 138.57 | 0.0066 | 0.0013 |
| B10 [o] | 0.137 | 147.91 | 0.0066 | 0.0013 |

[o] Calculated from fuel heat content and fuel fossil carbon content by volume for motor gasoline, diesel fuel oil, ethanol and biodiesel given in EPA Center for Corporate Climate Leadership (2020) and EIA State Energy Data System (2020)

### Table 10. Solid biomass fuels

| Fuel type | Heat Content (MMBtu per short ton) | $CO_2$ Factor (lb $CO_2$/MMBtu) | $CH_4$ Factor (lb $CH_4$/MMBtu) | $N_2O$ Factor (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Agricultural byproducts | 8.25 | Not relevant | 0.0705 | 0.0093 |
| Black liquor | 11.76[p] | Not relevant | 0.0042 | 0.0009 |
| Manufacturing residues | 10.39 | Not relevant | 0.0705 | 0.0093 |
| Wood and wood waste | 8.6 to 17.2 (depending on moisture content)[q] | Not relevant | 0.0159 | 0.0079 |

### Table 11. Biogas fuels

| Fuel type | Heat content (MMBtu/MMcf) | $CO_2$ Factor (lb $CO_2$/MMBtu) | $CH_4$ Factor (lb $CH_4$/MMBtu) | $N_2O$ Factor (lb $N_2O$/MMBtu) |
|---|---|---|---|---|
| Landfill gas | 485 | Not relevant | 0.0071 | 0.0014 |
| Other biogases | 655 | Not relevant | 0.0071 | 0.0014 |

**Source**: EPA Center for Corporate Climate Leadership (CCCL), GHG Emission Factors Hub, stationary combustion (2020), all factors except those listed in footnotes o-q.



[p] EIA, Renewable Energy Annual (2009)

[q] USFS Forest Products laboratory, Fuel Value Calculator

# Attachment 2. Protocols and methods for calculating GHG emissions

- American Petroleum Council, Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry (2009)
- American Public Transportation Association, Quantifying Greenhouse Gas Emissions from Transit, APTA SUDS CC-RP-001-09, Rev. 1, 2018
- California Air Resources Board, et al., Local Government Operations Protocol, version 1.1, May 2010
- Environmental Protection Agency (EPA), Inventory of US Sources and Sinks of Greenhouse Gases 1990-2019, EPA-430-R-21-005 (2021)
- EPA, 40 CFR Part 98—Mandatory Greenhouse Gas Reporting (2009)
- EPA Center for Corporate Climate Leadership (CCCL), GHG Inventory Guidance: Stationary Combustion Guidance (2020)
- EPA CCCL, GHG Inventory Guidance: Mobile Combustion Guidance (2020)
- EPA CCCL, GHG Inventory Guidance: Indirect Emissions from Purchased Electricity (2020)
- EPA CCCL, GHG Inventory Guidance: Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases (2020)
- EPA CCCL, Scope 3 Inventory Guidance
- ICLEI, U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions, version 1.2, 2019
- Intergovernmental Panel on Climate Change (IPCC), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol. 1-5 (2006)
- IPCC, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (2013)
- IPCC, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol 1-5 (2019)
- IPCC, Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003)
- Minnesota Department of Transportation (MnDOT), Minnesota Infrastructure Carbon Estimator tool (MICE)
- National Council for Air and Stream Improvement, Inc. (NCASI), Calculation Tools for Estimating Greenhouse Gas Emissions from Pulp and Paper Mills V.1.1, 2005
- The Climate Registry, General Reporting Protocol, V 3.0 (2019)
- J. Smith, et al., Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States, Gen. Tech. Rep. NE-343. USFS, 2006
- The Climate Registry, Electric Sector Protocol: Annex to the General Reporting Protocol, V. 1.0. (2009)
- USDA, Office of the Chief Economist, Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory, Technical Bulletin 1939, 2014
- USDA, Office of the Chief Economist, US Agriculture and Forest Greenhouse Gas Inventory 1990-2013 Technical Bulletin 1943, 2016

- World Business Council for Sustainable Development, and World Resources Institute, The GHG Protocol: A corporate reporting and accounting standard (revised edition) (2020)
- World Business Council for Sustainable Development, and World Resources Institute, Calculating Greenhouse Gas Emissions from Iron and Steel Production: A component tool of the Greenhouse Gas Protocol Initiative (2009)