Estimation of Greenhouse Gas Emissions

Recommended Methods for Selected Stationary Source Categories

Last Updated January 2, 2025

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Table of Contents

Table of Figures

Acronyms and Key Terms

ASTM	American Society for Testing and Materials
CEM	Continuous Emissions Monitor
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DNR	Iowa Department of Natural Resources
DSCFM	Dry Standard Cubic Feet per Minute
EIIP	Emission Inventory Improvement Program
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
GWP	Global Warming Potential
HAP	Hazardous Air Pollutant
HFC	Hydrofluorocarbons
HFE	Hydrofluorinated ethers
IAC	Iowa Administrative Code
IPCC	Intergovernmental Panel on Climate Change
LBS	Pounds
LPG	Liquefied Petroleum Gas
MMBtu	Million British Thermal Units
MMcf	Million Cubic Feet
MMscf	Million Standard Cubic Feet
$mtCO_2e$	Metric Tons of Carbon Dioxide Equivalent
NACAA	National Association of Clean Air Agencies
N_2O	Nitrous Oxide
NF_3	Nitrogen Trifluoride
NO_X	Nitrogen Oxides
PFC	Perfluorocarbons
PSD	Prevention of Significant Deterioration
SCF	Standard Cubic Feet
SF_6	Sulfur Hexafluoride

Chapter 1: Introduction

Purpose

This document provides guidance for estimating greenhouse gas emissions from select stationary sources. It is intended to reflect the most recent information on data sources, emission factors, and methods that are consistent with EPA guidance. There are several different chemicals considered greenhouse gases. 567 IAC 20.2 defines greenhouse gas as meaning:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFC)
- Perfluorocarbons (PFC)
- Sulfur hexafluoride (SF_6)

Emission estimate methods discussed in this document consider stationary source emissions only. It does not cover emissions from fuel suppliers or any sources such as vehicle miles traveled, offsite waste disposal, or electricity consumption.

This document does not mandate the use of specific estimation methods, but recommends appropriate emission factors and estimation methods. It is intended to be a living document which the DNR plans to periodically update to incorporate new or updated emission factors and methods as they become available. Suggest uses of the document by facilities may include:

- Calculating actual emissions to determine if a facility is subject to the federal Greenhouse Gas Reporting Program (GHGRP).
- Calculating potential emissions for Iowa DNR construction permit applications.
- Calculating potential emissions to evaluate applicability for permit programs such as Prevention of Significant Deterioration (PSD).

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Chapter 2: Emissions Estimation Methods

This chapter provides a general overview of available methods for estimating emissions. For greenhouse gas emissions, EPA states that the estimation methods prescribed in the federal Mandatory Reporting of Greenhouse Gases[1] rule (also known as the Greenhouse Gas Reporting Program (GHGRP)) should be used as a primary reference in emissions inventories and permit applications.[2] This document is consistent with EPA's recommendation and discusses estimation methods for specific source categories in Chapters 3, 4, and 5 of this document. Additional resources for estimation methods are listed at the end of this chapter.

When selecting the method used to calculate emissions, it is important to understand the difference between potential and actual emissions. In general, **potential emissions** reflect the emissions that will occur if an emission unit is operated at its maximum design rate for an entire year (8,760 hours). Federal enforceable limits may be used to reduce the calculated potential emissions. Examples of federally enforceable limits found in permits include restrictions on the amount of fuel burned, hours operated, or raw material processed. **Actual emissions** are the actual rate of pollutant emissions from an emission unit calculated using the emission unit's actual operating hours, production rates, and quantities of materials processed, stored, or combusted for the calendar year. Please refer to the definitions of both potential to emit and actual emissions from 567 IAC 22.100 located in the glossary of this document. Examples of both potential and actual emission calculations can be found on pages 13 – 14 of this document.

General Hierarchy

Emissions must be based on the best possible method and may vary between source categories. In general, DNR recommends that greenhouse gas emissions be calculated using the same hierarchy of estimation methods as used for criteria and hazardous air pollutants. The methods listed below are in order of decreasing accuracy. Supporting documentation that allows DNR to recreate your calculations should be included for any calculations that cannot be easily verified. Please note that CEM data and stack tests are measures of actual emissions during a specific time period.

1. ***Continuous Emissions Monitoring (CEM)*** systems directly measure pollutant concentrations in the exhaust stack 24 hours a day. This is the most accurate method for determining actual emissions.

[1] §40 CFR 98.

[2] See "Resources for Estimating Greenhouse Gas Emissions".

Most likely used for: CO_2 emissions from utilities, Portland cement plants, large combustion units, or other units with CEMs.

2. A ***Stack Test*** measures the concentration of pollutants in the exhaust stack during the test period. Stack test data can provide an accurate source-specific emission rate for many different processes and pollutants.

   Most likely used for: CO_2 emissions from combustion sources and other process-related CO_2 emissions from specific source categories.

3. ***Material Balance or Mass Balance*** can only be used on specific types of emission units. Information must first be gathered on process rates, material used, and material properties (usually from ***material safety data sheets*** (MSDS)). By combining this information with the knowledge of the process, an emission estimation can be made.

   Most likely used for: SF_6, HFC, and PFC emissions.

4. ***Emission Factors*** are the basis for many calculations. Emission factors represent industry averages and show the relationship between emissions and a measure of production. Emission factors for select industries and processes, as well as reference sources for additional information, are provided in this document.

   Most likely used for: CO_2, CH_4, and N_2O emissions from fossil fuel combustion.

5. ***Vendor Supplied Factors*** may be used if a more preferred method is not available. This data may be used to calculate emissions if the manufacturer's data is based on approved stack testing and no significant changes have been made to the emission unit. Supporting documentation must be submitted to show how the estimation was made.

6. ***Engineering Estimation*** is allowed if a more preferred method is not available. Some processes may have no published guidance regarding the estimation of emissions. In these cases, the estimation must be the best possible assessment given the amount of data available. Supporting documentation must be submitted to show how the estimation was made.

Other Greenhouse Gas-Specific Resources

On its New Source Review Website, EPA has published a list of resources that may prove useful to sources and permitting authorities in identifying, characterizing and estimating greenhouse gas emissions. The list includes:

- Federal Greenhouse Gas Reporting Program (GHGRP)
- ENERGY STAR Industrial Sector Energy Guides and Plant Energy Performance Indicators (benchmarks)
- Inventory of U.S. Greenhouse Gas Emissions and Sinks
- EPA's Voluntary Partnerships for Greenhouse Gas Reductions:
    - Landfill Methane Outreach Program (LMOP)
    - Combined Heat and Power (CHP) Partnership Program
    - Green Power Partnership
    - Coalbed Methane Outreach Program (CMOP)
    - Methane Programs for the Oil and Natural Gas Industry
    - Fluorinated Gas Partnership Programs

Other sources include:

- The Climate Registry Reporting Protocols
- The Greenhouse Gas Protocol Initiative

Chapter 3: Stationary Fossil Fuel Combustion Sources

CO_2, N_2O, and CH_4 are all emitted from the combustion of fossil fuels from stationary sources. CO_2 is formed from the oxidation of the fuel carbon, CH_4 is a production of incomplete combustion, and N_2O is formed by oxygen-nitrogen reactions. DNR recommends that emissions of these pollutants be calculated using the estimation methods and emission factors in the federal Greenhouse Gas Reporting Program (GHGRP) in 40 CFR 98 Subpart C. This subpart includes four methods (called tiers) for calculating actual GHG emissions from stationary fossil fuel combustion sources:

Table 1 – Tiers in 40 CFR 98 Subpart C

Tier	Method
Tier 4	Calculate emissions using CEMs data.
Tier 3	Calculates emissions from solid and liquid fuels using annual average carbon content from fuel sampling and an annual average molecular weight for gaseous fuels.
Tier 2	Calculates emissions using an annual average high heat value (HHV) from fuel sampling and a default emission factor.
Tier 1	Calculates emissions using a default HHV and a default emission factor.

DNR does not require use of a specific tier method, but **actual** greenhouse gas emissions from stationary fossil fuel combustion should be calculated in a similar approach:

1. CEMs data. If not available then,
2. Stack test data. If not available then,
3. Fuel sampling data and a default emission factor. If not available then,
4. A default HHV and a default emission factor.

Potential greenhouse gas emissions should be calculated using the maximum design rate of the emission unit in conjunction with any federally enforceable permit limits and:

1. Fuel sampling data and a default emission factor. If not available then,
2. A default HHV and a default emission factor.

If using a default HHV or default emission factor to calculate potential or actual greenhouse gas emissions, use the value listed in Table C-1 and C-2 of §40 CFR 98 Subpart C. These tables have been included in this document for convenience as Tables 2 and 3. Conversions for units of measure can be found in Appendix A of this document. The DNR has also developed a spreadsheet-based calculation tool using these emission factors called "Stationary Fossil Fuel Combustion Tool.xls" that can be used to calculate both potential and actual emissions.

The §40 CFR 98 Subpart C CO_2 emission factors assume 100% of the carbon in the fuel is converted to CO_2. They are comparable to emission factors found in WebFIRE[3] and to the emission factors that DNR used on its GHG reporting spreadsheets for 2007 – 2009, but vary slightly because of differences in the high heating values used to generate the emission factors. The §40 CFR 98 Subpart C CH_4 and N_2O emission factors are from Intergovernmental Panel on Climate Change (IPCC) estimation guidelines and are more conservative than their corresponding CH_4 and N_2O emission factors in AP-42[4] and WebFIRE, which are based on test data.

Table 2 - Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel[5]

Fuel Type	Default High Heat Value (HHV)	Default CO_2 emission factor	
Coal and Coke	MMBtu/ton[6]	kg CO_2/MMBtu	lb CO_2/MMBtu[7]
Anthracite	25.09	103.69	228.60
Bituminous	24.93	93.28	205.65
Subbituminous	17.25	97.17	214.22
Lignite	14.21	97.72	215.44
Coal Coke	24.80	113.67	250.60
Mixed (Commercial sector)	21.39	94.27	207.83
Mixed (Industrial coking)	26.28	93.90	207.01
Mixed (Industrial sector)	22.35	94.67	208.71
Mixed (Electric Power sector)	19.73	95.52	210.59
Natural Gas	MMBtu/scf	kg CO_2/MMBtu	lb CO_2/MMBtu
(Weighted U.S. Average)	1.026×10^{-3}	53.06	116.98
Petroleum Products	MMBtu/gallon	kg CO_2/MMBtu	lb CO_2/MMBtu
Distillate Oil No. 1	0.139	73.25	161.49
Distillate Oil No. 2	0.138	73.96	163.05
Distillate Oil No. 4	0.146	75.04	165.43
Residual Fuel Oil No. 5	0.140	72.93	160.78
Residual Fuel Oil No. 6	0.150	75.10	165.57
Used Oil	0.138	74.00	163.14
Kerosene	0.135	75.20	165.79
Liquefied petroleum gases (LPG)	0.092	61.71	136.05
Propane	0.091	62.87	138.60
Propylene	0.091	67.77	149.41
Ethane	0.068	59.60	131.40
Ethanol	0.084	68.44	150.88
Ethylene	0.058	65.96	145.22

[3] U.S. EPA, WebFIRE - Factor Information Retrieval (FIRE) Data System, 2005.

[4] U.S. EPA, AP-42 Compilation of Air Pollutant Emission Factors, Volume 1, Fifth Edition, 1995.

[5] From Table C-1 of §40 CFR 98 Subpart C as amended on December 9, 2016.

[6] Table C-1 of §40 CFR 98 Subpart C uses the term "short ton", which DNR refers to throughout this document as "ton".

[7] Table C-1 of §40 CFR 98 lists only the kg/MMBtu emission factors. DNR has converted them to lb/MMBtu for convenience using a conversion of 1 kg = 2.20462 lbs.

Table 2 (continued)

Petroleum Products	MMBtu/gallon	kg CO_2/MMBtu	lb CO_2/MMBtu
Isobutane	0.099	64.94	143.17
Isobutylene	0.103	68.86	151.81
Isobutylene	0.103	68.86	151.81
Butane	0.103	64.77	142.79
Butylene	0.105	68.72	151.50
Naphtha (<401 deg F)	0.125	68.02	149.96
Natural Gasoline	0.110	66.88	147.44
Other Oil (>401 deg F)	0.139	76.22	168.04
Pentanes Plus	0.110	70.02	154.37
Petrochemical Feedstocks	0.125	71.02	156.57
Petroleum Coke	0.143	102.41	225.78
Special Naphtha	0.125	72.34	159.48
Unfinished Oils	0.139	74.54	164.33
Heavy Gas Oils	0.148	74.92	165.17
Lubricants	0.144	74.27	163.74
Motor Gasoline	0.125	70.22	154.81
Aviation Gasoline	0.120	69.25	152.67
Kerosene-Type Jet Fuel	0.135	72.22	159.22
Asphalt and Road Oil	0.158	75.36	166.14
Crude Oil	0.138	74.54	164.33
Other fuels - solid	MMBtu/ ton	kg CO_2/MMBtu	lb CO_2/MMBtu
Municipal Solid Waste (MSW)	9.95	90.7	200.11
Tires	28.00	85.97	189.53
Plastics	38.00	75.00	165.35
Petroleum Coke	30.00	102.41	225.78
Other fuels - gaseous	MMBtu/scf	kg CO_2/MMBtu	lb CO_2/MMBtu
Blast Furnace Gas	0.092×10^{-3}	274.32	604.77
Coke Oven Gas	0.599×10^{-3}	46.85	103.29
Propane Gas	2.516×10^{-3}	61.46	135.50
Fuel Gas[7]	1.388×10^{-3}	59.00	130.07
Biomass fuels - solid	MMBtu/ton	kg CO_2/MMBtu	lb CO_2/MMBtu
Wood and Wood Residuals (dry basis)	17.48	93.80	206.79
Agricultural Byproducts	8.25	118.17	260.52
Peat	8.00	111.84	246.56
Solid Byproducts	10.39	105.51	232.61
Biomass Fuels - gaseous	MMBtu/scf	kg CO_2/MMBtu	lb CO_2/MMBtu
Landfill Gas	0.485×10^{-3}	52.07	114.79
Other Biomass Gases	0.655×10^{-3}	52.07	114.79
Biomass Fuels - liquid	MMBtu/gallon	kg CO_2/MMBtu	lb CO_2/MMBtu
Ethanol	0.084	68.44	150.88
Biodiesel (100%)	0.128	73.84	162.79
Rendered Animal Fat	0.125	71.06	156.66
Vegetable Oil	0.120	81.55	179.79

Table 3 - Default CH_4 and N_2O Emission Factors for Various Types of Fuel[8]

	Default CH_4Emission Factor		Default N_2O Emission Factor	
Fuel Type	**kg CH_4/MMBtu**	**lb CH_4/MMBtu[9]**	**kg N_2O/MMBtu**	**lb N_2O/MMBtu[9]**
Coal and Coke (All fuel types in Table C-1)	1.1×10^{-02}	2.4×10^{-02}	1.6×10^{-03}	3.5×10^{-03}
Natural Gas	1.0×10^{-03}	2.2×10^{-03}	1.0×10^{-04}	2.2×10^{-04}
Petroleum (All fuel types in Table C-1)	3.0×10^{-03}	6.6×10^{-03}	6.0×10^{-04}	1.3×10^{-03}
Fuel Gas	3.0×10^{-03}	6.6×10^{-03}	6.0×10^{-04}	1.3×10^{-03}
Municipal Solid Waste	3.2×10^{-02}	7.1×10^{-02}	4.2×10^{-03}	9.3×10^{-03}
Tires	3.2×10^{-02}	7.1×10^{-02}	4.2×10^{-03}	9.3×10^{-03}
Blast Furnace Gas	2.2×10^{-05}	4.9×10^{-05}	1.0×10^{-04}	2.2×10^{-04}
Coke Oven Gas	4.8×10^{-04}	1.1×10^{-03}	1.0×10^{-04}	2.2×10^{-04}
Biomass Fuels – Solid (All fuel types in Table C-1, except wood and wood residuals)	3.2×10^{-02}	7.1×10^{-02}	4.2×10^{-03}	9.3×10^{-03}
Biomass Fuels – Gaseous (All fuel types in Table C-1)	3.2×10^{-03}	7.1×10^{-03}	6.3×10^{-04}	1.4×10^{-03}
Biomass Fuels – Liquid (All fuel types in Table C-1)	1.1×10^{-03}	2.4×10^{-03}	1.1×10^{-04}	2.4×10^{-04}

Examples

Example 1

Calculate the actual CO_2, CH_4, and N_2O emissions from a natural gas boiler that combusted 25,500,000 standard cubic feet (scf) of natural gas in a given year. No CEMS, stack test, or fuel sampling data is available. [10]

$$CO_2 = \frac{25{,}500{,}000 \text{ scf}}{\text{year}} \times \frac{1.026 \text{ x } 10^{-03} \text{ MMBtu}}{\text{scf}} \times \frac{116.98 \text{ lbs. } CO_2}{\text{MMBtu}} \times \frac{\text{ton}}{2{,}000 \text{ lbs.}} = 1{,}530.27 \text{ tons } CO_2$$

$$1{,}530.27 \text{ tons } CO_2 \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 1{,}388.23 \text{ metric tons } CO_2$$

[8] From Table C-1 of §40 CFR 98 Subpart C as amended on December 9, 2016.

[9] Table C-2 of §40 CFR 98 Subpart C lists only the kg/MMBtu emission factors. DNR has converted them to lb/MMBtu for convenience using a conversion of 1 kg = 2.20462 lbs.

[10] The example equations include conversions from tons to metric tons as examples for those facilities subject to the US EPA GHGRP, which requires reporting in units of metric tons.

$$CH_4 = \frac{25{,}500{,}000 \text{ scf}}{\text{year}} \times \frac{1.026 \text{ x } 10^{-3} \text{ MMBtu}}{\text{scf}} \times \frac{2.2 \text{ x } 10^{-03} \text{ lbs. } CH_4}{\text{MMBtu}} \times \frac{\text{ton}}{2{,}000 \text{ lbs.}} = 0.029 \text{ tons } CH_4$$

$$0.029 \text{ tons } CH_4 \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 0.026 \text{ metric tons } CH_4$$

$$N_2O = \frac{25{,}500{,}000 \text{ scf}}{\text{year}} \times \frac{1.026 \text{ x } 10^{-3} \text{ MMBtu}}{\text{scf}} \times \frac{2.2 \text{ x } 10^{-04} \text{ lbs. } N_2O}{\text{MMBtu}} \times \frac{\text{ton}}{2{,}000 \text{ lbs.}} = 0.0029 \text{ tons } N_2O$$

$$0.0029 \text{ tons } N_2O \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 0.0026 \text{ metric tons } N_2O$$

Example 2

Calculate the potential CO_2, CH_4, and N_2O emissions from a generator that has a maximum hourly rated capacity of 75 gallons per hour of residual fuel oil #6.

$$CO_2 = \frac{75 \text{ gallons}}{\text{hour}} \times \frac{0.150 \text{ MMBtu}}{\text{gallons}} \times \frac{165.57 \text{ lbs. } CO_2}{\text{MMBtu}} \times \frac{8{,}760 \text{ hours}}{\text{year}} \times \frac{\text{ton}}{2{,}000 \text{ lbs.}} = \frac{8{,}158.46 \text{ tons } CO_2}{\text{year}}$$

$$8{,}158.46 \text{ tons } CO_2 \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 7{,}401.19 \text{ metric tons } CO_2$$

$$CH_4 = \frac{75 \text{ gallons}}{\text{hour}} \times \frac{0.150 \text{ MMBtu}}{\text{gallons}} \times \frac{6.6 \text{ x } 10^{-03} \text{ lbs. } CH_4}{\text{MMBtu}} \times \frac{8{,}760 \text{ hours}}{\text{year}} \times \frac{\text{ton}}{2000 \text{ lbs.}} = \frac{0.33 \text{ tons } CH_4}{\text{year}}$$

$$0.33 \text{ tons } CH_4 \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 0.30 \text{ metric tons } CH_4$$

$$N_2O = \frac{75 \text{ gallons}}{\text{hour}} \times \frac{0.150 \text{ MMBtu}}{\text{gallons}} \times \frac{1.3 \text{ x } 10^{-03} \text{ lbs. } CH_4}{\text{MMBtu}} \times \frac{8{,}760 \text{ hours}}{\text{year}} \times \frac{\text{ton}}{2000 \text{ lbs.}} = \frac{0.06 \text{ tons } N_2O}{\text{year}}$$

$$0.06 \text{ tons } N_2O \times \frac{0.90718 \text{ metric tons}}{\text{ton}} = 0.05 \text{ metric tons } N_2O$$

To learn how to convert the greenhouse gas emissions in units of carbon dioxide equivalents (CO_2e), please see Chapter 6 of this document.

Chapter 4: CO_2, CH_4, and N_2O Emissions from Industrial and Other Source Categories

Greenhouse gases are also emitted from several stationary source categories (other than fossil fuel combustion) that may currently operate in Iowa. If CEMS or stack test data is not available, the estimation methods in the federal Greenhouse Gas Reporting Program (GHGRP) in §40 CFR 98 should be used. However, some exceptions are noted below. In general, GHG emissions from stationary fossil fuel combustion sources in these source categories should be calculated using GHGRP - §40 CFR 98.30 Subpart C unless the industry-specific GHGRP subpart contains another method be used. Table 4 below includes only source categories that DNR assumes currently operate in Iowa. A full list of the source categories covered by the federal GHGRP in §40 CFR 98 is included in this document as Appendix B.

Table 4 – Recommended Emission Estimated Methods for Industrial and Other Source Categories

Source Categories	Recommended Estimation Method
Ammonia Manufacturing	GHGRP - §40 CFR 98.70 (Subpart G)
Brick Manufacturing	GHGRP - §40 CFR 98.30 (Subpart C)[11]
Cement Production	GHGRP - §40 CFR 98.80 (Subpart H)
Electricity Generation	GHGRP - §40 CFR 98.40 (Subpart D)
Ethanol Fermentation	*DRAFT - GHG Emissions Estimation Methodology for Selected Biogenic Source Categories*.[12]
Glass Production	GHGRP - §40 CFR 98.140 (Subpart N)
Gypsum Manufacturing	GHGRP - §40 CFR 98.30 (Subpart C)[13]
Hot Mix Asphalt Plants	GHGRP - §40 CFR 98.30 (Subpart C)[14]
Iron and Steel Production	GHGRP - §40 CFR 98.170 (Subpart Q)
Industrial Waste Landfills	• GHGRP - §40 CFR 98.460 (Subpart TT) • See also *DRAFT - GHG Emissions Estimation Methodology for Selected Biogenic Source Categories*.[15]
Industrial Wastewater Treatment	• GHGRP -§40 CFR 98.350 (Subpart II) • See also *DRAFT - GHG Emissions Estimation Methodology for Selected Biogenic Source Categories*.[16]
Lime Manufacturing	GHGRP - §40 CFR 98.190 (Subpart S)
Miscellaneous Uses of Carbonate[17]	GHGRP - §40 CFR 98.210 (Subpart U)

[11] No process GHG emissions emitted. GHGs are emitted from fossil fuels combusted in the kiln and dryer.
[12] RTI International. *DRAFT - GHG Emissions Estimation Methodology for Selected Biogenic Source Categories* (2010): 4-1 – 4-6.
[13] No process GHG emissions emitted. GHGs are emitted from fossil fuels combusted in the calciner and dryer.
[14] No process GHG emissions emitted. GHGs are emitted from fossil fuels combusted in the dryer and hot oil heater.
[15] RTI International 2-1 – 2-14.
[16] RTI International 3-1 – 3-12.
[17] This includes greenhouse gas emissions from soda ash used in corn wet milling.

Table 4 (continued)

Source Categories	• Recommended Estimation Method
Municipal Solid Waste Landfills	• LandGEM [18] • See also *DRAFT* - *GHG Emissions Estimation Methodology for Selected Biogenic Source Categories*.[19]
Nitric Acid Production	GHGRP - §40 CFR 98.220 (Subpart V)
Petrochemical Production	GHGRP - §40 CFR 98.240 (Subpart X)
Petroleum and Natural Gas Systems	GHGRP - §40 CFR 98.230 (Subpart W)
Pulp and Paper Manufacturing	GHGRP - §40 CFR 98.270 (Subpart AA)
Wastewater Treatment	• See Industrial Wastewater Treatment above. • See also *DRAFT* - *GHG Emissions Estimation Methodology for Selected Biogenic Source Categories*.[20]

[18] United States Environmental Protection Agency. *Landfill Gas Emissions Model (LandGEM), version 3.03* (2020).

[19] RTI International. *DRAFT* - GHG Emissions Estimation Methodology for Selected Biogenic Source Categories (2010): 2-1 – 2-14.

[20] RTI International 3-1 – 3-12.

Chapter 5: Fluorinated Gases (HFC, PFC, and SF_6)

The 1990 Clean Air Act Amendments and the Montreal Protocol phase out the use of ozone depleting substances, and hydrofluorocarbons (HFCs) are currently used as an alternative. Some perfluorocarbons (PFCs) are currently used as well, but on a much smaller scale.[21] Sulfur hexafluoride (SF_6) is used primarily by electric utilities in transmission and distribution, accounting for approximately 77% of U.S SF_6 emissions in 2014.[22] It is also used in semiconductor manufacturing and can also be used in thermal, sound, and high voltage insulation. Table 5 below only includes source categories the DNR assumes currently operate in Iowa. A full list of the source categories covered by the federal GHGRP in §40 CFR 98 is included in this document as Appendix B.

Table 5 – Recommended Emission Estimation Methods for HFC, PFC, and SF_6

Source Categories	Recommended Estimation Method
Electronics Manufacturing	GHGRP – §40 CFR 98.90 (Subpart I)
Electric Transmission and Distribution Equipment – Manufacture Of	GHGRP - §40 CFR 98.450 (Subpart SS)
Electric Transmission and Distribution Equipment – Use Of	GHGRP - §40 CFR 98.300 (Subpart DD)
Magnesium Production	GHGRP – §40 CFR 98.200 (Subpart T)
Substitutes for Ozone-Depleting Substances • Aerosols • Fire extinguishing equipment • Fire suppression and explosion protection • Foam production • Insulation – high voltage, sound, thermal • Refrigeration and air conditioning • Solvent cleaning • Sterilization	Mass Balance Equation – see below

Mass Balance Estimation Method

Actual emissions of HFC, PFC, and SF_6, also known as F-gas emissions, from substitutes of ozone depleting substances should be using a mass balance equation that derives emissions from a facility's inventory of F-gases, subtracting the quantity consumed and quantity recovered as shown in Equation 4 below.

[21] Ashford et al, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 7: Emissions of Fluorinated Substitutes for Ozone Depleting Substances* (2006): 7.7.

[22] U.S.EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (2024): p. ES-4.

Equation 4:

Emissions (lbs.) = Quantity Added (lbs.) – Quantity Consumed (lbs.) – Quantity Recovered (lbs.)

Global Warming Potentials

Fluorinated gases have high global warming potentials (GWPs), values used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are further discussed in Chapter 6 of this document.

Chapter 6: Converting to Carbon Dioxide Equivalent (CO_2e)

As discussed in Chapter 5, the potency of various greenhouse gases can vary and are indicated by the pollutants' GWP. Greenhouse gas emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO_2e) that allows for better comparison of the impact of different greenhouse gases. CO_2e is calculated by multiplying the mass amount of each greenhouse gas by its GWP and then summing the resulting value. CO_2e should be calculated using Equation 5 below:

Equation 5:

$$tons\ CO2e = \sum_{i=0}^{n} GHGi\ x\ GWPi$$

Where:
GHG_i = Mass emissions of each greenhouse gas
GWP_i = Global warming potential for each greenhouse gas
n = the number of greenhouse gases emitted

Example:
Calculate the greenhouse gas emissions in units of carbon dioxide equivalent from a generator that has the potential to emit 8,158.46 tons CO_2, 0.33 tons CH_4, and 0.06 tons N_2O per year.

$$tons\ CO2e = (8{,}158.46 \times 1) + (0.33 \times 28) + (0.06 \times 265) = 8{,}183.60$$

When calculating CO_2e, the GWP value published in §40 CFR Part 98, Subpart A, Table A-1 as of January 1, 2025 should be used per the definition of *"subject to regulation"* in 567 IAC 22.100. The global warming potentials of some common greenhouse gases are included in Table 6 for convenience.

Table 6 - Global Warming Potentials of Common Greenhouse Gases[23]

Common Name	Name	Chemical Formula	CAS Number	GWP (100 year)
	Carbon dioxide	CO_2	124-38-9	1
	Methane	CH_4	74-82-8	28
	Nitrous Oxide	N_2O	10024-97-2	265
HFC-23	trifluoromethane	CHF_3	75-46-7	12,400
HFC-32	difluoroethane	CH_2F_2	75-10-5	677
HFC-41	fluoromethane	CH_3F	593-53-3	116
HFC-43-10mee	1,1,1,2,2,3,4,5,5,5-decafluoropentane	$CF_3CHFCHFCF_2CF_3$	138495-42-8	1,650

[23] §40 CFR Part 98, Subpart A, Table A-1 as of January 1, 2025.

Table 6 (continued)

Common Name	Name	Chemical Formula	CAS Number	GWP (100 year)
HFC-125	pentafluoroethane	C_2HF_5	354-33-6	3,170
HFC-134	1,1,2,2-tetrafluoroethane	$C_2H_2F_4$	359-35-3	1,120
HFC-134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	811-97-2	1,300
HFC-143	1,1,2-trifluoroethane	$C_2H_3F_3$	430-66-0	328
HFC-143a	1,1,1-trifluoroethane	$C_2H_3F_3$	420-46-2	4,800
HFC-152	1,2-difluroethane	CH_2FCH_2F	624-72-6	16
HFC-152a	1,1-difluoroethane	CH_3CHF_2	75-37-6	138
HFC-161	fluoroethane	CH_3CH_2F	353-36-6	4
HFC-227ea	1,1,1,2,3,3,3-heptafluoropropane	CH_3HF_7	431-89-0	6,450
HFC-236cb	1,1,1,2,2,3-hexafluoropropane	$CH_2FCF_2CF_3$	677-56-5	1,210
HFC-236ea	1,1,1,2,3,3-hexafluoropropane	CHF_2CHFCF_3	431-63-0	1,330
HFC-236fa	1,1,1,3,3,3-hexafluoropropane	$C_3H_2F_6$	690-39-1	8,060
HFC-245ca	1,1,2,2,3-pentafluoropropane	$C_3H_3F_5$	679-86-7	716
HFC-245fa	1,1,1,3,3-pentafluoropropane	$CHF_2CH_2CF_3$	460-73-1	858
HFC-365mfc	1,1,1,3,3-pentafluorobutane	$CH_3CF_2CH_2CF_3$	406-58-6	804
PFC-14	perfluoromethane	CF_4	75-73-0	6,630
PFC-116	perfluoroethane	C_2F_6	76-16-4	11,100
PFC-218	perfluorpropane	C_3F_8	76-19-7	8,900
PFC-3-1-10	perfluorobutane	C_4F_{10}	355-25-9	9,200
PFC-318	perfluorocyclobutane	$C\text{-}C_4F_8$	115-25-3	9,540
PFC-4-1-12	perfluoropentane	C_5F_{12}	678-26-2	8,550
PFC-5-1-14	perfluorohexane	C_6F_{14}	355-42-0	7,910
SF_6	Sulfur hexafluoride	SF_6	2551-62-4	23,500

Glossary

Actual emissions means the actual rate of emissions of a pollutant from an emissions unit, as determined in accordance with the following:

1. In general, actual emissions as of a particular date shall equal the average rate, in tons per year, at which the unit actually emitted the pollutant during a two-year period which immediately precedes that date and which is representative of normal source operations. The director may allow the use of a different time period upon a demonstration that it is more representative of normal source operations. Actual emissions shall be calculated using the unit's actual operating hours, production rates, and types of materials processed, stored or combusted during the selected time period. Actual emissions for acid rain affected sources are calculated using a one-year period.
2. Lacking specific information to the contrary, the director may presume that source-specific allowable emissions for the unit are equivalent to the actual emissions of the unit.
3. For any emissions unit which has not begun normal operations on a particular date, actual emissions shall equal the potential to emit of the unit on that date.
4. For purposes of calculating early reductions of hazardous air pollutants, actual emissions shall not include excess emissions resulting from a malfunction or from startups and shutdowns associated with a malfunction.

Actual emissions for purposes of determining fees shall be the actual emissions calculated over a period of one year.

Biogenic - Produced by living organisms or biological processes. Examples of biogenic greenhouse gas emissions are CO_2 emissions from trees, vegetation, decomposition of solid waste, etc.

Carbon Dioxide (CO_2) - A naturally occurring gas that is also a byproduct of burning fossil fuels and biomass, other industrial processes, and land-use changes.

Continuous Emission Monitor (CEM) – Equipment that measures the concentration or emission rate of a gas or particulate matter using analyzer measurements and a conversion equation, graph, or computer program. Installation and operation of a CEM may be required by EPA or DNR in order to determine compliance with specific standards. Operation of a CEM must meet performance specifications, certification procedures, and recordkeeping and reporting requirements as specified in applicable regulations.

Emission Factor – The relationship between the amount of pollution produced and the amount of raw material processed. For example – pounds of CO_2 emitted per ton of coal combusted.

Fluorinated Gases "F-Gases"- Gases sometimes used as substitutes for ozone depleting substances. HFC, PFC, and SF_6 are "F-gases" and are emitted from a variety of industrial processes. "F-gases" are

commonly emitted in smaller quantities, but are important because they have high global warming potentials (GWP).

Global Warming Potential (GWP) – Values used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. It is the radiative forcing that results from the addition of 1 kilogram (2.2 pounds) of a gas to the atmosphere, compared to an equal mass of carbon dioxide, which has a global warming potential of 1. The higher the GWP, the more heat the specific gas can keep in the atmosphere.

Greenhouse Gas (GHG) – Any gas that absorbs and re-emits infrared radiation into the atmosphere. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFC), and perfluorocarbons (PFC).

Hydrofluorocarbons (HFC) – A group of human-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms.

Hydrofluorinated ethers (HFE) – A group of refrigerant gases that have been developed as alternatives to chlorofluorocarbons and hydrofluorocarbons (HFC).

Mass Balance - A process of estimating emissions using knowledge of the process, process rate, material used, and material properties.

Methane (CH_4) – A colorless, flammable, odorless hydrocarbon that is a greenhouse gas.

Nitrogen Trifluoride (NF_3) – A high-GWP gas used in the manufacture of flat panel televisions, computer displays and other products.

Nitrous Oxide (N_2O) – A greenhouse gas formed from soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.

Perfluorocarbons (PFC) – A group of human-made chemicals composed of carbon and fluorine. PFC have no commercial uses and are emitted as a byproduct of aluminum smelting and semiconductor manufacturing.

Potential to emit means the maximum capacity of a stationary source to emit any air pollutant under its physical and operational design. Any physical or operational limitation on the capacity of a source to emit an air pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its

design if the limitation is enforceable by the administrator. This term does not alter or affect the use of this term for any other purposed under the Act, or the term “capacity factors” as used in Title IV of the Act or regulations relating to acid rain.

For the purposes of determining potential to emit for country grain elevators, the provisions set forth in 567 – subrule 22.10(2) shall apply.

For purposes of calculating potential to emit for emergency generators, “maximum capacity” means one of the following:

1. 500 hours of operation annually, if the generator has actually been operated less than 500 hours per year for the past five years;
2. 8,760 hours of operating annually, if the generator has actually been operated more than 500 hours in one of the past five years; or
3. The number of hours specified in a state or federally enforceable limit.

Stack Test – A test that measures the concentration of pollutants in the exhaust stack. Measurements are performed following procedures specified and developed by the US EPA and/or Iowa DNR. Such testing is required by DNR to be conducted by various stationary sources to determine compliance with applicable air emission limits.

Sulfur Hexafluoride (SF_6) – A greenhouse gas used primarily to insulate high-voltage equipment and to assist in the manufacturing of cable cooling systems.

Appendix A – Units of Measure Conversions[24]

To convert from	To	Multiply by
Kilograms (kg)	Pounds (lbs)	2.20462
Pounds (lbs)	Kilograms (kg)	0.45359
Pounds (lbs)	Metric tons	4.53592×10^{-4}
Short tons (referred to in this document as "tons")	Pounds (lbs)	2,000
Short tons(referred to in this document as "tons")	Metric tons	0.90718
Metric tons	Short tons	1.10231
Metric tons	Kilograms (kg)	1,000
Cubic meters (m^3)	Cubic feet (ft^3)	35.31467
Cubic feet (ft^3)	Cubic meters (m^3)	0.028317
Gallons (liquid, US)	Liters (l)	3.78541
Liters (l)	Gallons (liquid, US)	0.26417
Barrels of Liquid Fuel (bbl)	Cubic meters (m^3)	0.15891
Cubic meters (m^3)	Barrels of Liquid Fuel (bbl)	6.289
Barrels of Liquid Fuel (bbl)	Gallons (liquid, US)	42
Gallons (liquid, US)	Barrels of Liquid Fuel (bbl)	0.023810
Gallons (liquid, US)	Cubic meters (m^3)	0.0037854
Liters (l)	Cubic meters (m^3)	0.001
Feet (ft)	Meters (m)	0.3048
Meters (m)	Feet (ft)	3.28084
Miles (mi)	Kilometers (km)	1.60934
Kilometers (km)	Miles (mi)	0.62137
Square feet (ft^2)	Acres	2.29568×10^{-5}
Square meters (m^2)	Acres	2.47105×10^{-4}
Square miles (mi^2)	Square kilometers (km^2)	2.58999
Degrees Celsius (°C)	Degrees Fahrenheit (°F)	°C = (5/9) x (°F -32)
Degrees Fahrenheit (°F)	Degrees Celsius (°C)	°F = (9/5) x °C +32
Degrees Celsius (°C)	Kelvin (K)	K = °C + 273.15
Kelvin (K)	Degrees Rankine (°R)	1.8
Joules	Btu	9.47817×10^{-4}
Btu	MMBtu	1×10^{-6}
Pascals (Pa)	Inches of Mercury (inHg)	2.95334×10^{-4}
Inches of Mercury (inHg)	Pounds per square inch (psi)	0.49110
Pounds per square inch (psi)	Inches of Mercury (inHg)	2.03625

[24] Table A-2 to Subpart A of §40 CFR 98

Appendix B – §40 CFR 98 Subparts[25]

Rule Section	Subpart		Initial Reporting Year
98.10	A	General Provisions	2010
98.20	B	Reserved	
98.30	C	General Stationary Fuel Combustion Sources	2010
98.40	D	Electricity Generation	2010
98.50	E	Adipic Acid Production	2010
98.60	F	Aluminum Production	2010
98.70	G	Ammonia Manufacturing	2010
98.80	H	Cement Production	2010
98.90	I	Electronics Manufacturing	2010
98.100	J	Ethanol Production **NOTE:** EPA has made a final decision not to include ethanol production as a distinct Subpart in §40 CFR Part 98.	N/A
98.110	K	Ferroalloy Production	2010
98.120	L	Fluorinated Gas Production	2011
98.130	M	Food Processing **NOTE:** EPA has made a final decision not to include food processing as a distinct Subpart in §40 CFR Part 98.	N/A
98.140	N	Glass Production	2010
98.150	O	HCFC-22 Production and HF-23 Destruction	2010
98.160	P	Hydrogen Production	2010
98.170	Q	Iron and Steel Production	2010
98.180	R	Lead Production	2010
98.190	S	Lime Manufacturing	2010
98.200	T	Magnesium Production	2011
98.210	U	Miscellaneous Uses of Carbonate	2010
98.220	V	Nitric Acid Production	2010
98.230	W	Petroleum and Natural Gas Systems	2011
98.240	X	Petrochemical Production	2010
98.250	Y	Petroleum Refineries	2010
98.260	Z	Phosphoric Acid Production	2010
98.270	AA	Pulp and Paper Manufacturing	2010
98.280	BB	Silicon Carbide Production	2010
98.290	CC	Soda Ash Manufacturing	2010
98.300	DD	Use of Electric Transmission and Distribution Equipment	2011
98.310	EE	Titanium Dioxide Production	2010
98.320	FF	Underground Coal Mines	2011
98.330	GG	Zinc Production	2010

[25] https://www.epa.gov/ghgreporting/resources-subpart-ghg-reporting

§40 CFR 98 Subparts (continued)

Rule Section	Subpart	Rule Section	Initial Reporting Year
98.340	HH	Municipal Solid Waste Landfills	2010
98.350	II	Industrial Wastewater Treatment	2011
98.360	JJ	Manure Management **NOTE:** EPA is not implementing subpart JJ of §40 CFR Part 98 using funds provided in its appropriations due to a Congressional restriction prohibiting the expenditure of funds for this purpose.	N/A
98.370	KK	Suppliers of Coal **NOTE:** EPA has made a final decision to not include reporting requirements for suppliers of coal as a Subpart in §40 CFR Part 98 at this time.	N/A
98.380	LL	Suppliers of Coal-based Liquid Fuels	2010
98.390	MM	Suppliers of Petroleum Products	2010
98.400	NN	Suppliers of Natural Gas and Natural Gas Liquids	2010
98.410	OO	Suppliers of Industrial Greenhouse Gases	2010
98.420	PP	Suppliers of Carbon Dioxide	2010
98.430	QQ	Imports and Exports of Equipment Pre-charged with Fluorinated GHGs or Containing Fluorinated GHGs in Closed-cell Foams	2011
98.440	RR	Carbon Dioxide Injection and Geologic Sequestration	2011
98.450	SS	Manufacture of Electric Transmission and Distribution Equipment	2011
98.460	TT	Industrial Waste Landfills	2011
98.470	UU	Injection of Carbon Dioxide	2011
98.480	VV	Geologic Sequestration of Carbon Dioxide with Enhanced Oil Recovery Using ISO 27916	2025
98.490	WW	Coke Calciners	2025
98.500	XX	Calcium Carbide Producers	2025
98.510	YY	Caprolactam, Glyoxal, and Glyoxylic Acid Production	2025
98.520	ZZ	Ceramics Manufacturing	2025

Appendix C – Document Revision History

Date	Revision(s) Made
Fall 2007	First versions of document posted.
03/17/11	Document updated to recommend use of federal GHG Reporting Program emission factors and federal Mandatory Reporting Rule subparts. Stationary Fossil Fuel Combustion Calculation Tool created.
01/09/12	Hyperlinks updated.
09/09/13	Contact phone number changed.
02/03/14	Font size increased, global warming potentials language updated, biogenic emissions language updated, and revision history added. Emission factors in Table 2 and Table 3 and calculation examples updated to match emission factors in Table C-1 of §40 CFR 98 Subpart C as amended on November 29, 2013 and effective on January 1, 2014.
03/22/17	Global warming potentials updated, hyperlinks updated, footnotes added, biogenic emissions language removed and general copy editing.
01/02/25	Global warming potentials updated, hyperlinks updated, contact changed, and general copy editing.