MINNESOTA ENVIRONMENTAL QUALITY BOARD

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 the Next Generation Energy Act (Minn. Stat. § 216H) into law, which requires the tracking of certain greenhouse gas (GHG) emissions. The statute also includes statewide GHG emission reduction goals, from a 2005 baseline.

It is important that environmental documents required by the Minnesota Environmental Policy Act (MEPA) include usable information about the potential effects of a proposed project on GHG emissions and climate change.

Estimation of GHG emissions is a useful way to measure the potential climate impacts of a proposed project. It also helps track progress in meeting state and local GHG reduction goals and supports efforts to reduce emissions, mitigate, and adapt to the impacts of climate change.

The purpose of this section of the guidance is to help project proposers and responsible governmental units (RGU) estimate GHG emissions by developing a carbon footprint in response to item 18 of the Environmental Assessment Worksheet (EAW) Form. This guidance document is meant to support an RGU as they develop climate related information on the EAW form.

This guidance section should serve as a starting point for information to help answer item 18 of the EAW form, but it does not limit the use of other reliable and relevant tools for quantifying and assessing GHG emissions. This guidance is not exhaustive and RGUs are encouraged to use any relevant tools beyond those listed below. 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?

In general, a carbon footprint is the total greenhouse gas emissions associated with a project. This includes greenhouse gas emissions from direct use of fuel, such as providing heat to a building or fuel in a car. It also includes greenhouse gases that come from producing the goods or services necessary to complete a project, including emissions from power plants that make electricity or factories that make the products used in the project. It also encompasses the emissions associated with any involved products' disposal.

A carbon footprint generally includes any upstream and downstream emissions from a project. Upstream emissions include those related to the production, acquisition, or transportation of goods or services required for the project. Downstream emissions include those related to the handling and disposal of any resultant products at the end of their life.

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 GHG emissions

- 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

Specific to item 18 of the EAW Form, GHG emission sources include all project sources of GHG emissions by source, type, and phase. Common phases include pre-purchase, transportation, production, operation/use, and disposal.

Emissions can be categorized as either direct or indirect. Direct emissions are emissions released directly from properties owned or under the control of the project proposer. These are also commonly referred to as “Scope 1” emissions. This includes emissions from on-site energy use and mobile equipment during construction.

Indirect emissions originate either upstream or downstream of the project. They are also commonly referred to as “Scope 2” and “Scope 3” emissions. Scope 2 emissions are emissions associated most often with the offsite generation of purchased electricity, steam, and heating and cooling.

Scope 3 emissions are from the offsite provision of waste management services, including land disposal (landfilling), recycling, and solid waste composting, use of sold products, and transportation and distribution for waste management. According to the Environmental Protection Agency, “Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly affects in its value chain. Scope 3 emissions include all sources not within an organization’s scope 1 and 2 boundary. The scope 3 emissions for one organization are the scope 1 and 2 emissions of another organization. Scope 3 emissions, also referred to as value chain emissions, often represent the majority of an organization’s total greenhouse gas (GHG) emissions. Scope 3 emission sources include emissions both upstream and downstream of the organization’s activities.”

The U.S. Environmental Protection Agency (EPA) annually prepares a detailed analysis of GHG emissions by source and type. A list of these sources is shown in Table 1, arranged by type of greenhouse gas emitted. GHG sources in Minnesota are assessed biennially by the Minnesota Pollution Control Agency (MPCA). Environmental review documents generally include sources shown in Table 1 that are potentially associated with, and may result in, GHG emissions from the proposed project.

The GHG types 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)

Table 1. Sources of greenhouse gases

Source	Gas Type
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[1]	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
Industrial solvent use (electronics, precision cleaning)	PFCs, HFCs
Petrochemicals, other chemical manufacture[2]	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[3], 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

[1] Lubricants, waxes
[2] Adhesives, binders, chemical intermediates, fillers, humectants, paint and coating additives, reagent catalysts, resins, sealants, solvents, surface treatment agents
[3] CO_2 from combustion of petrochemical part of solid and hazardous waste

Table 1. Sources of greenhouse gases (continued)

Source	Gas Type
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

Step 2: Identify types of GHGs emitted

In response to item 18 of the EAW Form for a project's carbon footprint, it is typical for reporting to include emissions of:

- carbon dioxide (CO2)
- nitrous oxide (N2O)
- methane (CH4)
- sulfur hexafluoride (SF6)
- two families of gases known as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)

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)
- hydrochlorofluorocarbons (HCFCs)
- hydrofluoroethers (HFEs)
- sulfuryl fluoride (SO2F2)
- ozone
- various idiocarbons and chlorocarbons

For more information on these GHG types, 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 of each gas, 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.

Table 2. Greenhouse gas global warming potentials

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

Projected GHG emissions are conventionally developed on an average annual basis and include the proposer's best estimate of average annual emissions over the proposed life or 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 and any materials' end of life. To include construction emissions in the footprint, emissions should be annualized by dividing total construction GHG releases to the atmosphere by project life.

In project GHG accounting, it is conventional to report GHG emissions by source, type, and project phase (i.e., construction, operations), and then sum emissions to a project total. It is recommended that emissions be reported using the reporting framework and categories shown in Table 3, which additionally breaks out emissions by 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	Chemical Emitted
Direct emissions	Scope 1-emissions	Operations	combustion	stationary; area; mobile	CO_2,[4] N_2O, CH_4
	Scope 1-emissions	Operations	non-combustion process[5]	stationary[6]	CO_2, CH_4, N_2O, HFCs, PFCs, other fully fluorinated GHGs
	Scope 1-emissions	Construction	combustion	mobile	CO_2, N_2O, CH_4
	Scope 1-emissions	Construction	land-use	area	CO_2, N_2O, CH_4
Indirect Emissions	Scope 2-emissions	Operations	off-site electricity/steam production	grid-based	CO_2, CH_4, N_2O
	Scope 3-emissions	Operations	off-site waste management	stationary; area	CO_2, CH_4
Atmospheric Removals of GHGs	Scope 1-sinks	Construction/ operations	land-use	area	CO_2 removals to terrestrial storage

A sink is a reduction in atmospheric GHGs by storing carbon in another form. Carbon removals from the atmosphere act to offset emissions of CO_2 to the atmosphere. 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. Given the atmosphere's continued retention of CO_2 after 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.

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

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

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

[6] 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

Treatment of emitted biomass CO_2

Biogenic CO_2 emissions should be included in the proposed facility's carbon footprint if they result from permanent land-use change. Permanent land-use changes may include:

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

Beyond emissions from permanent land use change, other emissions of CO_2 from biomass combustion sources or ecosystem or animal respiration generally are not included in project accounting. Unless released 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 is often assumed in carbon footprint development.

Table 4. Common Biomass CO_2 Sources[7]

Type	State	Source
Common Biomass Fuels	Solid fuels	sawdust, hogged bark, waste wood, other papermill and sawmill residuals, some types of refuse-derived fuel (RDF), 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		organics 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)

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.

For emissions related to materials management, the EPA's Waste Reduction Model (WARM) is commonly used. According to the EPA website, "EPA created the Waste Reduction Model (WARM) to provide high-level estimates of potential greenhouse gas (GHG) emissions reductions, energy savings, and economic impacts from several different waste management practices. WARM estimates these impacts from baseline and alternative waste management

[7] 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, may sometimes (on a case-by-case basis) be treated as carbon neutral

practices—source reduction, recycling, anaerobic digestion, combustion, composting and landfilling."

Table 5. Summary of potential reporting elements for a 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 over the life of the project and emissions disaggregated by source and project phase
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 projected life or design service life of the project
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 • Emissions from purchased electricity/steam • Off-site emissions from purchased waste disposal services • Upstream and downstream sources
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

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).[8] The simplified IPCC methods usually take the form of linear equations involving emission factors and activity factors. The Environmental Protection Agency'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 as one example for each scope and emission type outlined in Table 3 above.

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

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, Appendix B 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.*[9] The simplified formula is:

> *tons CO_2-e = Emission Factor Based on Land Type Carbon Flux (tons CO_2e/area) * area of land use change*

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 * total area of land use change in U.S.*[10]

Terrestrial carbon sequestration (TCS) is the process of carbon being absorbed by plants through photosynthesis and stored as carbon in soils and biomass. The offsets value of TCS for projects with lifetimes of 50 years or more is generally assessed at full value, while projects with lifetimes of 20 years and 25 to 49 years are assessed at 40% and 75% offsets values,[11] respectively. In practice, offsets value may be calculated by multiplying total tons of CO_2

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

[10] Section 6.1. Ibid.

[11] 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

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.[12]

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.

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.

More highly developed methods exist of greater complexity, including some developed by the IPCC. A more complete list of methodological sources that might be consulted is included in Appendix B. For specific sources, these may provide an additional 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 available at time of publication. This is not an exhaustive list. These may be used by project proposers to estimate emissions from individual or multiple GHG sources.

Table 6. Tools for estimating GHG emissions from different sources

Tool name	GHG sources covered
SGEC Tool "Simplified GHG Emissions Calculator"	"Simplified GHG Emissions Calculator" stationary source combustion, mobile source combustion, biomass and biofuels combustion, refrigerant and cooling, fire suppression, electricity and steam purchases, off-site solid waste management

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 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.

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

MPCA feedlot tool[13]	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
Virtual (Dairy) Farm	Crop production, enteric methane (dairy cows), on-farm energy use, manure management
EPA Waste Reduction Model (WARM)	Solid waste reuse, recycling, composting, incineration, landfilling
COMET-Planner	Conservation and nutrient management practices in crop production and grazing

Project proposers should provide sufficient background and technical information so that the emissions calculations are replicable. Once calculated in nominal tons of emissions, emissions should be converted to CO_2-equivalent short tons and sum 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.

Section 2 – Climate mitigation

This section provides guidance and resources to help respond to EAW item 18b. There are many ways to mitigate a project's impact on the climate by reducing its GHG emissions, and new mitigation options are rapidly emerging. Many of these mitigations can also reduce costs and make compliance with future climate regulation easier and more affordable.

EAW item 18b(i): How to identify and assess reasonably available mitigation options

There are many existing resources that identify GHG mitigation measures that can be used to reduce project emissions. Moreover, projects implementing these mitigations can often benefit from tax credits, rebates, or other financial subsidies provided through federal, state, or local governments or through utility-run programs. Many future GHG mitigations can be more easily and cost-effectively implemented by anticipating them in the project's original design. For example, if a project anticipates replacing gas-fired furnaces or other appliances with electric heat pumps in the future, it could reduce the cost of that future replacement by including upgraded electrical wiring and circuit boxes at the time of construction. Similarly, if a project anticipates adding solar panels in the future it could orient its rooftops with that in mind, or design landscaping to avoid shading future solar panels. Electrical systems can also be designed with future electric vehicle charging needs in mind, even if charging stations are not part of the original project design.

[13] Available by request from the MPCA

See various categories below with links to resources that give additional technical and available financial assistance information.

(1) **Energy efficiency**: Increasing energy efficiency reduces a project's emissions. Common mitigation measures in this category include:

   a. Designing and constructing energy efficient buildings along with installing energy-efficient appliances, equipment, and lighting

   b. Utilizing process efficiencies for extraction and production to reduce energy and water consumption

Additional technical information on energy efficiency and financial subsidies is available in Appendix C.

(2) **Electrifying appliances and equipment**: Projects can usually reduce GHG emissions by using electric appliances and equipment in lieu of fossil-fuel burning appliances and equipment. For example, heat pumps can replace gas-fired appliances. While electrification of project appliances increases electricity use, electrification typically reduces on-site emissions even more, and GHG benefits will increase over the years as the power grid continues to decarbonize. Additional technical information on electrifying appliances and equipment and financial subsidies for electrification is available in Appendix D.

(3) **Distributed electricity generation:** Projects can reduce their emissions by generating electricity on-site, such as through the installation of solar panels on rooftops or elsewhere at a facility. Considerable financial support is available for solar power and storage through tax credits and rebates. Additional technical and financial assistance information on electricity generation is available in Appendix E.

(4) **Transportation**: Projects that involve mobile sources can reduce GHGs by electrifying their fleets or on-site mobile equipment and by providing electric vehicle charging stations. Additional technical and financial assistance information on transportation electrification is available in Appendix F.

(5) **Land Use:** Projects can reduce GHG emissions associated with land use, and even create GHG sinks through best practices in land-use management, nutrient and sediment run-off control, on-site terrestrial biogenic carbon sequestration, and wetland mitigation, among others. Additional technical and financial assistance information on land use GHG emissions is available in Appendix G.

EAW item 18b(ii): Quantifying GHG reductions from mitigations

Environmental review documents generally include complete descriptions, quantifications, and a detailed assessment of the planned mitigation activity as a part of the proposed project. Resources provided in the previous section and in Part I of this guidance can help quantify the emission reductions expected from various mitigations. The assessment should also explain why the selected mitigation for the project was preferred over other mitigation options.

In quantifying potential emission reductions or emission offsets, project proposers should provide sufficient background technical information to enable the reader to replicate the calculations.

EAW item 18b(iii): Quantifying net lifetime emissions and effects on GHG reduction goals

Project proposers and RGUs should be aware that projects proposed today face the prospect of needing to greatly reduce, and even eliminate their GHG emissions in the years ahead as national, state, and local governments are setting increasingly more ambitious GHG reduction goals and policies. Achieving these reductions will affect virtually all projects with GHG emissions during their operating lifetime.

For example, Minnesota's Climate Action Framework, published in 2022, sets forth the goal of reducing the state's GHG emissions by 50% by 2030 and of achieving "net-zero" emissions by 2050.[14] These are more ambitious targets than those enacted by the state in 2007 via the Next Generation Energy Act,[15] reflecting advances in the climate science and the growing global response. The Minnesota Framework's goals are consistent with the United States' pledge to reduce GHG emissions to achieve net-zero GHG emissions by 2050. They are also aligned with the international agreements to take steps to limit global warming to 1.5 degrees Celsius.

Many Minnesota cities and other local units of government have similarly issued plans to achieve reductions in GHG emissions, and some are updating plans adopted years ago.[16] Local units of government should be contacted to obtain the latest local climate plans.

To calculate a project's net lifetime GHG emissions, multiply its annual emissions by its predicted years of operational life. Then, the project's net lifetime emissions can be compared to the Next Generation Energy Act goals[17] and any other more stringent state or local GHG reduction goals and Minnesota's Climate Action Framework.[18] Responses to this question should discuss how the project aligns with the Next Generation Energy Act and other GHG reduction goals by achieving a similar scale and timing of GHG emission reductions.

Many future GHG mitigations can be more easily and cost-effectively implemented by anticipating them in the project's original design. The answer to item 18b(iii) should list any project design features the project plans to implement that would facilitate future GHG reductions for the project (e.g., upgraded electrical to support potential future HVAC and appliance electrification and renewable energy installation).

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[14] Minnesota's Climate Action Framework, https://climate.state.mn.us/sites/climate-action/files/Climate%20Action%20Framework.pdf

[15] Minn. Stat. § 216J.02, subd. 1.

[16] City Climate Action Plans in Minnesota: Overview and Review, 2022, https://www.house.leg.state.mn.us/comm/docs/DvlEmiU0SE23Iao3b_Qv8g.pdf

[17] The Next Generation Energy Act goals are listed at Minn. Stat. § 216H.02, subd. 1.

[18] Available at https://climate.state.mn.us/sites/climate-action/files/Climate%20Action%20Framework.pdf

Section 3 – Climate adaptation and resilience

The purpose of this section is to help project proposers and responsible governmental units (RGU) respond to the specific climate adaptation and resilience 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.

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.

This item is intended to lay the groundwork for understanding how climate change is likely to affect the area where the project is located throughout the life of the project. This groundwork is important for several reasons:

- Facilities, infrastructure, and other assets constructed as part of the project may be subjected to increasingly extreme conditions over time. Anticipating and adapting to these projected conditions will provide greater resilience for the project throughout its expected life.
- Environmental effects may change over time as climate conditions become more extreme.
- Design decisions for the project may affect the surrounding area in positive or negative ways as the climate continues to warm and with greater precipitation extremes. Examples include mitigating or contributing to urban heat island effects, localized flooding, stress on the local electric grid and/or water resources.

As described by the Minnesota Department of Natural Resources webpage, Minnesota's climate shows the following trends:

- Warmer and wetter
- Cold weather warming
- More damaging rains

These three trends are expected to continue in the future in Minnesota along with two additional projected changes:

- Increasing risk of heat waves
- Increasing risk of drought

This description of current 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.

When establishing a description of climate change specific to the most representative geographic unit or location of the project, keep these things in mind:

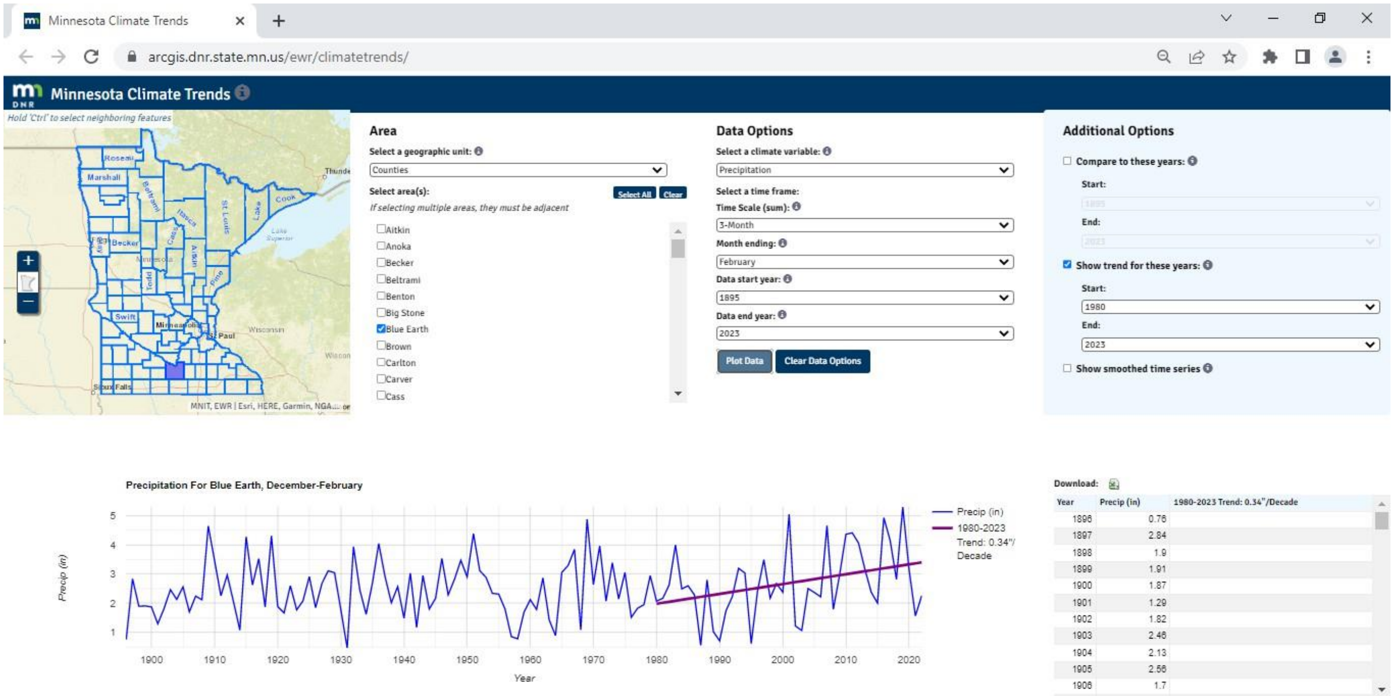
- Depending on the data source, model, or tool used, you might be able to type in a specific address, click on a specific location in a map tool, or select the applicable census tract, county, major watershed, state forest, state park, or other geography – choosing whatever is consistent with how you justified the geographic scale for the rest of your project analysis.
- Look at historical climate trends data to establish current project conditions. Historical climate information will be based on actual data from specific reporting stations. Discuss the time frame options and trend years you selected for this data, and why it fairly represents your project.
- Explore projected (future) climate data to anticipate conditions during the life of the project. Projected climate data is modeled, so data from different sources may be based on models with somewhat differing methodologies, assumptions about the factors that affect climate change, and resolution / scale (e.g., downscaled global data to a 25km grid vs. 10km vs. 4km, special treatment of lakes, CMIP5 climate models vs. CMIP6). Typically, smaller grid sizes are more specific to local climatic conditions if a "downscaling" process is applied that is based on physical relationships and atmospheric processes (dynamical), rather than on statistical techniques.
- Many sources offer projected data for multiple future time periods, so be sure to select the period that best aligns with the life of the effects of the project.
- Many sources offer projected data for multiple model scenarios. It can be helpful to review and discuss multiple models.

Current climate trends

An available Minnesota source for determining location-specific ***current*** climate trends for temperature ranges and total precipitation based on historical data is the Minnesota Climate Trends tool.

The Minnesota Climate Trends tool shows historical data for one or multiple adjacent selected climate divisions, counties, deer permit areas, ecological subsections, major watersheds, state forests, state parks, tribal governments, wildlife management areas, and the entire state. It allows comparisons, trend lines, and smoothed time series for warming (average, minimum, and maximum temperature) and for total precipitation. The time scale for data is from 1 month to 60 months ending in any month – or annual – going back to 1895. This tool allows the user to look at historical data and trends annually, for individual months or for seasons relevant to the project. Use the tool to explore each of the project-relevant climate variables and associated time frames. See an example from the tool immediately below (subject to change). *(Source: Minnesota Department of Natural Resources)*

Image 1. Minnesota Climate Trends tool



Directions for the [Minnesota Climate Trends tool](#):

Step 1: Open the tool and under "Area," select an appropriate geographic unit (i.e., watershed, county, etc.) and specific area(s) consistent with your project analysis.

Step 2: Under "Data Options" select a climate variable (precipitation, temperature, etc.) and a time frame which includes the time scale, month ending, data start year, and data end year. For example, it may be helpful to evaluate your project only in terms of winter climate trends if your project will only be operating in the winter. Additionally, construction schedules, C&D waste disposal, or other project specific details may call for month-specific analysis.

Step 3: Under Additional Options, click "Show trend for these years" and pick whatever start and end dates are desired for the trend line. Setting the trend line from 1980 to the most recent year with complete data is an approach often used.

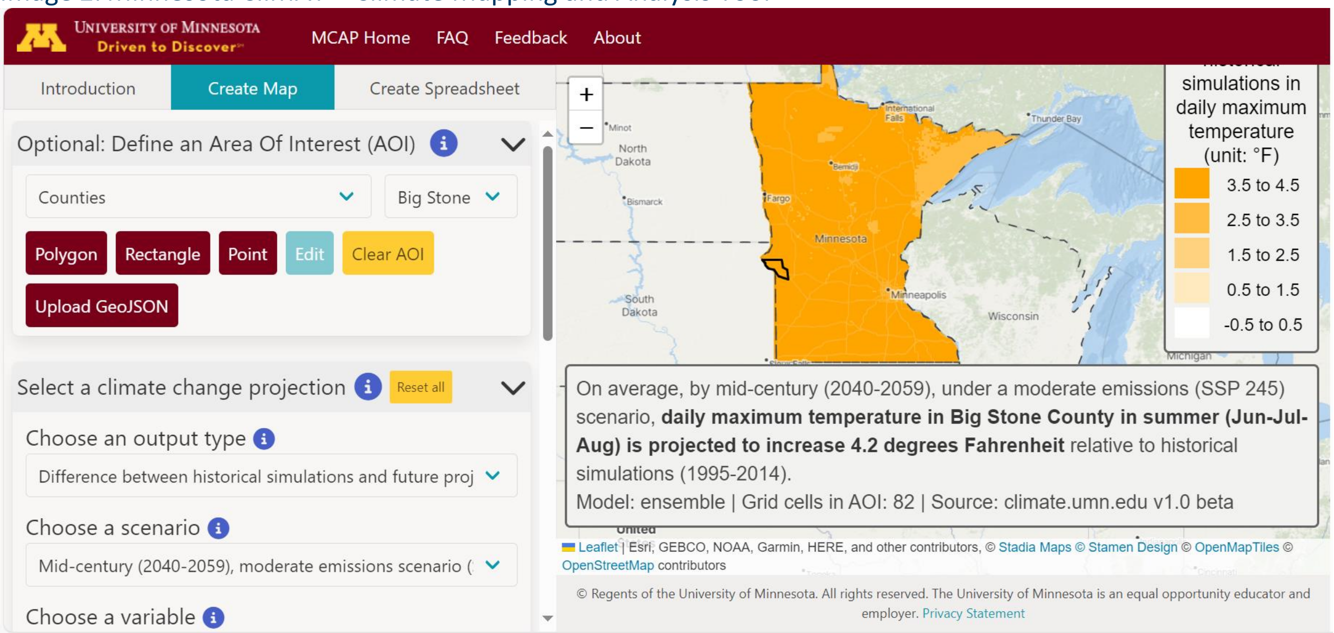
Step 4: Click "Plot Data" back under "Data Options" Scroll down for a graphical representation of the data and a data table. To open/save an Excel spreadsheet of the data, click the icon next to "Download" in the upper left of the data table.

Anticipated climate changes – projections for climate variables

Minnesota CliMAT - Climate Mapping and Analysis Tool (CMIP6) is an interactive online tool that provides highly localized climate projections for Minnesota. Users can view climate projections down to the 4km/2.6mile scale across the state, visualizing even how specific towns will likely be impacted in the coming decades. MN CliMAT uses the latest generation of global climate models, called CMIP6 (used for the Fifth National Climate Assessment).

"Create Map" allows users to define an Area of Interest (AOI) within Minnesota to view what the future climate might look like for a chosen emissions scenario, variable, and time period. AOIs can be selected on the map from predefined options such as counties or watersheds, drawn by hand, or uploaded in a geographic data file. See an example immediately below (subject to change). *(Source: University of Minnesota Climate Adaptation Partnership)*

Image 2. Minnesota CliMAT – Climate Mapping and Analysis Tool



Directions for Minnesota CliMAT:

Step 1: Click on "Launch the tool" and select the "Create Map" tab.

Step 2: "Define an Area of Interest (AOI)". Choose from three options for defining the geographic area consistent with your project analysis: (1) select a pre-made AOI from the drop-down menu (i.e., counties, climate divisions, state boundary, state parks, state forests, One Watershed One Plan units, HUC 8 watersheds, tribal governments, ceded territory boundaries, electric service areas), or (2) draw an AOI on the map by selecting the polygon, rectangle, or point tool to define a geographic area that incorporates at least one grid cell, or (3) upload a GeoJSON file to define the geography.

Step 3: "Choose an output type". Use the drop-down menu to select projected future conditions or the change from that geographical area's historical climate (i.e., modeled values, difference between historical simulations and future projections, percent difference).

Step 4: "Choose a scenario". Use the drop-down menu to select from either the moderate or high-emissions scenario for the appropriate period – mid-century (2040-2059), late-century (2060-2079), or end-of-century (2080-2099). Explore multiple scenarios and appropriate periods to help anticipate conditions during the life of the project, and also to assess conditions during the period that best aligns with the life of the effects of the project.

Step 5: "Choose a variable". Use the drop-down menu to select from the multiple options under each of the headings (i.e., precipitation values and thresholds, precipitation intensity, snow, humidity, temperature averages, minimum temperature thresholds, maximum temperature thresholds, soil, lakes). Each option shows the time frames for which the data is available, and clicking on that option does not work if an unavailable time frame is selected (Step 6 drop-down menu). Explore all the variables which might have bearing on the project during the life of the project and the life of the effects of the project.

Step 6: "Choose a time frame". Use the drop-down menu to select from multiple time frame options which include the year (Y), the growing season (GS), one of the meteorological seasons (S), or a specific month (M). The time frame allows the user to view projected climate changes for portions of the year that might specifically affect project or facility design, operations, or effects. Explore various time frames to get a complete picture because averages may obscure important seasonal or monthly differences. Be sure the time frame fits with the availability of data for the selected variable.

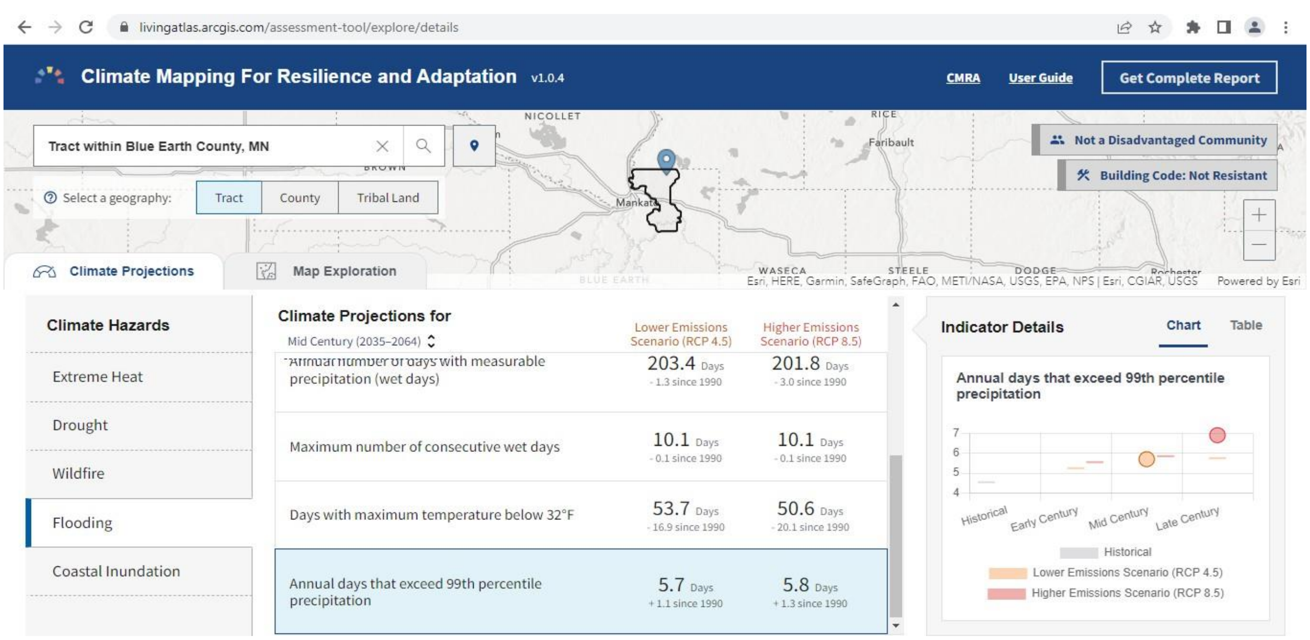
Step 7: "Map options". If drawing the AOI on the map, make it easier by using the drop-down menu to "Choose a basemap" type that will be the most helpful to identify the appropriate area of interest. Click applicable "Show / Hide / Round" options (e.g., roads). Use the slider to "Set transparency of climate data" at a level that shows the features of the basemap and options selected.

Anticipated climate changes – climate hazard projections

Available national sources for location-specific data related to anticipated climate change hazards including extreme heat, drought, wildfire, flooding, and storm intensity include the following.

Climate Mapping for Resilience and Adaptation (CMRA) Assessment Tool: This tool explores current and anticipated extreme heat, drought, wildfire, and flooding hazards by tract, county, or tribal land for two emissions scenarios in any of three time periods – Early Century (2015-2044), Mid Century (2035-2064), and Late Century (2070-2099). It includes climate projections for numerous variables related to each climate hazard. [CMRA is scheduled to be updated in September 2024 with CMIP6 climate model data replacing (older) CMIP5 data.] See an example of the tool immediately below (subject to change). *(Source: U.S. Global Change Research Program)*

Image 3. Climate Mapping for Resilience and Adaptation tool



Directions for the CMRA Assessment Tool:

Step 1: Open the tool and click on the "Launch" button.

Step 2: "Find address or place". In the address bar, type in a specific address or a more general location such as a city or county name to see options and select the most relevant. Then to get a more exact location, repeatedly click the "+" icon on the map to the needed scale and drag the map around to the right place. Then, next to the address bar, click on the location icon. Click again on the desired place on the map.

Step 3: "Select a geography". Click on whichever geography (i.e., Census Track, County, Tribal Area) is most consistent with your project analysis.

Step 4: In the "Climate Projections" tab, click on one of the "Climate Hazards" listed in the left menu bar (i.e., Extreme Heat, Drought, Wildfire, Flooding). Explore each of the climate hazards relevant to the project.

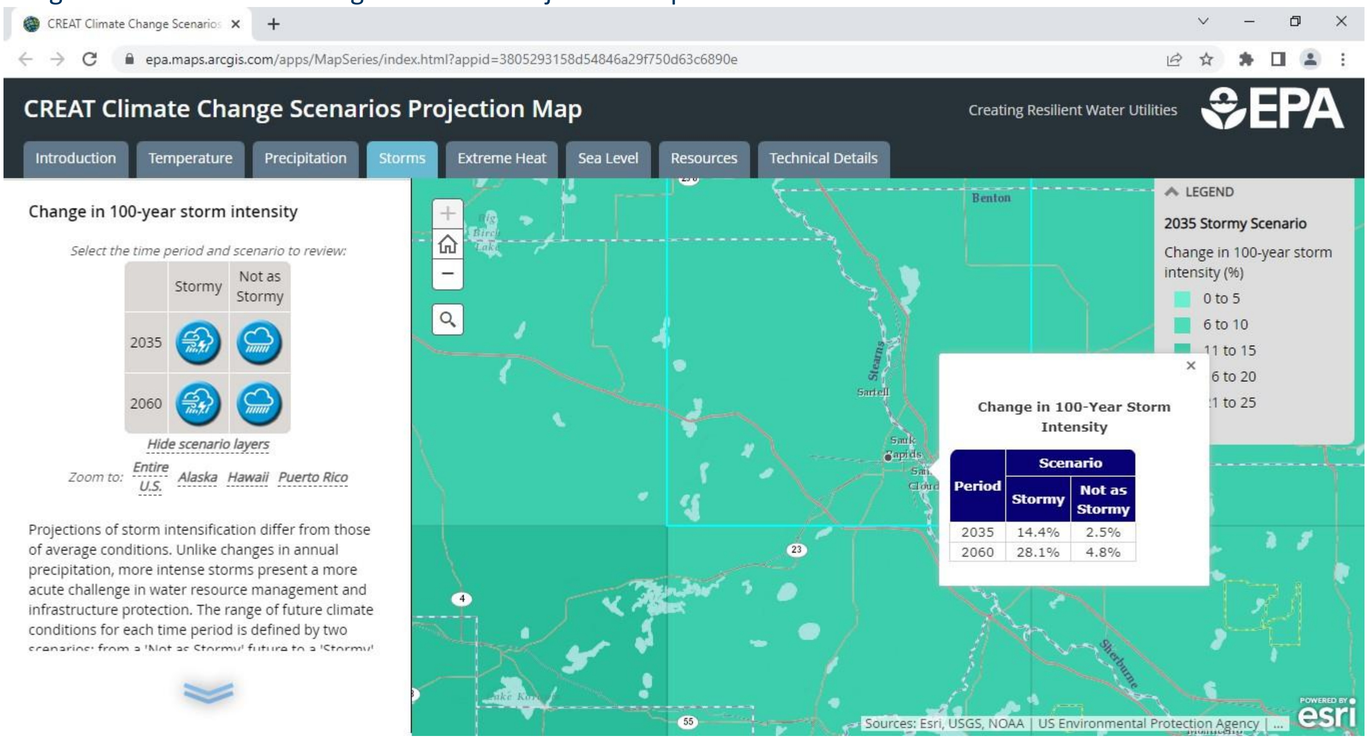
Step 5: "Climate Projections for". Use the up/down arrows to see the menu of time periods (i.e., Early Century, Mid Century, Late Century) and select the most relevant to the life of the project. Then scroll through the related climate projections shown and select any of interest to see the associated "Indicator Details" Chart (or Table) on the righthand side.

Step 6: "Get Complete Report". To download printable images (landscape presentation format) of the climate projection data for that location for each of the five hazards, first select the "County" geography and then click on the "Get Complete Report" button at the top right-hand corner of the page.

Anticipated climate changes – climate scenarios projections

CREAT Climate Change Scenarios Projection Map. This tool provides projections of storm intensification, which differ from those of average conditions. Unlike changes in annual precipitation, more intense storms present a more acute challenge in water resource management and infrastructure protection. The range of future climate conditions is defined by two scenarios – a "Stormy" future and a "Not as Stormy" future. The two time periods, centered on 2035 and 2060, are provided as short- and long-term infrastructure and water resource planning horizons. Climate models used were drawn from the (older) CMIP5 dataset. *(Source: U.S. Environmental Protection Agency)*

Image 4. CREAT Climate Change Scenarios Projection Map



Directions for the CREAT Climate Change Scenarios Projection Map:

Step 1: Click on the "Storms" tab to see data for projected change in 100-year storm intensity.

Step 2: Use the "+" icon and drag the map to zoom in to the specific location.

Step 3: Click on the location on the map to see a pop-up with specific projected (future) percentage changes for each of the time periods and scenarios.

Anticipated climate changes – additional information sources

Fifth National Climate Assessment, especially Chapter 24: Midwest, or more current version if available: The NCA report is an official U.S. Government report about climate change vetted by 13 federal agencies. It relies on the climate-related scenarios that are generated for the IPCC assessments (see bullet below). NCA5 contains useful information in Chapter 31: Adaptation about what is needed to make adaptation strategies successful. *(Source: U.S. Global Change Research Program)*

Explore the NCA5 Interactive Atlas, based on CMIP6 climate models. To access a variety of temperature and precipitation climate projection maps in the Atlas follow these steps: click on Climate Maps, click Open the Explorer, click Open Map, select your preferred map, use +/- to locate area of interest on the map, click on the county of interest to get a popup and then on Select Feature in upper right corner of the popup to toggle between data for three climate scenarios). *(Source: U.S. Global Change Research Program)*

Intergovernmental Panel on Climate Change Assessment Report (IPCC 6, or more current version if available): Through its assessments, the IPCC determines the international state of knowledge on climate change. It identifies where there is agreement in the scientific community and where further research is needed. The modeled climate scenarios generated by scientists from around the world used in the IPCC assessment are the basis for all local sources of projected (future) climate data. Use this source for general context about the most up-to-date assessment of global and regional climate trends. The Summary for Policymakers discusses the Shared Socioeconomic Pathways (SSPs) scenarios and modelled pathways used for the assessment (based on CMIP6 climate models). *(Source: Intergovernmental Panel on Climate Change)*

National Oceanic and Atmospheric Administration (NOAA): NOAA Climate.gov is an additional source of timely and authoritative scientific data and information about climate, coordinated with many of the other sources listed. The dataset on Future Climate Projections – Graphs & Maps is based on (older) CMIP5 climate models. *(Source: National Oceanic and Atmospheric Administration)*

Caveats and definitions

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(s) it affects.
- Life of the project: (options relevant to different project types)
- Proposed life: the period of time the project is proposed to operate or last.
- Design service life: expected period of use as intended by the designer, after which it may need to be replaced.
- 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. Identify the risk of long-term impacts that climate trends might pose to the proposed activities throughout the project life, considering how conditions may continue to change throughout that time. 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 the future climate reality aligns with 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.
  - 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 urban heat island (UHI) effect in the area.
- Construction materials:
  - Dark roofing and siding materials absorb heat during the day and radiate it at night, which increases the UHI effect and amplifies the warming temperatures of climate change.
- Site design:
  - Retaining mature trees can provide shading of structures to reduce energy use and many ecosystem services, including air quality and stormwater benefits.
  - Siting and orientation of buildings has ramifications for energy use, flood risk, and more.

Available sources for information on causes and mitigations of urban heat:

- 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 Compendium 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.

Land use

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

For purposes of describing existing and planned land uses, open space is any natural space, public or private, that is used primarily for passive recreation (passive recreation uses are those that require little to no landscape modifications, e.g., birdwatching), animal habitat, and/or for maintaining ecological services and/or rural character. Open space may or may not be protected by federal, state, or local entities. Examples could include woodlands, prairie, groundwater recharge areas, or greenways.

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

- Reduction or loss of tree cover may lead to the loss of many climate resilience benefits, leading to more intense stormwater runoff, increased urban heat island effect, 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 landscapes is available in the EPA's "Reducing Urban Heat Islands: Compendium of Strategies".
- Increased heat and longer growing seasons can increase or reduce crop production, causing producers to modify land use and cropland management to adapt. Longer growing seasons enable additional pest and weed growth, likely increasing 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.
- Prolonged drought can result in habitat loss from constriction of wetlands, ponds, and lakes, and may also affect area wells and groundwater resources.
- 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 can result in increased icing of roadways, trails, sidewalks, and parking lots, requiring increased salting. Chlorides from salting can degrade lake water quality, impact aquatic life, degrade soil, and kill landscape plantings.

Consider the risk potential for critical facilities proposed to be sited in floodplains or other areas identified as at risk for localized flooding considering changing precipitation and event intensity. Critical facilities are facilities necessary to a community's public health and safety.

In further considering land use, also discuss the compatibility with land use, planning, and zoning as it relates primarily to development and the projected climate changes for the project location.

Available sources for identifying locations that are more vulnerable to extreme heat and/or localized flooding due to land use:

- Heat Vulnerability in Minnesota Tool: Use this tool to assess community vulnerability to extreme heat. The tool provides recent historical data on excessive heat warnings and heat advisories, as well as projections for cooling degree days. Select the study area (HSEM Region, County). In the "Sensitivity" menu, select "% impervious surface". Select your preferred variable for historical or projected heat data in the "Exposure" menu. Zoom in on the maps using the "+" icon to locate your project site. See more resources about specific climate change in Minnesota on the Climate & Health website. *(Source: University of Minnesota)*
- Climate Vulnerability Assessment Regional Risks and Opportunities for the Twin Cities Region: This website includes tools, resources and mitigation actions for current regional climate hazards including Extreme Heat (Story Map and Extreme Heat Map Tool) and Localized Flooding (Story Map and Localized Flood Map Screening Tool) related to existing land use. This data is a comprehensive resource for the seven-county region (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties) governed under the Metropolitan Council. *(Source: Metropolitan Council)*
- The Growing Shade Mapping Tool for projects located in the Twin Cities metropolitan area provides a customized report showing tree canopy and other data for the specific geography (cities/townships, neighborhoods in Minneapolis and St. Paul, or census block group). *(Source: Metropolitan Council)*

Contamination/hazardous materials/wastes

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

- Increased leaching from disposed wastes of contaminants into the groundwater
- Increased erosion of exposed soil and other earthen materials
- Increase in contact water volumes that may require collection and treatment
- Increased erosion on the working face of waste storage or containment
- Increased 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 system was designed based on smaller precipitation events
- Increased stormwater sediments or solids that need proper disposal
- Increases in leachate and contact water needing treatment; 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, leading to additional potential water quality effects
- Increased extreme heat and humidity, making environmental effects such as odors more likely and may increase their severity
- Increased freeze/thaw cycles and more "unseasonal" weather making 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
- Increased flooding events 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 can increase stresses to 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, and more. This may damage infrastructure and create situations that result in accidental spills and releases. Include these anticipated consequences of climate change in the spill prevention plan contingency plans as relevant.

EAW item 8: Cover types

Minnesota is already 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., higher percentage loss of tree canopy or changes from natural vegetated areas to impervious surfaces like parking lots, roofs, and sidewalks). One approach for consideration in minimizing climate change effects 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. Green infrastructure does not include stormwater pond wet sedimentation basins. Stormwater ponds are not constructed infiltration systems.

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 installment (not the area that drains into the installment). 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 infrastructure installments included in the "green infrastructure" category are described below:

- **Constructed infiltration systems** – Examples of such infiltration systems include, but are not limited to:
    - **Raingardens** - Raingardens utilize 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. More information is

available on the Minnesota Pollution Control Agency's Green Infrastructure benefits of bioretention webpage.
    - **Bioswales** - 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 vegetation. 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. 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. 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. For the Twin Cities Region, the Growing Shade Mapping Tool provides a customized report showing tree canopy and other data for the specific geography (cities/townships, neighborhoods in Minneapolis and St. Paul, or census block group). *(Source: Metropolitan Council)*

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 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 (USDA, 2010).

EAW item 12: Water resources

Include 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 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
- Changes in streamflow highs and lows
- Increases in the frequency of freeze-thaw cycles
- Later ice in and earlier ice out
- Longer growing season

Climate change may amplify environmental impacts of a project. For example:

- If 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, it could lead to the water becoming even less hospitable for native aquatic species.
- Additional runoff may add contaminants to surface waters already more polluted by increased extreme precipitation and flooding from climate change.
- Increased use of groundwater added to greater frequency of drought may affect area wells and groundwater resources for multiple uses.

An available source for streamflow data projected for late century:

- Streamflow Projections Map: The tool provides historical streamflow observations and projected changes (ratio of projected future flows divided by baseline historical flows) for the late 21st century (2071-2100). Separate tabs are provided for future projected average flow, projected high flow, and projected low flow for both the "Wetter Projection" (90th percentile) and the "Drier Projection" (10th percentile). *(Source: Environmental Protection Agency)*

In the Projected Low Flow tab, three types of ratios are displayed - annual low, 2-yr low, and 10-year low. Zoom in to see colors on the map that provide a range for the annual low projected streamflow ratio for wetter or drier. Click on the table to the left of the map to select a specific period of time and projection scenario for all the grid cells with colors explained on the map legend. Click a grid cell on the map to get the specific projected low ratios for that general location for both wetter and drier and for the three ratio types.

In the Projected High Flow tab, zoom in to see colors on the map that provide a range for the annual high projected streamflow ratio for wetter or drier. Click on the table to the left of the map to select a scenario for all the grid cells with colors explained on the map legend. Click a grid cell on the map to get the specific projected high ratio for that general location for wetter and drier.

The Projected Average Flow tab is structured the same as the Projected High Flow tab. *(Source: Environmental Protection Agency)*

Wastewater

Include a characterization of potential climate-driven elements that may influence long-term wastewater disposal and to provide ideas on possible mitigation measures for these potential effects on wastewater.

An available source to assess climate change risk and explore mitigation measures:

- Climate Resilience Evaluation and Awareness Tool (CREAT) Risk Assessment Application for Water Utilities: This tool assists water sector utilities in assessing climate-related risks to utility assets and operations. Throughout CREAT's five modules, users consider climate impacts and identify adaptation options to increase resilience. *(Source: Environmental Protection Agency)*

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

- 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.
- Keep in mind that some fields are available for land application of septage only during certain times of the year. Consider whether the project as designed will have sufficient storage flexibility and proximate land availability to protect against changing precipitation patterns and increasing concerns about air and water quality.
- As applicable, explore whether mitigations such as setting up a regular septage-pumping schedule or spreading out the schedule over multiple months or years for a project with many septic systems will help provide sufficient protection.

Stormwater

Include a characterization of 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 changes 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 snowmelt, and the impacts of warmer temperatures may intensify the effects on water quality and quantity. Examples include:

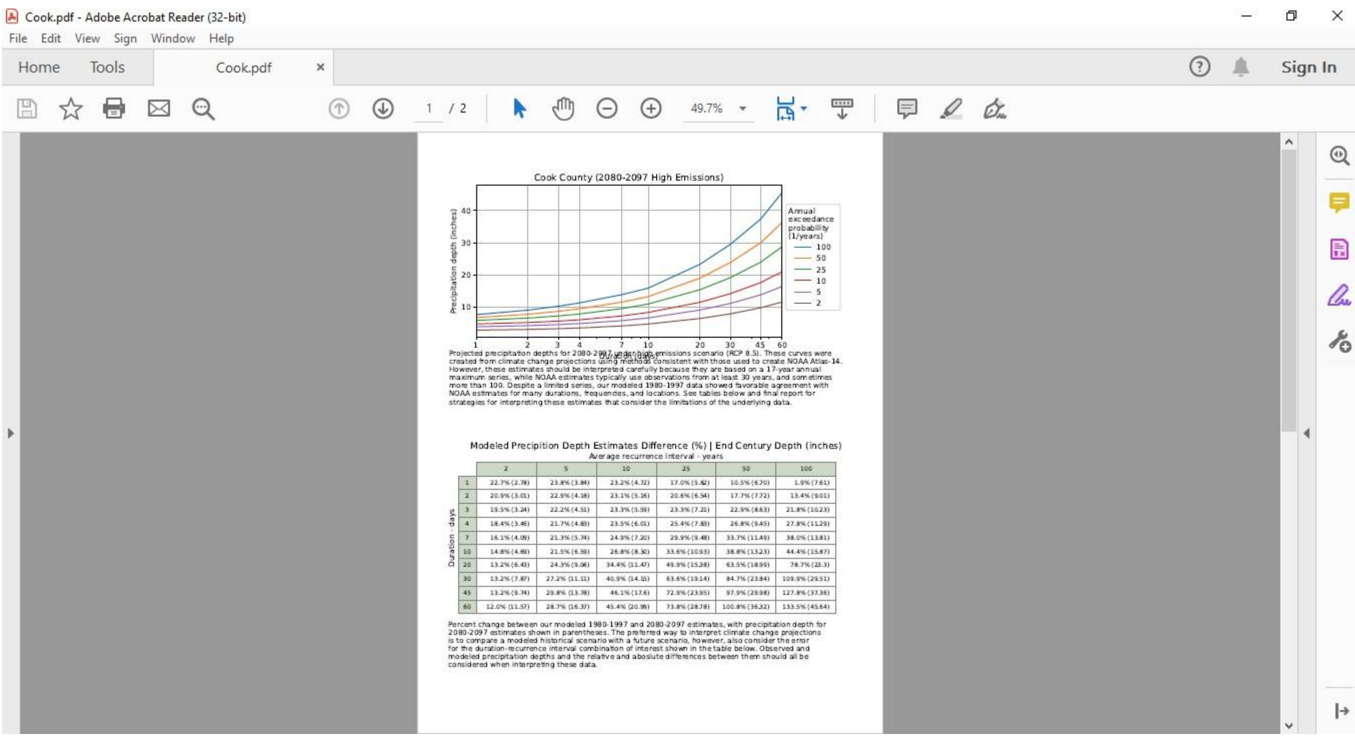
- Climate change trends toward more frequent and intense extreme precipitation, riverine flooding, localized flash flooding at streams, stormwater management facilities, and in upland areas lacking overflow and conveyance capacity.
- Winter warming leads to increased frequency and intensity of freeze/thaw cycles, which increases deicing chemical, salt, and sand application; these materials are eventually 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, including pathogens and environmental contaminants dangerous to people and livestock.
- With increased precipitation, stormwater management features become overwhelmed and have reduced effectiveness for controlling the rate of runoff or pollutant capture, leading to increased sediment and contaminants entering 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, leading to habitat loss or impacts to cropland and 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 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.

An available source for projected precipitation depths:

- [Equipping Municipalities with Climate Change Data to Inform Stormwater Management]: Read the Final Report and use the Minnesota county-level reports for more specificity about projected precipitation amounts over a range of durations and recurrence intervals (e.g., 100-year 24-hour storms) based on a high emissions scenario for the end-of-century time frame 2080-2097. This Atlas-14 replication for Minnesota's future climate utilizes the same downscaled 10km grid data from CMIP5 climate models as the Minnesota Climate Explorer. See example county report with data tables immediately below. The authors intend to update this Atlas-14 replication soon using Minnesota CliMAT dynamically downscaled 4km grid data which is based on CMIP6 climate models. *(Source: University of Minnesota Center for Science, Technology, and Environmental Policy)*

Image 6. Projected precipitation depths example from U of M Atlas-14 replication (CMIP5)



Projected precipitation depths for 2080-2097 under high emissions scenario (RCP 8.5). These curves were created from climate change projections using methods consistent with those used to create NOAA Atlas-14. However, these estimates should be interpreted carefully because they are based on a 17-year annual maximum series, while NOAA estimates typically use observations from at least 30 years, and sometimes more than 100. Despite a limited series, our modeled 1980-1997 data showed favorable agreement with NOAA estimates for many durations, frequencies, and locations. See tables below and final report for strategies for interpreting these estimates that consider the limitations of the underlying data.

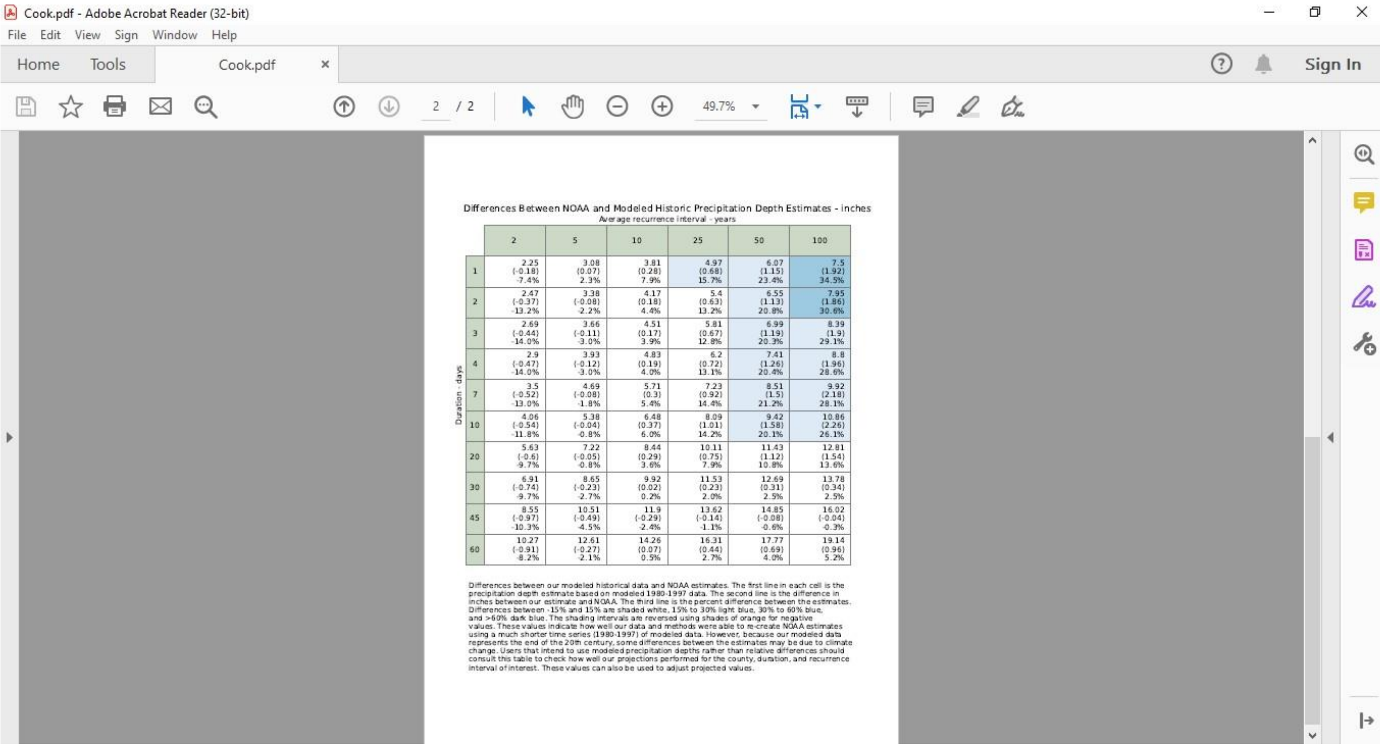
Modeled Precipition Depth Estimates Difference (%) | End Century Depth (inches)

Average recurrence interval - years

Duration - days	2	5	10	25	50	100
1	22.7% (2.78)	23.8% (3.84)	23.2% (4.72)	17.0% (5.82)	10.5% (6.70)	1.9% (7.61)
2	20.9% (3.01)	22.9% (4.18)	23.1% (5.16)	20.6% (6.54)	17.7% (7.72)	13.4% (9.01)
3	19.5% (3.24)	22.2% (4.51)	23.3% (5.59)	23.3% (7.21)	22.9% (8.63)	21.8% (10.23)
4	18.4% (3.46)	21.7% (4.83)	23.5% (6.01)	25.4% (7.83)	26.8% (9.45)	27.8% (11.29)
7	16.1% (4.09)	21.3% (5.74)	24.9% (7.20)	29.9% (9.48)	33.7% (11.49)	38.0% (13.81)
10	14.8% (4.69)	21.5% (6.59)	26.8% (8.30)	33.6% (10.93)	38.8% (13.23)	44.4% (15.87)
20	13.2% (6.43)	24.3% (9.06)	34.4% (11.47)	49.9% (15.38)	63.5% (18.99)	78.7% (23.3)
30	13.2% (7.87)	27.2% (11.11)	40.9% (14.15)	63.6% (19.14)	84.7% (23.84)	109.9% (29.51)
45	13.2% (9.74)	29.8% (13.78)	46.1% (17.6)	72.9% (23.95)	97.9% (29.98)	127.8% (37.36)
60	12.0% (11.57)	28.7% (16.37)	45.4% (20.99)	73.8% (28.78)	100.8% (36.32)	133.5% (45.64)

Percent change between our modeled 1980-1997 and 2080-2097 estimates, with precipitation depth for 2080-2097 estimates shown in parentheses. The preferred way to interpret climate change projections is to compare a modeled historical scenario with a future scenario, however, also consider the error for the duration-recurrence interval combination of interest shown in the table below. Observed and modeled precipitation depths and the relative and abosiute differences between them should all be considered when interpreting these data.

Image 7. Validation modeling of historic precipitation depths example from U of M Atlas-14 replication (CMIP5)



Differences Between NOAA and Modeled Historic Precipitation Depth Estimates - inches

Average recurrence interval - years

Duration - days	2	5	10	25	50	100
1	2.25 (-0.18) -7.4%	3.08 (0.07) 2.3%	3.81 (0.28) 7.9%	4.97 (0.68) 15.7%	6.07 (1.15) 23.4%	7.5 (1.92) 34.5%
2	2.47 (-0.37) -13.2%	3.38 (-0.08) -2.2%	4.17 (0.18) 4.4%	5.4 (0.63) 13.2%	6.55 (1.13) 20.8%	7.95 (1.86) 30.6%
3	2.69 (-0.44) -14.0%	3.66 (-0.11) -3.0%	4.51 (0.17) 3.9%	5.81 (0.67) 12.8%	6.99 (1.19) 20.3%	8.39 (1.9) 29.1%
4	2.9 (-0.47) -14.0%	3.93 (-0.12) -3.0%	4.83 (0.19) 4.0%	6.2 (0.72) 13.1%	7.41 (1.26) 20.4%	8.8 (1.96) 28.6%
7	3.5 (-0.52) -13.0%	4.69 (-0.08) -1.8%	5.71 (0.3) 5.4%	7.23 (0.92) 14.4%	8.51 (1.5) 21.2%	9.92 (2.18) 28.1%
10	4.06 (-0.54) -11.8%	5.38 (-0.04) -0.8%	6.48 (0.37) 6.0%	8.09 (1.01) 14.2%	9.42 (1.58) 20.1%	10.86 (2.26) 26.1%
20	5.63 (-0.6) -9.7%	7.22 (-0.05) -0.8%	8.44 (0.29) 3.6%	10.11 (0.75) 7.9%	11.43 (1.12) 10.8%	12.81 (1.54) 13.6%
30	6.91 (-0.74) -9.7%	8.65 (-0.23) -2.7%	9.92 (0.02) 0.2%	11.53 (0.23) 2.0%	12.69 (0.31) 2.5%	13.78 (0.34) 2.5%
45	8.55 (-0.97) -10.3%	10.51 (-0.49) -4.5%	11.9 (-0.29) -2.4%	13.62 (-0.14) -1.1%	14.85 (-0.08) -0.6%	16.02 (-0.04) -0.3%
60	10.27 (-0.91) -8.2%	12.61 (-0.27) -2.1%	14.26 (0.07) 0.5%	16.31 (0.44) 2.7%	17.77 (0.69) 4.0%	19.14 (0.96) 5.2%

Differences between our modeled historical data and NOAA estimates. The first line in each cell is the precipitation depth estimate based on modeled 1980-1997 data. The second line is the difference in inches between our estimate and NOAA. The third line is the percent difference between the estimates. Differences between -15% and 15% are shaded white, 15% to 30% light blue, 30% to 60% blue, and >60% dark blue. The shading intervals are reversed using shades of orange for negative values. These values indicate how well our data and methods were able to re-create NOAA estimates using a much shorter time series (1980-1997) of modeled data. However, because our modeled data represents the end of the 20th century, some differences between the estimates may be due to climate change. Users that intend to use modeled precipitation depths rather than relative differences should consult this table to check how well our projections performed for the county, duration, and recurrence interval of interest. These values can also be used to adjust projected values.

Water appropriation

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. Include an evaluation of how climate trends can impact the long-term sustainability of water appropriations needed for a project and how proposed water use is resilient, including at least the following:

- How the water use demand can be met with diversified sources of water to reduce short-term and long-term risks.
- Whether the demand for water use has been reduced through conservation and efficiency.
- Can some supply be met through water recycling and reuse, rainwater and stormwater harvesting, and/or other methods?
- If appropriations are restricted in times of short water supply due to climate change impacts such as drought, the feasibility of ceasing water appropriations as a contingency.

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

Include an assessment of how fish, wildlife, plant communities, and sensitive ecological resources interact with climate trends and predictions for the proposed project.

Available resources to consider:

- 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, and Chapter 3 identifies target habitat/ecosystems most sensitive to climate change. The Wildlife Action Network includes concepts such as, providing movement corridors along climate gradients and building-out protected habitat to provide ecotonal shifts. See also scientific references on page 36.
- 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, and 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.

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 include:

- Warming winters lead 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, and 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.

Appendix A. Default fuel heat content and stationary source emission factors

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

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
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 >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 [19]	0.126	138.57	0.0066	0.0013
B10 [20]	0.137	147.91	0.0066	0.0013

[19] 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)

[20] 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[21]	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)[22]	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

[21] EIA, Renewable Energy Annual (2009)

[22] USFS Forest Products laboratory, Fuel Value Calculator

Appendix B. 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, U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 2006, DOI: 10.2737/ne-gtr-343.
- 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)

Appendix C – Sources for technical information on energy efficiency and financial subsidies

Information on energy efficiency and financial subsidies is available from many sources, including, but not limited to the following:

Technical resources
Energy efficiency technical and financial information, Minnesota Department of Commerce: https://mn.gov/commerce/energy/conserving-energy/
Home energy efficiency, Minnesota Department of Commerce: https://mn.gov/commerce/energy/conserving-energy/efficiency/
Efficient home building, Minnesota Department of Commerce: https://mn.gov/commerce/energy/conserving-energy/efficient-buildings/
Home energy guide, Minnesota Department of Commerce: https://mn.gov/commerce-stat/pdfs/home-energy-guide.pdf
Energy efficiency consulting for single and multi-family new construction, Center for Energy and Environment (CEE): https://www.mncee.org/new-construction-services
Energy saving equipment on the farm, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/energy-saving-equipment-farm
Xcel Energy efficient buildings program, Xcel Energy: https://mn.my.xcelenergy.com/s/business/new-building-programs/energy-efficient-buildings
Energy efficiency strategies and upgrades, American Council for an Energy-Efficient Economy (ACEEE): https://www.aceee.org/topic/ee-strategies-and-upgrades
Design guides for energy efficient commercial buildings (including office buildings, K-12, big box retail, hospitals, and grocery stores), Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy: https://www.energy.gov/eere/buildings/advanced-energy-design-guides
Zero energy buildings resource hub, Office of Energy Efficiency and Renewable Energy, US Department of Energy: https://www.energy.gov/eere/buildings/zero-energy-buildings-resource-hub
Energy efficiency guidance for commercial new construction, Energy Star: https://www.energystar.gov/buildings/resources_audience/service_product_providers/commercial_new_construction
Save energy, commercial buildings, Energy Star: https://www.energystar.gov/buildings/save_energy_commercial_buildings?s=mega
Resources for residential new construction, Energy Star: https://www.energystar.gov/partner_resources/residential_new

Energy efficiency education and trainings, Building Science Corporation: https://buildingscience.com/service/education-and-training
Builder's guide to cold climates, Building Science Corporation: https://buildingscience.com/bookstore/books/builders-guide-cold-climates
Tools and guides, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/tools-guides
Resource for builders on zero-energy homes, Getting to Zero: https://gettingtozeroforum.org/residential-resources/
Advanced energy design guides for buildings, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): https://www.ashrae.org/technical-resources/aedgs
Financial resources
Opportunity for businesses to save on efficiency improvements, Center for Energy and Environment (CEE): https://www.mncee.org/179d-expansion-provides-another-opportunity-businesses-save-efficiency-improvements
Evaluate the economics of energy efficiency projects, Energy Star: https://www.energystar.gov/buildings/save_energy_commercial_buildings/economics_efficiency_projects
Tax incentives for energy-efficiency upgrades in commercial buildings, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, https://www.energy.gov/eere/buildings/tax-incentives-energy-efficiency-upgrades-commercial-buildings
Federal tax credits for builders of energy efficient homes, Energy Star: https://www.energystar.gov/about/federal_tax_credits/federal_tax_credit_archives/tax_credits_home_builders
Tax deductions for commercial buildings, Energy Star: https://www.energystar.gov/about/federal_tax_credits/tax_credits_commercial_buildings
Database of state incentives for renewables & efficiency, DSIRE: https://www.dsireusa.org/
Federal energy efficiency tax incentives, SmarterHouse: https://smarterhouse.org/resources/federal-tax-incentives
Grants for farmers and rural businesses, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/grants-farmers-rural-businesses

Appendix D - Sources for technical and financial information on electrifying appliances and equipment

Information on electrifying appliances and equipment, as well as on financial subsidies for electrification, is available, but not limited to, the following:

Technical resources
Ground source heat pumps, Minnesota Department of Commerce: https://mn.gov/commerce/energy/conserving-energy/ground-source/
Electrify Everything Minnesota, Minnesota Center for Energy and Environment (CEE): https://www.mncee.org/electrifyeverythingmn?home
Geothermal in Minnesota, Clean Energy Resource Teams (CERTS): https://www.cleanenergyresourceteams.org/geothermal-minnesota
Electrification resources, Getting to Zero: https://gettingtozeroforum.org/electrification/
Electrify everything in your home, Rewiring America: https://www.rewiringamerica.org/electrify-home-guide
Heat pump systems, Office of Energy Efficiency and Renewable Energy, U.S Department of Energy: https://www.energy.gov/energysaver/heat-pump-systems
Cold climate air source heat pump technical information, Northeast Energy Efficiency Partnerships: https://neep.org/high-performance-air-source-heat-pumps/air-source-heat-pump-installer-and-consumer-resources
Industrial heat pumps: electrifying industry's process heat supply, American Council on an Energy Efficient Economy (ACEEE): https://www.aceee.org/research-report/ie2201
Electrifying space heating in existing commercial buildings, American Council on an Energy Efficient Economy (ACEEE): https://www.aceee.org/research-report/b2004
Air-source heat pumps, Energy Star: https://www.energystar.gov/products/air_source_heat_pumps
Electrification, U.S. Green Building Council: https://www.usgbc.org/about/priorities/electrification
Financial information
Federal rebates, tax credits, energy efficiency programs, Minnesota Department of Commerce: https://mn.gov/commerce/energy/federal-rebates/
Federal energy efficiency tax incentives, SmarterHouse: https://smarterhouse.org/resources/federal-tax-incentives
Guide to the inflation reduction act, Rewiring America: https://www.rewiringamerica.org/IRAguide

IRA savings calculator, Rewiring America: https://www.rewiringamerica.org/app/ira-calculator
The Inflation Reduction Act: What you need to know (scroll down to "Residents + Energy Efficiency Rebates" and "Residents + Heat Pumps"), Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/inflation-reduction-act-what-you-need-know

Appendix E - Sources for technical and financial assistance information on electricity generation

Considerable financial support is available for solar power and storage through tax credits and rebates. Additional technical and financial assistance information is available, but not limited to, the following:

Technical Resources
Solar energy for homes, Minnesota Department of Commerce: https://mn.gov/commerce/energy/solar-wind/solar-for-homes/
Minnesota solar guide, Minnesota Department of Commerce: https://mn.gov/commerce-stat/pdfs/solar-directory.pdf
Minnesota solar pathways solar guide, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/minnesota-solar-guide
Community solar gardens, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/solargardens
Powering K-12 education with solar energy, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/solarschools
Homeowner's guide to going solar, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy: https://www.energy.gov/eere/solar/homeowners-guide-going-solar
Wind energy for homes, Minnesota Department of Commerce: https://mn.gov/commerce/energy/solar-wind/wind-energy-homes/
Small wind energy systems, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/small-wind-energy-systems
Renewable energy for businesses and organizations, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/businesses-organizations
Buy renewable energy from your utility, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/green-pricing
Renewable opportunities, Xcel Energy: https://mn.my.xcelenergy.com/s/renewable
Renewable choices, Minnesota Power: https://www.mnpower.com/ProgramsRebates/RenewableChoices
Renewable energy, Otter Tail Power: https://www.otpco.com/ways-to-save/renewable-energy-residential/
Lease your land for solar or wind, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/lease-your-land-solar-or-wind
Renewable energy for greater Minnesota, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/greatrenewables
Financial Information
Grants for farmers and rural businesses, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/grants-farmers-rural-businesses
Federal Solar Tax Credits for Businesses, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy: https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses
Questions about the inflation reduction act guide, Clean Energy Resource Teams (CERTs):

https://www.cleanenergyresourceteams.org/tools-guides
The inflation reduction act: What you need to know (scroll down to "Commercial"), Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/inflation-reduction-act-what-you-need-know
Model RFP for third-party solar, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/3rdpartyrfp
Database of state incentives for renewables & efficiency, DSIRE: https://w ww.dsireusa.org/

Appendix F – Sources for technical and financial assistance information on transportation electrification

Projects that involve mobile sources can reduce GHG emissions by electrifying their fleets or on-site mobile equipment and by providing electric vehicle charging stations. Additional technical and financial assistance information is available, but not limited to, the following:

Technical resources
Finding the best options to electrify your fleet, Drive Electric Minnesota: https://driveelectricmn.org/electrify-your-fleet/
Adding EV chargers to homes and workplaces, Drive Electric Minnesota: https://driveelectricmn.org/electric-vehicles/businesses-and-employers/
Electrify fleets & support charging, Clean Energy Resource Teams (CERTs): https://www.cleanenergyresourceteams.org/cities-charging-ahead
90 minute course on EVs and charging for architects, developers & real estate professionals, Shift2Electric: https://www.shift2electric.com//realestatepro
Workplace charging for electric vehicles, Office of Energy Efficiency & Renewable Energy, U.S Department of Energy: https://afdc.energy.gov/fuels/electricity_charging_workplace.html
Smartway heavy-duty truck electrification resources, U.S. Environmental Protection Agency: https://www.epa.gov/smartway/smartway-heavy-duty-truck-electrification-resources
Financial information
Clean vehicle credit for commercial use of EVs, Internal Revenue Service: https://www.irs.gov/credits-deductions/commercial-clean-vehicle-credit

Appendix G - Sources for technical and financial assistance information on land use GHG emissions

Projects can reduce GHG emissions associated with land use, and even create GHG sinks, such as through best practices in land-use management, nutrient and sediment run-off control, on-site terrestrial biogenic carbon sequestration, and wetland mitigation, among others. Additional technical and financial assistance information is available at:

Technical resources
Greenhouse gas reduction potential of agricultural best management practices, Minnesota Pollution Control Agency: https://www.pca.state.mn.us/sites/default/files/p-gen4-19.pdf
Climate change trends and action plan, Minnesota Board of Water and Soil Resources: Climate Change Trends + Action Plan 2022.pdf (state.mn.us)
Nature and climate solutions for Minnesota, The Nature Conservancy: https://www.nature.org/content/dam/tnc/nature/en/documents/NCSinMinnesotaReport_01.11.2021.pdf
Climate-smart agriculture and forestry mitigations (includes eligible financial support through EQIP, CSP, and other programs), Natural Resources Conservation Service of the U.S. Department of Agriculture: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/climate/climate-smart-mitigation-activities
Virtual farm, Carbon calculator tool from Penn State's College of Agricultural Sciences and Penn State Extension, in collaboration with the University of Wisconsin-Madison: https://www.virtualfarm.psu.edu/virtual-farm/