



**Department of
Natural Resources**

2023 Iowa Statewide
Greenhouse Gas Emissions
Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	basic oxygen furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CEMS	continuous emission monitoring system
CH ₄	methane
CO ₂	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CRP	Conservation Reserve Program
DATIM	Design and Analysis Toolkit for Inventory and Monitoring
DNR	Iowa Department of Natural Resources
DOT	United States Department of Transportation
EAB	Emerald Ash Borer
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GWP	global warming potential
HDGV	heavy duty gas vehicle
HDDV	heavy duty diesel vehicle
IDALS	Iowa Department of Agriculture and Land Stewardship
IDOT	Iowa Department of Transportation
IEA	International Energy Agency
IEDA	Iowa Economic Development Authority
ILPA	Iowa Limestone Producers Association
IPCC	Intergovernmental Panel on Climate Change
LDC	local distribution company
LDDT	light duty diesel truck
LDDV	light duty diesel vehicle
LDGT	light duty gasoline truck
LDGV	light duty gasoline vehicle
LULUCF	land use, land use change, and forestry
MC	motorcycle
MMtC	million metric tons carbon
MMtCO ₂ e	million metric tons carbon dioxide equivalent
MISO	Midcontinent Independent System Operator

Acronyms and Key Terms (Continued)

MSW	municipal solid waste
N	nitrogen
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NO ₃ -	nitrates
NO ₂ -	nitrites
NO _x	nitrogen oxides
N ₂ O	nitrous oxide
NRCS	Natural Resources and Conservation Service
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
RCI	residential, commercial, and industrial
SEDS	EIA's State Energy Data System
SF ₆	sulfur hexafluoride
SIT	State Inventory Tool
STEO	Short Term Energy Outlook
T & D	transmission and distribution
TSD	technical support document
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	vehicle miles traveled
WRI	World Resources Institute

Chapter 1 – General Calculation Method

Iowa Code 455B.104 requires that “by December 31 of each year, the department shall submit a report to the governor and the general assembly regarding the greenhouse gas (GHG) emissions in the state during the previous calendar year and forecasting trends in such emissions....” This Technical Support Document (TSD) provides documentation and additional calculations to support the [2023 Iowa Statewide Greenhouse Gas Emissions Inventory Report](#). Total Iowa GHG emissions from 2014 – 2023 are provided in Appendices A and B of this document. A state-specific inventory provides an in-depth analysis of emission trends and develops a baseline to track progress in reducing emissions.

This inventory is based on statewide activity data from agriculture, fossil fuel combustion, industrial processes, natural gas transmission and distribution, transportation, solid waste, and wastewater treatment. It also includes carbon emitted or sequestered from land use, land use change, and forestry (LULUCF).

Method

Emissions were calculated using the most recent version of the United States Environmental Protection Agency’s (EPA) State Greenhouse Gas Inventory Tool (SIT)¹ and using available Iowa-specific activity data. The energy and industrial processes sectors were also supplemented with GHG emissions data submitted by individual Iowa facilities to the federal GHG reporting program (40 CFR 98). The calculation methods in the SIT are based on the August 2004 version of EPA’s Emission Inventory Improvement Program (EIIP) guidance for greenhouse gases (ICF 2004). The individual modules for each sector are Excel workbooks populated with emission factors and default activity data for years 1990 – 2021, but allow the user to enter better state-specific activity data when it is available. Detailed information on the activity data used is provided in the corresponding chapter for each sector, under the “Method” heading. The individual modules then calculate the resulting GHG emissions from each sector. The results from each module were then tabulated in an Excel spreadsheet. The SIT Projection Tool was then used to forecast emissions to 2040. The SIT modules and their corresponding chapters in this TSD are listed in Table 1. The coal module was not used, as there are no coal mines currently operating in Iowa.

Table 1: TSD Chapters and Corresponding SIT Modules

TSD Chapter	SIT Module	Release Date	Pollutants Addressed
Agriculture	Ag	1/31/24	CH ₄ , N ₂ O
Energy	CO ₂ FFC	1/31/24	CO ₂
	Stationary Combustion	1/31/24	CH ₄ , N ₂ O
Industrial Processes	IP	1/31/24	CO ₂ , N ₂ O, HFC, PFC, SF ₆
Natural Gas Transmission & Distribution	Natural Gas and Oil	1/31/24	CH ₄
Transportation	Mobile Combustion	1/31/24	CO ₂ , CH ₄ , N ₂ O
Waste	Solid Waste	1/31/24	CO ₂ , CH ₄
	Wastewater	1/31/24	CH ₄ , N ₂ O
Land Use, Land Use Change, and Forestry	LULUCF	1/31/24	CO ₂ , N ₂ O
Indirect Emissions from Electricity Consumption	Electricity Consumption	1/31/24	CO ₂
Future Emissions	Projection Tool	1/31/24	CO ₂ , CH ₄ , N ₂ O, HFC, PFC, SF ₆

¹ The SIT may be downloaded at <https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool>.

Global Warming Potentials (GWP)

The potency of the various greenhouse gases differs, so greenhouse gas emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO₂e) that allows for better comparison of the impact of the different greenhouse gases. CO₂e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting values. CO₂e was calculated using Equation 1.

Equation 1:

$$\text{tons CO}_2\text{e} = \sum_{i=0}^n \text{GHG}_i \times \text{GWP}_i$$

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

The DNR used the GWPs from the Intergovernmental Panel on Climate Change’s (IPCC) Fourth Assessment Report (AR4) to estimate emissions through emissions year 2022 (IPCC 2007). Beginning with 2023 emissions, DNR used the GWPs from the IPCC’s Fifth Assessment Report (AR5) (IPCC 2014). All values in this report, 2014-2022, were updated to the AR5 GWP. The GWP values used are shown in Table 2.

Table 2: Global Warming Potentials

Pollutant	GWP used by DNR until 2022 (IPCC AR4 2007)	GWP used by DNR in this report (IPCC AR5 2014)
Carbon Dioxide (CO ₂)	1	1
Methane (CH ₄)	25	28
Nitrous Oxide (N ₂ O)	298	265
Sulfur Hexafluoride (SF ₆)	22,600	23,500
Hydrofluorocarbons (HFC) Perfluorocarbons (PFC)	Varies by pollutant – For a complete list, refer to DNR’s Greenhouse Gas Emissions Estimation Guidance .	Varies by pollutant – For a complete list, refer to DNR’s Greenhouse Gas Emissions Estimation Guidance .

Chapter 2 - Agriculture

This chapter includes non-energy greenhouse gas (GHG) emissions from livestock and crop production in Iowa. GHG emissions from fossil fuel-fired agricultural equipment are discussed in *Chapter 6 – Transportation*, and carbon emissions and sinks from agriculture are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry (LULUCF)* of this document.

GHG emissions are emitted from four agricultural sectors in Iowa – enteric fermentation, manure management, agricultural soils, and agricultural burning. The GHGs emitted are methane (CH₄) and nitrous oxide (N₂O). Table 3 summarizes the source of GHG emissions in each sector. N₂O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2023).

Table 3: Sources of Agricultural GHG Emissions in Iowa

Sector		GHGs Emitted	Source of Emissions
Enteric Fermentation		CH ₄	Microbial activity in the digestive systems of dairy cattle, beef cattle, sheep, goats, swine, and horses.
Manure Management		CH ₄ , N ₂ O	Decomposition of manure during storage and treatment of livestock manure.
Agricultural Soils	Residues, legumes, and histosols	N ₂ O	Biological nitrogen fixation by crops, crop residues remaining on fields, and cultivation of high organic content soils (histosols).
	Fertilizers	N ₂ O	Application of manure, fertilizers, etc. to soils and leaching/runoff of nitrogen into ground or surface water.
	Animals	N ₂ O	Animal excretions directly on to soils such as pastures.
Agricultural Burning		CH ₄ , N ₂ O	Burning of crop residues.

Method

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency’s (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated January 31, 2024 (ICF 2024a and 2024b).

Enteric Fermentation

The SIT calculates CH₄ emissions from enteric fermentation by multiplying various livestock populations by an annual CH₄ emission factor (kilograms CH₄ per head). The data sources for the animal populations used are listed in Table 4. The number of “Feedlot Heifers” and “Feedlot Steers” was derived by applying a 35/65 heifer/steer ratio to the “Total Number on Feed.”

Manure Management

This sector includes CH₄ and N₂O emissions from manure when it is being stored and treated in a manure management system. In general, CH₄ emissions increase in more anaerobic (lacking oxygen) conditions while N₂O emissions increase under aerobic conditions (Strait et al. 2008). The same dairy cattle, beef cattle, sheep, goat, horse, and swine populations were used as for the enteric fermentation sector for consistency. Several other animal types were added as shown in Table 4.

Table 4: Animal Population Data Sources

Animal Type	Year	Data Source
Dairy cattle	2023	2023 Iowa Agricultural Statistics Bulletin (USDA 2023)
Beef cattle		
Goats		
Sheep		
Breeding swine		
Market swine under 60 lbs. ²		
Market swine 60 – 119 lbs. ³		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Broilers	2022 census value used as proxy for	USDA-NASS Quick Stats (USDA 2024)
Horses	2023	
Turkeys		
Chickens	2022 census value used as proxy for	2023 Iowa Agricultural Statistics Bulletin (USDA 2023)
Hens	2023	

In addition, the number of “Sheep on Feed” and “Sheep off Feed” were derived by applying a 6.5/93.5 on feed/off feed ratio to the total number of sheep.

Agricultural Soils

N₂O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2023). N₂O is emitted when the natural processes of denitrification and nitrification interact with agricultural practices that add or release nitrogen (N) in the soil profile. Denitrification is the process of converting nitrate to nitrogen gas. It is carried out by microorganisms in an oxygen-lacking environment. Nitrification occurs when ammonia is converted to nitrites and nitrates by naturally occurring, specialized bacteria in the environment.

Direct N₂O emissions occur at the site of application of both synthetic and organic fertilizers to the soil, production of N-fixing crops, and integration of crop residues into the soil by practices such as cultivation. Indirect emissions occur when N is made available or is transported to another location following volatilization, leaching or runoff, and is then converted to N₂O (EPA 2024).

Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2024) were used to calculate N₂O from nitrogen-fixing crops, including alfalfa, soybeans, and rye. It was also used to calculate the quantity of nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans.

Soil Cultivation - Nitrous Oxide (N₂O)

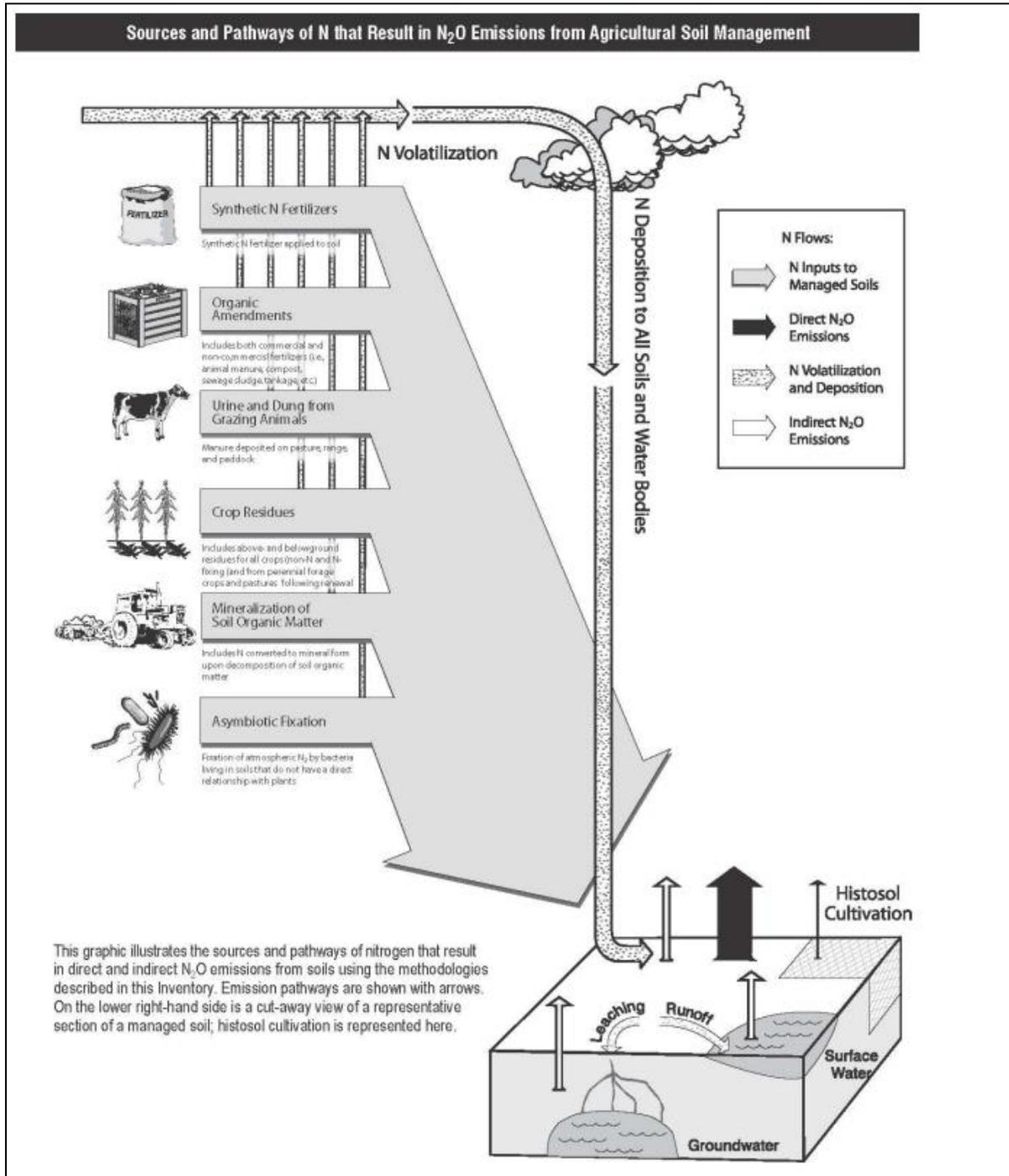
N₂O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently available (Bedmarek 2012), so the DNR estimated the number of cultivated histosols acres by

² SIT uses the category of market swine under 60 lbs., but USDA uses the category of market swine under 50 lbs.

³ SIT uses the category of market swine 60 – 119 lbs., but USDA uses the category of market swine 50 - 119 lbs.

multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2024) and by the average percentage of each crop that is tilled (Sucik 2011b). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, “...all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a histosol would require some type of artificial drainage in order to be consistently row cropped” (Sucik 2011a).

Figure 1: Sources and Pathways of N₂O Emissions in Ag Soils (EPA 2023)



Fertilizer Utilization

The DNR calculated fertilizer emissions for 2023 using fertilizer tonnages from the *Fertilizer Tonnage Distribution in Iowa 2023 Crop Year* (IDALS 2023). The IDALS fertilizer data is provided per the 2023 growing season, which is from July 2022 – June 2023.

Agricultural Soil Carbon Flux

This is the third year that DNR has included agricultural soil carbon flux in the Iowa GHG inventory. Carbon is continuously cycled through soils in both cropland and grassland (EPA 2024). The amount of carbon stored varies depending on crop type, management practices (e.g., rotation, tillage, drainage, irrigation), and soil and climate variables. The net change in agricultural soil carbon is the change in the amount of carbon stored in soils over time (ICF 2024c). In 2020, EPA updated the SIT to calculate agricultural soil carbon flux using the same methodologies as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2018* (EPA 2020). However, EPA considers agricultural soil carbon flux under the Land Use, Land Use Change, and Forestry sector, so it is reported in that sector in this report as well. Please refer to *Chapter 9 – Land Use, Land Use Change, and Forestry* for the quantity of carbon stored in agricultural soils.

Adjustments

Since the DNR’s 2022 GHG Inventory Report was published in December 2023, the 2022 emissions from enteric fermentation, manure management, and agricultural soils have been updated as shown in Table 5 using revised activity data (such as animal populations or fertilizer application) from USDA or IDALS as follows:

- 2022 populations of bulls, steer stockers, heifer stockers, market swine and breeding swine were updated to match revised values in the 2023 Iowa Annual Statistics Bulletin (USDA 2023).
- Tons of soybeans produced, acres of soybeans harvested, and acres of corn harvested in 2022 were updated to match revised values in the USDA’s Quick Stats database (USDA 2024).

Table 5: Recalculated Agricultural Emissions (MMtCO₂e)

Category	2022 Value	2022 Updated Value
Enteric Fermentation	8.22	9.00
Manure Management	9.14	9.02
Agricultural Soils	21.72	18.17
Total	39.07	36.20

Results

GHG emissions from agriculture decreased 0.02% from 2022 – 2023 and decreased 5.20% from 2014 – 2023. Gross GHG emissions from agriculture were 36.20 MMtCO₂e in 2023, or 28.74% of Iowa’s total gross 2023 GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. Just over half of the agricultural emissions (50.24%) are from soils as shown in Figure 2 and Table 6.

Figure 2: Gross GHG Emissions from Agriculture (MMtCO₂e)

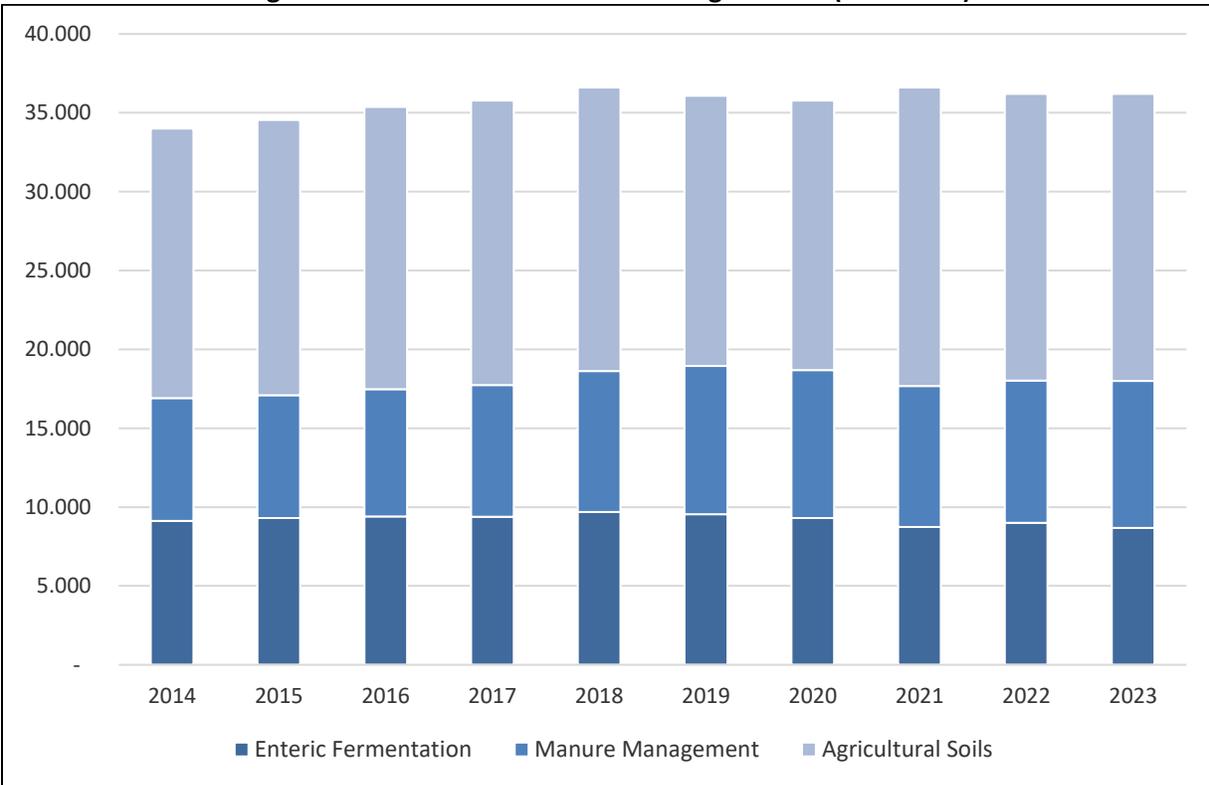


Table 6: Gross GHG Emissions from Agriculture (MMtCO₂e)⁴

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Enteric Fermentation	9.12	9.31	9.41	9.39	9.69	9.54	9.30	8.74	9.00	8.69
Manure Management	11.99	12.13	12.01	12.89	8.91	9.38	9.31	8.93	9.02	9.32
Agricultural Soils	17.07	17.45	17.89	18.05	17.99	17.13	17.09	18.92	18.17	18.18
Total	38.18	38.89	39.31	40.32	36.59	36.05	35.70	36.60	36.20	36.20

Enteric Fermentation

CH₄ emissions from enteric fermentation were 8.69 MMtCO₂e in 2023, decreasing 3.51% from 2022. This can be attributed to a 7.07% decrease in the total cattle population. While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 3, enteric fermentation emissions are primarily driven by cattle. This is because cattle emit more CH₄ than other ruminant animals due to their unique stomach. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 7.

⁴ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 3: 2023 Iowa Animal Populations (USDA 2024)⁵

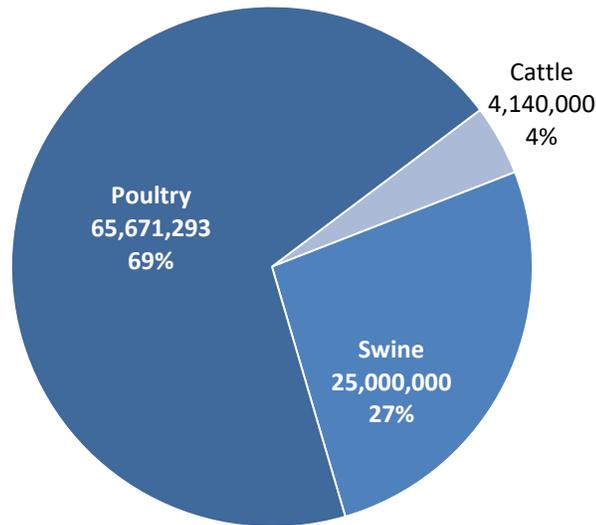


Table 7: Methane Emitted per Animal

Animal Type	kg/head CH ₄ Emitted (ICF 2024a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.3 – 144.8
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Manure Management

Factors influencing CH₄ and N₂O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 3.32% from 2022 and accounted for 25.76% of agricultural GHG emissions in 2023.

Agricultural Soils

The majority of GHG emissions from agricultural soils can be attributed to crop production (fertilizers, crop residues, and nitrogen fixing) as shown in Figure 4. Production of soybeans and alfalfa decreased in 2023 while there was an increase in production of corn and oats, as shown in Table 8. Updated data was not available for wheat, rye, pea, and sorghum production. In addition to increased crop production, total synthetic fertilizer use increased from 1,013 million kg N to 1,112 million kg N, an increase of 9.8%. This led to an overall increase in N₂O emissions from agricultural soils of 0.05% from the previous year. N₂O emissions from agricultural soils accounted for 50.24% of all agricultural GHG emissions and 14.44% of total gross statewide GHG emissions in 2023.

⁵ The goat, horse, and sheep population each account for less than 1% of the total animal population.

Figure 4: 2022 - 2023 Gross GHG Emissions from Agricultural Soils (metric tons N₂O)

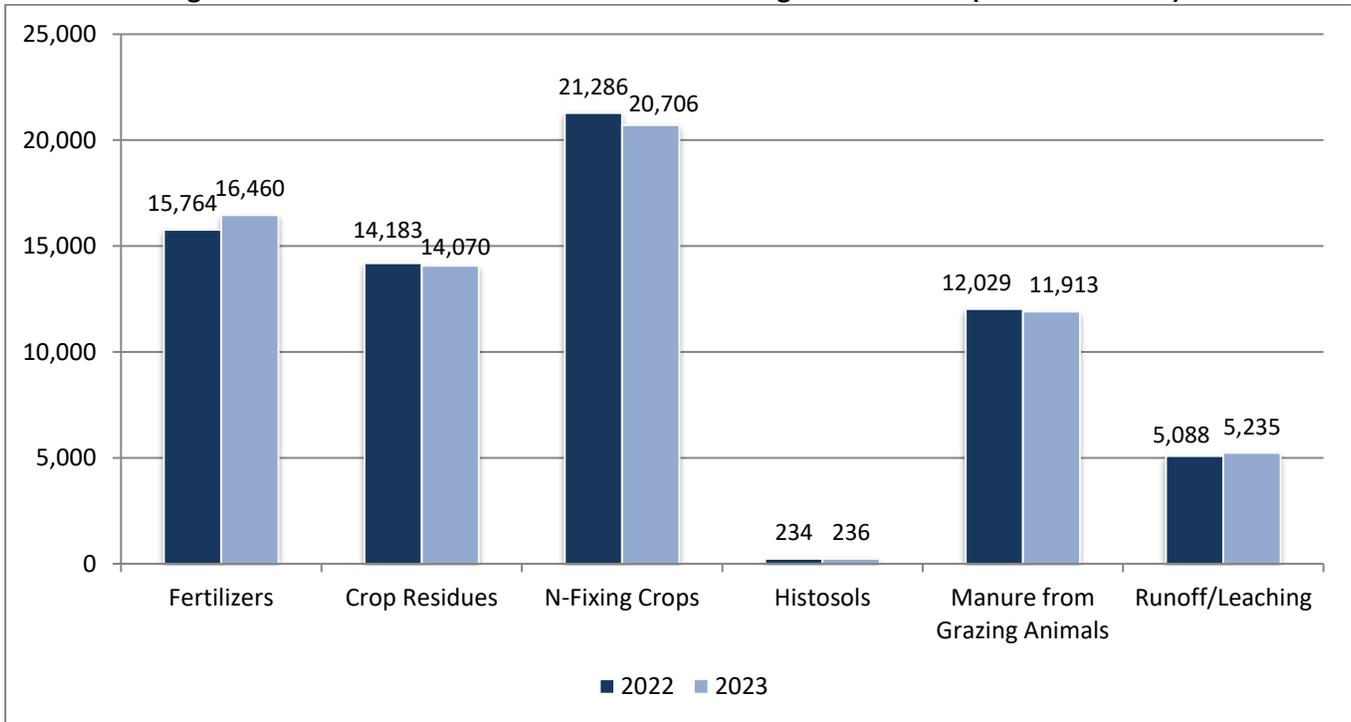


Table 8: Iowa Crop Production 2022 – 2023 (USDA 2024)

Crop	2022 (1000 Bushels)	2023 (1000 Bushels)
Barley	49	49
Corn for Grain	2,470,000	2,522,550
Oats	3,280	7,600
Rye	269	269
Sorghum for Grain	52	52
Soybeans	586,755	573,040
Wheat	951	951
Total	3,061,356	3,104,511
Crop	2022 (1000 tons)	2023 (1000 tons)
Alfalfa	2,701	2,400
Crop	2022 (1000 CWT)	2023 (1000 CWT)
Peas, Dry Edible	103	103

Uncertainty⁶

Enteric Fermentation

The quantity of methane (CH₄) emitted from enteric fermentation from livestock is dependent on the quality of the animal population estimates and the emission factors used for each animal type. Uncertainty is also introduced as animal populations are not constant, but vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. The emission factors for a given animal type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2024a).

⁶ This information is largely excerpted from the *SIT Agriculture Module* (ICF 2024a).

Manure Management

As with enteric fermentation, uncertainty occurs in animal populations and the emission factors used for each animal. However, the largest contributor to uncertainty in manure management emissions in the SIT is the lack of Iowa-specific data describing manure management systems and the CH₄ and N₂O emission factors used for these systems. In addition, there is uncertainty in the maximum CH₄ producing potential (B₀) used for each animal group. This value varies with both animal and diet characteristics, so estimating an average across an entire population introduces uncertainty. While the B₀ values used in the SIT vary by animal subcategory to attempt to represent as many of these differences as possible, there is not sufficient data available at this time to estimate precise values that accurately portray the B₀ for all animal types and feeding circumstances (ICF 2024a).

Agricultural Soils

The N₂O emissions from managed soils is dependent on a large number of variables other than N inputs. They include soil moisture, pH, soil temperature, organic carbon availability, oxygen partial pressure, and soil amendment practices. The effect of the combined interaction of these variables on N₂O flux is complex and highly uncertain. The methodology used in the SIT is based only on N inputs, does not include other variables, and treats all soils, except histosols, equally. In addition, there is limited knowledge regarding N₂O productions from soils when N is added to soils. It is not possible to develop emission factors for all possible combinations of soil, climate, and management conditions.

Uncertainties also exist in fertilizer usage calculations. The fertilizer usage does not include non-commercial fertilizers other than manure and crop residues, and site-specific conditions are not considered in determining the amount of N excreted from animals. Additional uncertainty occurs due to lack of Iowa-specific data for cultivation of histosols.

Chapter 3 – Fossil Fuel Consumption

This chapter includes GHG emissions from fossil fuel consumption in four categories: power plants, residential, industrial, and commercial. The residential, commercial, and industrial categories are often combined into one category called RCI. Fossil fuels combusted by mobile sources are included in the transportation sector and discussed in *Chapter 6 – Transportation*. Emissions from the electric generation category include direct emissions resulting from the combustion of fossil fuels at the electric generating station (i.e. power plant). Indirect emissions from electricity consumed at the point of use (i.e. residential electric water heaters) are discussed in *Chapter 10 – Indirect Emissions from Electricity Consumption*.

Method

Residential, Commercial, Industrial (RCI)

GHG emissions were calculated using two SIT modules – the CO₂FFC module for carbon dioxide (CO₂) emissions and the Stationary Combustion module for CH₄ and N₂O emissions (ICF 2024a-d). These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 9:

Table 9: Fuel Types Included in Fossil Fuel Consumption

Fuel Types	Residential	Commercial	Industrial
Asphalt/Road oil			X
Aviation gasoline blending components			X
Coal	X	X	X
Coking coal, other coal			X
Crude oil			X
Distillate fuel oil	X	X	X
Feedstocks			X
Kerosene	X	X	X
LPG	X	X	X
Lubricants			X
Misc. petroleum products			X
Motor gasoline		X	X
Motor gasoline blending components			X
Natural gas	X	X	X
Pentanes plus			X
Petroleum coke			X
Residual fuel		X	X
Still gas			X
Special naphthas			X
Unfinished oils			X
Waxes			X
Wood	X	X	X

The modules include energy consumption data for 1990 – 2021 from U.S. Energy Information Administration (EIA) State Energy Data System (SEDS) (EIA 2024b). Because Iowa-specific 2023 energy consumption data will not be published by the EIA until June 2025, the DNR projected 2023 energy consumption using projections provided by EPA in the SIT Projection Tool (ICF 2024a). These projections are based on the EIA’s *Annual Energy Outlook (AEO) 2022 with Projections to 2050* (EIA 2023) and applied to the SEDS consumption data.

Power Plants

Emissions from electricity generation at power plants were not calculated using fuel consumption data. Depending on the year, emissions from either EPA’s Clean Air Markets Division (CAMD 2024) or EPA’s federal GHG Reporting Program (EPA 2024) were used as follows:

2005 – 2009

CO₂ emissions reported to EPA by individual facilities subject to CAMD’s reporting requirements (generally speaking, those power plants that serve a generator with a nameplate capacity greater than 25 megawatts and sell at least one-third of their electricity to the grid) were used. This data is more accurate than the values from EIA because the CO₂ emissions reported by facilities to CAMD are actual measured emissions values from continuous emission monitoring systems (CEMS) located on electric generating units.

2010 - 2023

Power plants became subject to the federal GHG reporting program starting with calendar year 2010. Facilities are required to report CO₂, CH₄, and N₂O emissions. This CO₂ data is also from CEMS and is more accurate than EIA data. In addition, the CH₄ and N₂O emissions are calculated using facility-specific fuel heating values. The CO₂ data reported to the federal GHG reporting program is consistent with the CO₂ emissions reported by the same facilities to CAMD.

Adjustments

The DNR previously forecasted 2022 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2022 energy data was released by EIA in June 2024 (EIA 2024), so the DNR used the data to recalculate 2022 emissions as shown in Table 10.

Table 10: Recalculated RCI Emissions (MMtCO₂e)

Category	2022 Value	2022 Updated Value
Residential	4.92	5.37
Commercial	4.18	4.35
Industrial	24.62	25.80
Total	33.72	35.53

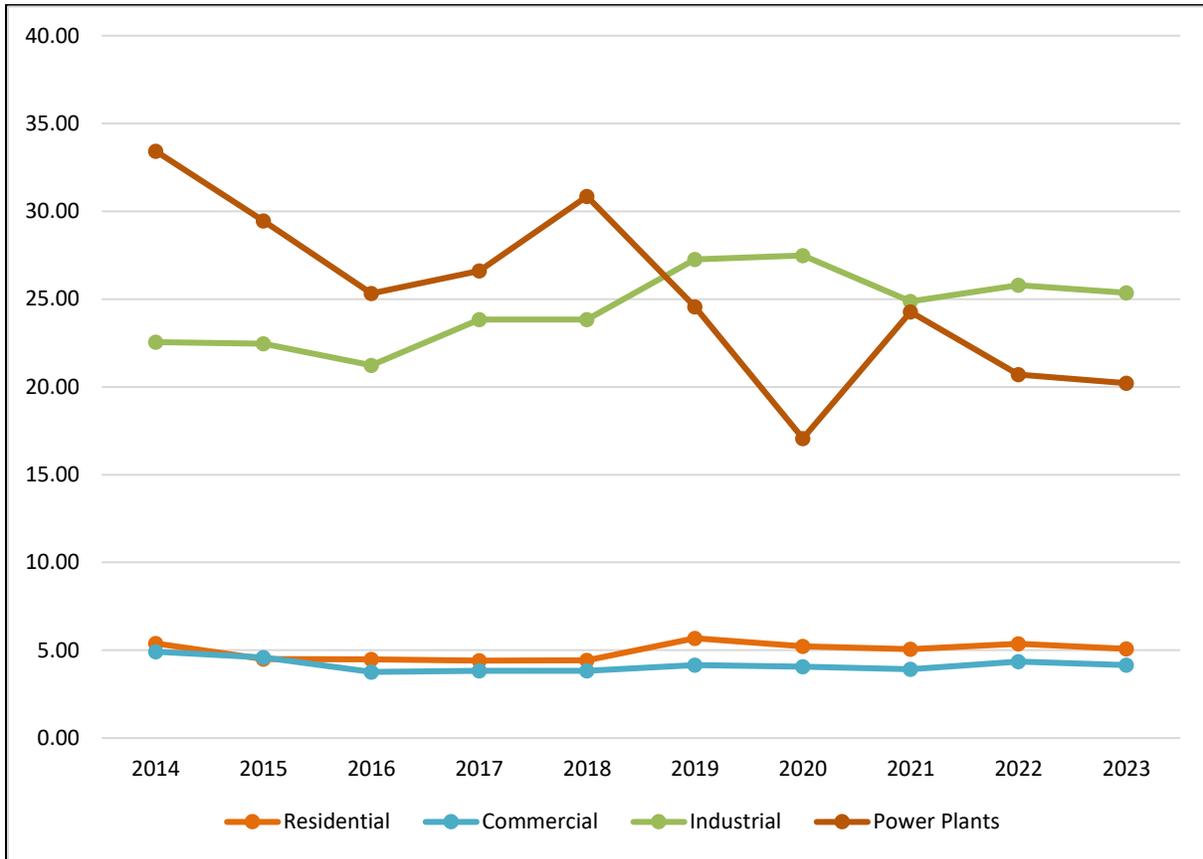
Results

Total GHG emissions from fossil fuel consumption in 2023 were 54.80 MMtCO₂e, a decrease of 2.55% from 2022 and a decrease of 17.32% from 2014 levels as shown in Table 11 and Figure 5. Emissions from all categories decreased from 2022 to 2023. The largest decrease was residential fuel combustion, which decreased by 5.54% and the smallest decrease was from industrial fuel combustion, which decreased by 1.71%. Emissions from power plants decreased by 2.38% from 2022 to 2023. With the exception of 2020, the 2023 emissions from power plants were the lowest since Iowa began calculating emissions in 2005. GHG emissions from this sector account for 43.51% of 2023 statewide GHG emissions.

Table 11: GHG Emissions from Fossil Fuel Consumption by Category (MMtCO₂e)⁷

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Residential	5.39	4.50	4.48	4.41	4.43	5.68	5.22	5.07	5.37	5.08
Commercial	4.92	4.60	3.77	3.83	3.83	4.15	4.06	3.93	4.35	4.15
Industrial	22.54	22.46	21.23	23.84	23.84	27.26	27.49	24.86	25.80	25.36
Power Plants	33.43	29.45	25.32	26.61	30.86	24.56	17.07	24.26	20.70	20.21
Total	66.27	61.02	54.80	58.68	62.95	61.65	53.83	58.12	56.23	54.80

Figure 5: GHG Emissions from Fossil Fuel Consumption by Category (MMtCO₂e)



As noted above, emissions from fossil-fuel fired power plants in 2023 decreased from 2022 and were the second lowest within the 2014-2023 timeframe. Annual emissions from electric power plants fluctuate due to differences in how electricity generation is dispatched by the grid operator, electricity demand by customers, other market forces, and changes in weather that affect the number of heating and cooling days per year.

⁷ Values do not include emissions from the transportation sector. Totals may not equal the sum of subtotals shown in this table due to independent rounding.

CO₂ Uncertainty⁸

The amount of CO₂ emitted from energy consumption depends on the type and amount of fuel that is consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Therefore, the more accurate these parameters, the more accurate the estimate of direct CO₂ emissions. Nevertheless, there are uncertainties associated with each of these parameters.

More uncertainty exists in state-level data than national total energy consumption data, especially when allocating consumption to the individual end-use sectors (i.e. residential, commercial, and industrial). The amount or rate at which carbon is emitted to the atmosphere can vary greatly depending on the fuel and use, and may vary at the state-level compared to the national default levels in the SIT.

The uncertainty in carbon content and oxidation are much lower than with fuel consumption data. Carbon contents of each fuel type are determined by EIA by sampling and the assessment of market requirements, and, with the exception of coal, do not vary significantly from state to state. EIA considers the variability of carbon contents of coal by state; these coefficients are also provided in the SIT.

Uncertainty is also introduced by the complexity in calculating emissions from the import/export of electricity. The precise fuel mix used to generate the power crossing state lines is very difficult to determine, so, an average fuel mix for all electricity generation within a specific region of the grid must usually be used. Moreover, these emissions factors are generated by emission monitors (rather than carbon contents of fuels), which may overestimate CO₂ emissions to a small extent.

CH₄ and N₂O Uncertainty⁹

The amount of CH₄ and N₂O emitted depends on the amount and type of fuel used, the type of technology in which it is combusted (e.g., boilers, water heaters, furnaces), and the type of emission control used. In general, uncertainty is improved by using more detailed combustion activity information. However, as noted in the Revised 1996 IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997), the contribution of CH₄ and N₂O to overall emissions is small and the estimates are highly uncertain.

Uncertainties also exist in both the emission factors and the EIA energy consumption data used to calculate emissions. For example, the EIA state-specific datasets do not fully capture the wood used in fireplaces, wood stoves, and campfires. As with CO₂, uncertainty is also introduced with allocating energy consumption data to the individual end-use sectors and estimation of the fraction of fuels used for non-energy.

⁸ This information is largely excerpted from the *SIT CO₂FFC Module* (ICF 2024a).

⁹ This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2024b).

Chapter 4 - Industrial Processes

This chapter includes non-combustion GHG emissions from a variety of industrial processes. The processes and GHG pollutants emitted from each category are shown in Table 12. Emissions from these industries do not include emissions from fossil fuel combustion, which are included in *Chapter 3 – Fossil Fuel Combustion*.

Table 12: Industrial Processes and GHG Emissions

Category	GHGs Emitted
Ammonia Production & Urea Consumption	CO ₂
Cement Production	CO ₂
Electric Power Transmission & Distribution	SF ₆
Iron and Steel Production	CO ₂
Lime Manufacture	CO ₂
Limestone and Dolomite Use	CO ₂
Nitric Acid Production	N ₂ O
Ozone Depleting Substances (ODS) Substitutes	HFCs, PFCs, and SF ₆
Semiconductor Manufacturing	HFCs, PFCs, and SF ₆
Soda Ash Use	CO ₂

Ammonia Production & Urea Consumption

CO₂ is released during the manufacture of ammonia. The chemical equations to calculate the release of CO₂ are complex, but in general, anhydrous ammonia is synthesized by reacting nitrogen with hydrogen. The hydrogen is typically acquired from natural gas. The majority of direct CO₂ emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO₂. Other emissions of CO₂ can occur during condensate stripping or regeneration of the scrubbing solution. CO₂ emissions may also be captured for use in urea synthesis or carbon sequestration and storage (WRI 2008). Four facilities in Iowa currently produce ammonia.

Cement Production

Carbon Dioxide (CO₂) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO₂. The CO₂ is vented to the atmosphere and the lime is then mixed with silica-containing materials such as clay to form clinker, an intermediate product that is made into finished Portland cement (ICF 2004). Two facilities in Iowa currently produce Portland cement.

Electric Power Transmission and Distribution

Sulfur hexafluoride (SF₆) is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2024b).

Iron and Steel

Iron and steel production is an energy-intensive process that also generates process-related GHG emissions. Steel is produced from pig iron or scrap steel in a variety of specialized steel-making furnaces, including electric arc furnaces (EAFs) and basic oxygen furnaces (BOFs) (EPA 2024b). There are currently no pig iron mills operating in Iowa. Two steel production facilities currently operating in Iowa use EAFs to produce steel from scrap. These furnaces use carbon electrodes, coal, natural gas, and other substances such as limestone and dolomite to aid in melting scrap and other metals, which are then improved to create the preferred grade of

steel. In EAFs, CO₂ emissions result primarily from the consumption of carbon electrodes and from the consumption of supplemental materials used to augment the melting process (EPA 2024b).

Lime Manufacture

Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO₂. The CO₂ is typically released to the atmosphere, leaving behind a product known as quicklime, which can then be used to produce other types of lime (ICF 2004). One facility currently manufactures lime in Iowa.

Limestone and Dolomite Use

Limestone and dolomite are used in industrial processes such as glass making, flue gas desulfurization, acid neutralization, etc.

Nitric Acid Production

Nitrous Oxide (N₂O) is produced when ammonia is oxidized to produce nitric acid. Three facilities in Iowa currently produce nitric acid.

Consumption of ODS Substitutes

Ozone Depleting Substances (ODS) are often used in refrigeration, air conditioning, aerosols, solvent cleaning, fire extinguishers, etc. However, ODS are being phased out per the Montreal Protocol and the 1990 Clean Air Act Amendments. The most common ODS are HFCs, but PFCs and SF₆ may also be used (ICF 2024b).

Semiconductor Manufacturing

DNR added emissions from semiconductor manufacturing to the inventory in 2017. It was previously assumed that semiconductors were not manufactured in Iowa. However, the 2017 Economic Census identifies eleven businesses in Iowa under the North American Industry Classification System (NAICS) for code 33441 – Semiconductor and Other Electronic Manufacturing (U.S. Census 2019).

Soda Ash Use

Soda ash is currently only produced in three states – Wyoming, Colorado, and California. However, commercial soda ash is used as a raw material in a variety of industrial processes and in many familiar consumer products such as glass, soap, and detergents (ICF 2024b). In Iowa, it is commonly used by corn wet milling facilities for pH control, in ion exchange regeneration, and in other operations (DNR 2010).

Other Industry Types

GHG emissions from adipic acid production, (primary) aluminum production, HCFC-22 production, and magnesium production and processing were not calculated, as the DNR is not aware of any of these facilities currently operating in Iowa.

Method

The 2023 emissions from industrial processes were calculated using either the SIT (ICF 2024a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2024a) as shown in Table 13.

Table 13: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2023	40 CFR 98 Subpart G	GHGRP (EPA 2024a)
Cement Production	2023	40 CFR 98 Subpart H	GHGRP (EPA 2024a)
Electric Power Transmission & Distribution	2022 as proxy for 2023	SIT	National GHG Inventory (EPA 2024b)
Iron and Steel Production	2023	40 CFR 98 Subpart Q	GHGRP (EPA 2024a)
Lime Manufacture	2023	40 CFR 98 Subpart S	GHGRP (EPA 2024a)
Limestone and Dolomite Use	2021 as proxy for 2022 - 2023	SIT	(USGS 2023)
Nitric Acid Production	2023	40 CFR 98 Subpart V	GHGRP (EPA 2024a)
ODS Substitutes	2022 as proxy for 2023	SIT	National GHG Inventory (EPA 2024b)
Semiconductor Manufacturing	2021 as a proxy for 2022-2023	SIT	SIT defaults
Soda Ash Use	2021 as a proxy for 2022-2023	SIT	(USGS 2023)

Categories Calculated using the SIT

Because current emissions data was not available for electric power transmission and distribution, the 2022 national emissions were used as a proxy for 2023. The 2022 value was calculated by determining the ratio between 2022 Iowa retail sales to 2022 national retail sales (EIA 2024), and applying that ratio to 2022 national emissions of SF₆. The 2022 retail sales ratio was used to calculate 2022 emissions

Emissions in 2021 from the use of limestone and dolomite in industrial processes were used as a proxy for 2022 – 2023 emissions. The 2021 value was calculated by multiplying Iowa’s 2021 consumption by the ratio of national consumption for industrial uses to total national consumption.

Emissions in 2022 from ODS substitutes were used as proxy for 2023. The 2022 value was calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa’s population is 0.96% of the total U.S. Population (U.S. Census 2024).

Emissions in 2023 from semiconductor manufacturing were calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa’s population is 0.96% of the total U.S. Population (U.S. Census 2024).

Emissions in 2023 from soda ash consumption were calculated using the national consumption value and assuming that Iowa emissions were 0.96% of national emissions because Iowa’s population is 0.96% of the total U.S. Population (U.S. Census 2024).

Adjustments

Emissions from limestone and dolomite use were adjusted for the years 2021 and 2022 by using updated activity data from USGS in the SIT. See Table 14 below for updates.

Table 14: Recalculated Emissions from Limestone and Dolomite Use (MMtCO₂e)¹⁰

	2021	2022
Previous Value	0.28	0.28

¹⁰ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

	2021	2022
Updated Value	0.81	0.81

Emissions from electric power transmission and distribution were recalculated using updated national emissions data for 2022. Changes are shown in Table 15 below.

Table 15: Recalculated Emissions from Electric Power T & D and ODS Substitutes

Subcategory	2022 Value	2022 Updated Value
Electric Power T & D	0.057	0.0823

Results

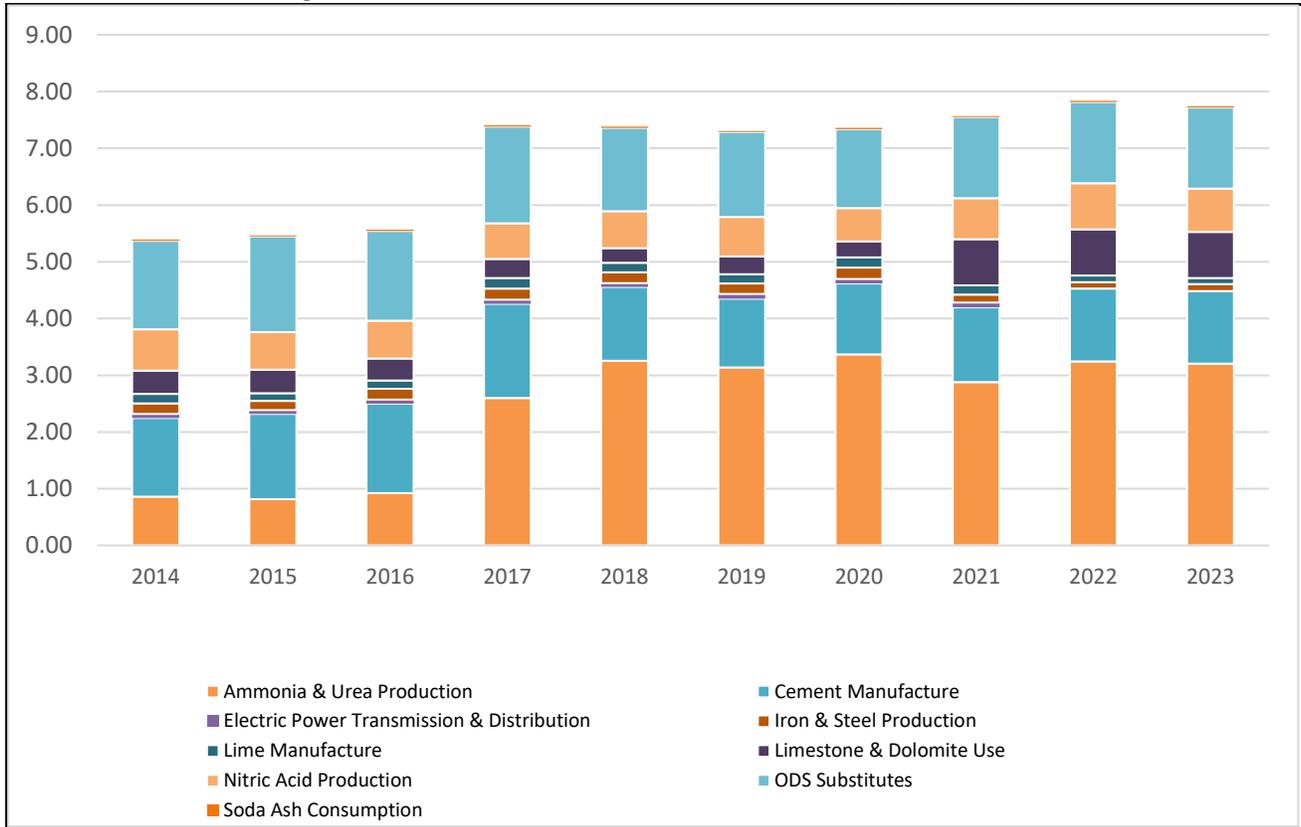
GHG emissions from industrial processes in 2023 were 7.82 MMtCO₂e, or 6.21% of total statewide GHG emissions. Emissions from this sector decreased 1.20% from 2022 as shown in Table 16 and Figure 6, primarily due to decreases in emissions in nitric acid production (-0.06 MMtCO₂e), ammonia and urea production (-0.04 MMtCO₂e), lime manufacture (-0.01 MMtCO₂e). The decrease was offset an increase in iron and steel production (0.01 MMtCO₂e) and no significant change in electric power transmissions and distribution, cement manufacture, limestone and dolomite use, ODS substitutes or soda ash consumption.

Table 16: GHG Emissions from Industrial Processes (MMtCO₂e)¹¹

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Ammonia & Urea	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88	3.24	3.20
Cement Manufacture	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31	1.28	1.28
Electric Power T&D	0.08	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
Iron & Steel Production	0.18	0.16	0.19	0.20	0.19	0.18	0.20	0.14	0.11	0.12
Lime Manufacture	0.17	0.13	0.15	0.18	0.16	0.17	0.18	0.16	0.12	0.11
Limestone & Dolomite Use	0.41	0.42	0.38	0.34	0.26	0.31	0.28	0.81	0.81	0.81
Nitric Acid Production	0.73	0.66	0.67	0.63	0.65	0.70	0.59	0.72	0.82	0.76
ODS Substitutes	1.56	1.69	1.58	1.71	1.47	1.4981	1.39	1.43	1.43	1.43
Semiconductor Manufacturing	0.028	0.0190	0.0097	0.0006	0.0007	0.0006	0.0006	0.0007	0.0007	0.0007
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	5.42	5.49	5.57	7.40	7.38	7.31	7.36	7.57	7.92	7.82

¹¹ Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2014– 203 rounded to 0.001 MMtCO₂e or less.

Figure 6: GHG Emissions from Industrial Processes (MMtCO₂e)



Uncertainty

Uncertainty occurs in categories where SIT default activity data was used instead of lowa-specific activity data, such as limestone and dolomite use, soda ash use, ODS substitutes, and electric power transmission and distribution.

Other major sources of uncertainty associated with calculating emissions from industrial processes are listed below:¹²

- The estimation of emissions for limestone and dolomite use contains some inherent uncertainty based on limestone’s variable composition.
- The use of population to disaggregate national emissions adds significant uncertainty.
- Uncertainties in emission estimates for electric power transmissions and distribution can be attributed to apportioning national emissions based on electricity sales. This method incorporates a low probability assumption that various emission reduction practices by industry occur evenly throughout the country.

¹² This information is largely excerpted from the *SIT Industrial Processes Module* (ICF 2024a).

Chapter 5 - Natural Gas Transmission & Distribution

This chapter includes GHG emissions from natural gas transmission and distribution (T & D) in Iowa. In this sector, methane (CH₄) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO₂) emissions from venting and flaring were not calculated due to a lack of data. GHG emissions from coal mining and natural gas production (including venting and flaring, oil production, oil transmission, and oil transportation), are not included as those activities are not currently taking place in Iowa.

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high-volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH₄ is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2024b).

The number of miles of transmission pipeline in Iowa was obtained from the United States Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Pipeline Safety (DOT 2024). In the past, DNR has contacted the Iowa Utilities Board (IUB) to determine the number of natural gas compressor and storage stations in the state. IUB has been unable to provide the data as they now track the facilities differently (Myers 2021). DNR has not received an application for a new compressor station or storage station in the past four years, and has assumed the number of stations has not changed since 2020 (Zayudis 2024).

Natural Gas Distribution

Natural gas is distributed through large networks of small, low-pressure pipelines. Natural gas flows from the transmission system to the distribution network at municipal gate stations, where the pressure is reduced for distribution within municipalities. CH₄ is emitted from leaks, meters, regulators, and accidents (ICF 2024b). Activity data from the DOT PHMSA's Office of Pipeline Safety was used for calculating emissions (DOT 2024). Data entered included miles of steel and cast-iron distribution pipeline, unprotected and protected; number of services; and number of steel services, unprotected and protected.

Results

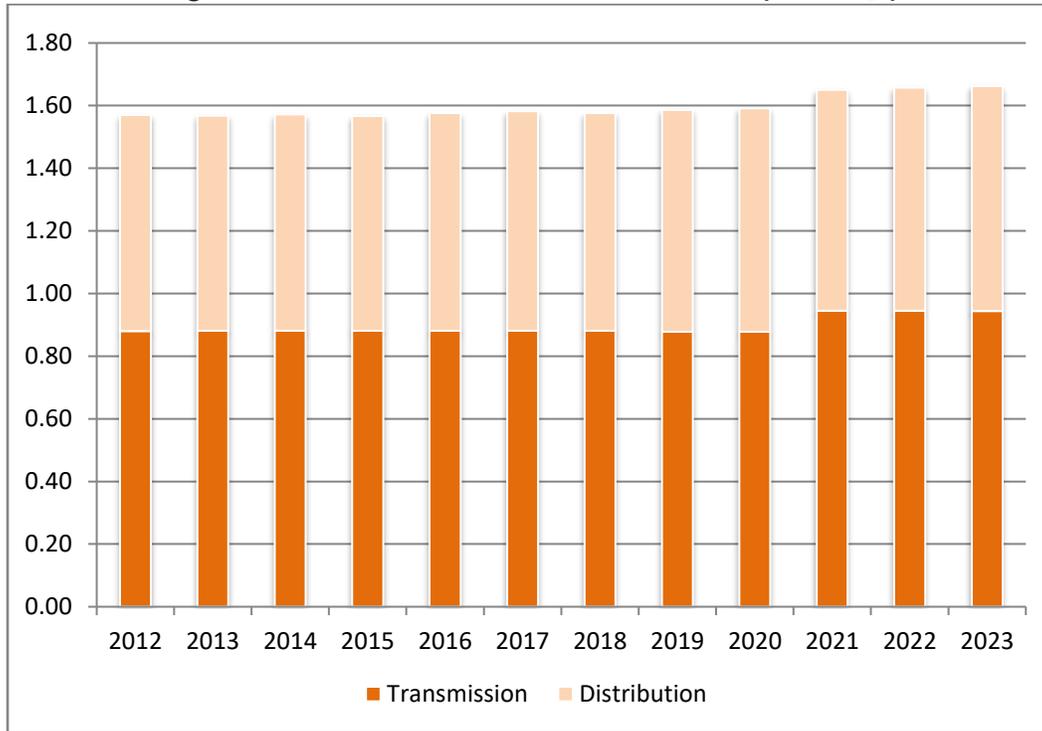
Total GHG emissions from natural gas transmission and distribution were 1.6622 MMtCO₂e¹³ in 2023, an increase of 0.3243% from 2022 and an increase of 5.77% from 2014 as shown in Table 17 and Figure 7. GHG emissions from this sector account for 1.32% of 2023 statewide GHG emissions.

¹³ DNR generally uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

Table 17: GHG Emissions from Natural Gas T & D (MMtCO₂e)

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Transmission	0.8807	0.8812	0.8811	0.8813	0.8808	0.8783	0.8783	0.9451	0.9453	0.9437
Distribution	0.6908	0.6852	0.6950	0.7013	0.6954	0.7079	0.7126	0.7047	0.7115	0.7184
Total	1.5715	1.5664	1.5761	1.5826	1.5762	1.5862	1.5909	1.6497	1.6568	1.6622

Figure 7: GHG Emissions from Natural Gas T & D (MMtCO₂e)



Uncertainty¹⁴

The main source of uncertainty in the SIT calculation methods is the emission factors. The emission factors used are based on a combination of statistical reporting, equipment design data, engineering calculations and studies, surveys of affected facilities and measurements. In the process of combining these individual components, the uncertainty of each individual component is pooled to generate a larger uncertainty for the overall emission factor. In addition, statistical uncertainties arise from natural variation in measurements, equipment types, operational variability, and survey and statistical methodologies. The method also does not account for regional differences in natural gas infrastructure and activity levels (ICF 2024a).

¹⁴ This information is largely excerpted from the *SIT Natural Gas and Oil Systems Module* (ICF 2022a).

Chapter 6 - Transportation

This chapter includes GHG emissions from both highway and non-highway vehicles such as aviation, boats, locomotives, tractors, other utility vehicles, and alternative fuel vehicles.

Method

Emissions were calculated using the SIT Mobile Combustion module (ICF 2024a), which was updated by EPA in 2022 to calculate CO₂, CH₄, and N₂O emissions from highway vehicles based on vehicle miles traveled, accounting for the vehicle type, vehicle age, and the annual vehicle miles traveled. Emissions from non-highway vehicles were calculated based on fossil fuel consumption. EPA updated the N₂O emissions factors in the 2021 SIT Mobile Combustion module, which are significantly higher than the factors used in the past.

Highway Vehicles (CH₄ and N₂O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH₄ and N₂O emissions from highway vehicles were calculated using the SIT as follows:

1. The vehicle miles traveled (VMT) for each vehicle type was calculated using the total 2022 annual VMT of 33,938 million miles from the Iowa Department of Transportation (IDOT 2024). Neither the IDOT nor FHWA track state-level VMT by the seven classes used in the SIT. The state VMT was distributed among seven vehicle/fuel classes using the national distribution percentages from the Tables A-71 and A-72 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022* (EPA 2024). The classes and the national distribution percentages are shown in Table 18.

Table 18: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2022 (EPA 2024)	2023 Iowa VMT (10 ⁶ miles)
Heavy duty diesel bus	HDDDB	0.47%	158
Heavy duty diesel vehicle	HDDV	8.58%	2,884
Heavy duty gas vehicle	HDGV	0.91%	304
Light duty diesel truck	LDDT	2.25%	757
Light duty diesel vehicle	LDDV	0.26%	94
Light duty gasoline truck	LDGT	49.31%	16,577
Light duty gasoline vehicle	LDGV	37.59%	12,637
Motorcycle	MC	0.64%	215
Total		100.00%	33,625

2. The VMT was then converted for use with existing emission factors. Iowa-specific emission factors were not available, so the SIT default emission factors were used. These factors are consistent with those used in the most recent national GHG inventory.
3. Next, the VMT was allocated by model year. Iowa-specific VMT data by model year was not available, so the VMT was allocated using the default national on-road age distribution by vehicle/fuel type in the SIT. The “Annual Vehicle Mileage Accumulation” table in SIT was updated to match that in Table A-76 in the most recent national inventory (EPA 2024).

- The control technology was then allocated by model year. Iowa-specific control technologies by model year were not available, so the national control technology values were used. The values in the SIT matched the Tables A-79, A-80, and A-81 in Annex 3 of the most recent national inventory (EPA 2024).

Non-highway Vehicles (CH₄ and N₂O)

Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH₄ and N₂O emissions from non-highway vehicles were calculated using data from either the Energy Information Administration (EIA) or Federal Highway Administration as shown in Table 19.

Table 19: Iowa-specific Non-Highway Activity Data Used

Vehicle Type	Fuel Type	Year	Data Source
Aviation	Gasoline	2022 used as proxy for 2023	EIA SEDS (EIA 2024)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2022 used as proxy for 2023	FHWA 2024
Heavy Duty Utility			
Tractors			
Construction			
Construction	Distillate Fuel	2020 used as proxy for 2021-2023	EIA Adjusted Sales (EIA 2022)
Locomotives			
Tractors			
Heavy Duty	Distillate Fuel	2021 used as proxy for 2022-2023	SIT default value
Small Utility	Gasoline		
Alternative Fuel Vehicles	Gasoline		

Adjustments

Emissions from non-highway vehicles were recalculated for 2022 as shown in Table 20 by using updated fuel activity data from EIA and the FHWA for gasoline vehicles. For the vehicles that operate using distillate fuel, DNR continued to use 2020 as a proxy for fuel usage in 2021-2023 because updated fuel usage was not available.

Table 20: Recalculated Emissions from Transportation (MMtCO₂e)¹⁵

Pollutant	2022 Value	2022 Updated Value
CO ₂	19.42	22.44
CH ₄	0.03	0.03
N ₂ O	0.23	0.23
Total	19.68	22.70

Results

Total GHG emissions from transportation were 23.13 MMtCO₂e in 2023 as shown in Table 21. This is an increase of 1.93% from 2022 due to a 2.09% increase in VMT from 2022 - 2023 as well as a change in the EPA model used to estimate vehicle emissions by vehicle class. CO₂ accounts for nearly all the Iowa transportation GHG emissions (98.89%) as shown in Figure 8. The majority of the transportation emissions (56.29%) are from gasoline highway

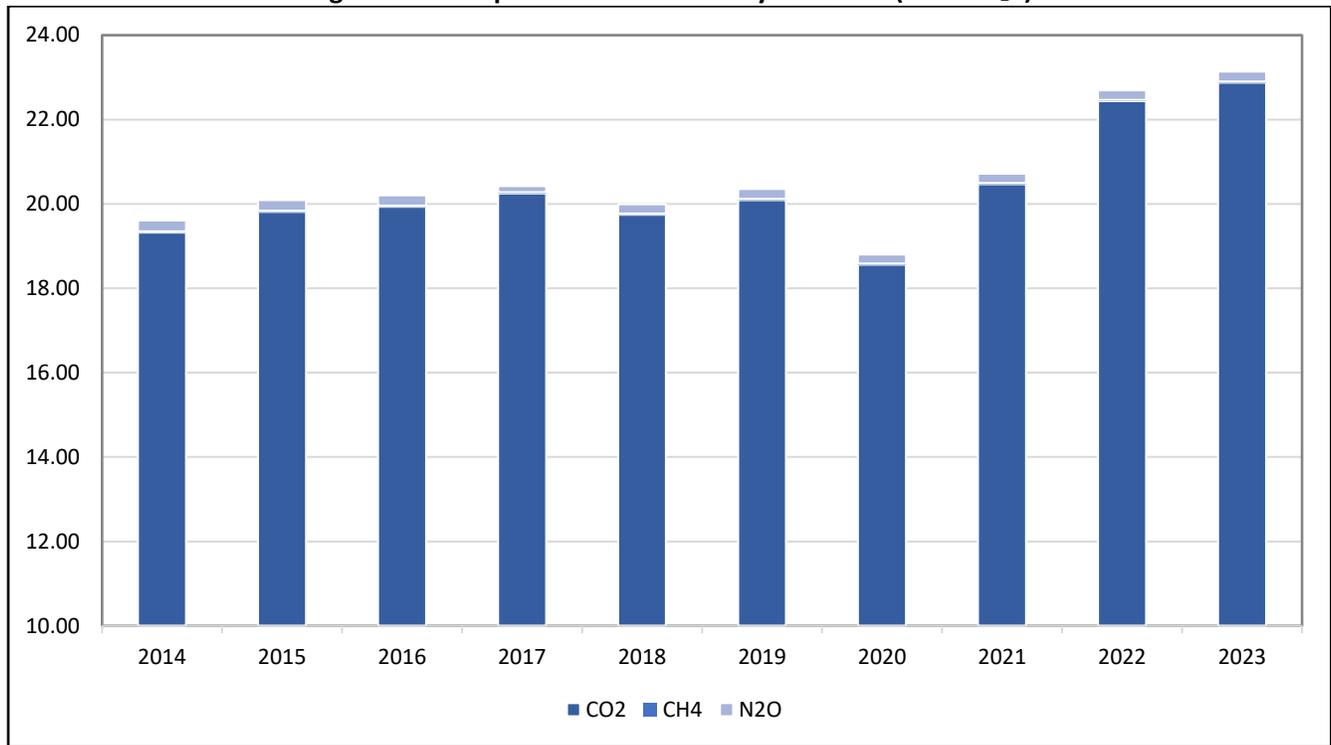
¹⁵ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

vehicles as shown in Figure 9. GHG emissions from this sector account for 18.37% of 2023 statewide GHG emissions.

Table 21: GHG Emissions from Transportation (MMtCO₂e)¹⁶

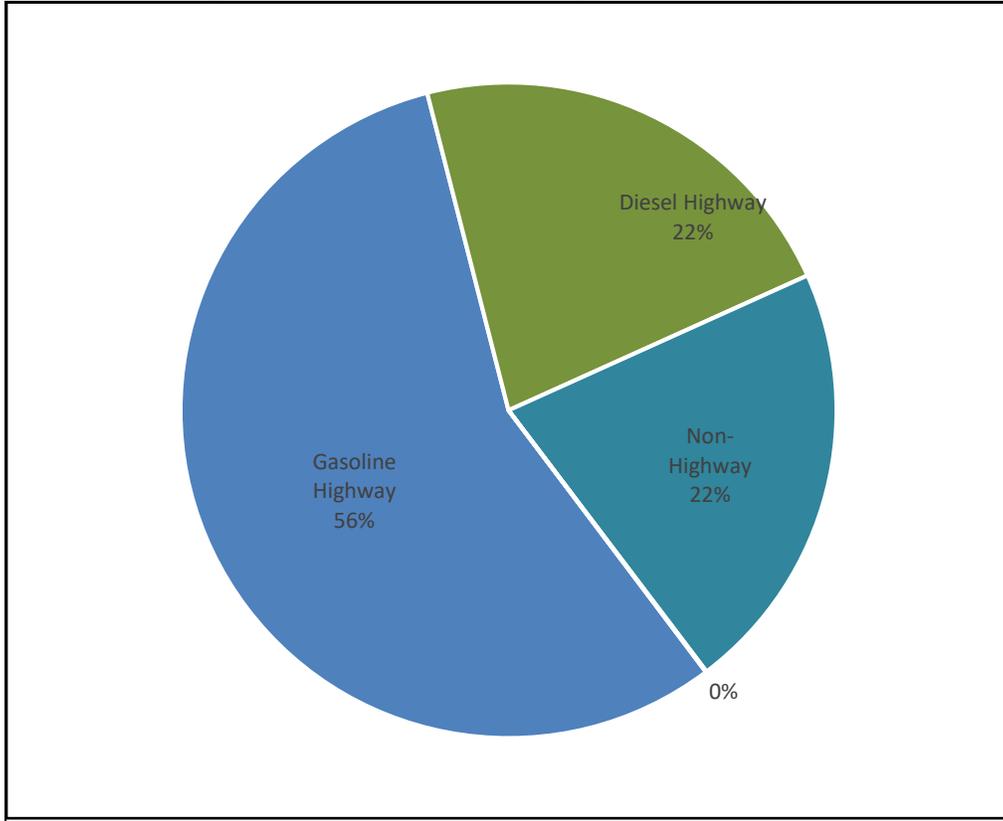
Pollutant	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO ₂	19.32	19.81	19.93	20.25	19.74	20.09	18.56	20.47	22.44	22.88
CH ₄	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N ₂ O	0.25	0.25	0.24	0.14	0.22	0.23	0.21	0.21	0.23	0.23
Total	19.61	20.09	20.20	20.42	19.99	20.35	18.80	20.71	22.70	23.13

Figure 8: Transportation Emissions by Pollutant (MMtCO₂e)



¹⁶ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 9: 2023 GHG Emissions by Fuel/Vehicle Type¹⁷



Uncertainty

Uncertainty occurs because national vehicle/fuel type, age distributions, and emission factors, which may not be reflective of Iowa conditions, were applied to Iowa-specific VMT data. There is also some uncertainty in the method EPA used to develop the national vehicle/fuel type distributions and to develop emission factors (EPA 2023). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable to locate Iowa-specific VMT data. Uncertainty may be introduced if the fuel consumption data or emission factors used do not reflect Iowa scenarios, such as using default national emission factors. In addition, it is assumed that all fuel purchased is consumed in the same year (ICF 2024b).

¹⁷ Emissions from alternative vehicles round to 0%.

Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH₄) emissions from municipal solid waste landfills and carbon dioxide (CO₂) and nitrous oxide (N₂O) emitted from the combustion of municipal solid waste to produce electricity. CH₄ emissions from landfills are a function of several factors, including:

- The total quantity of waste in municipal solid waste landfills,
- The characteristics of the landfills such as composition of the waste, size, and climate; the quantity of CH₄ that is recovered and flared, and
- The quantity of CH₄ oxidized in landfills instead of being released into the atmosphere.

Fluctuations in CH₄ emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, composting, and the rate of recycling of degradable materials such as paper and paperboard (EPA 2024b).

Method

Municipal Solid Waste (MSW) Landfills

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2024a), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO₂e or more to report their emissions. This included twenty-six Iowa landfills in 2023. An additional twenty Iowa MSW landfills were not required to report to the GHGRP. To calculate emissions for those that did not report to the GHGRP, the DNR calculated the potential methane emissions using EPA's Landfill Gas Emissions Model (LandGEM) version 3.02. It is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in MSW landfills (EPA 2005).

There are three landfills in Iowa that collect biogas, clean it and inject it into the natural gas pipeline system (Rath 2024). Combustion of this biogenic natural gas is not included in the amount of natural gas combusted in the state measured in the energy sector (Chapter 3 – Fossil Fuel Consumption). The facilities that inject biogas report actual greenhouse gas emissions to EPA's GHGRP, which DNR used in this inventory.

Combustion of Municipal Solid Waste

The amount of CH₄ emitted from waste to energy (WTE) facilities (i.e. power plants burning MSW to produce electricity) was calculated using data reported annually by individual facilities to the DNR's Air Quality Bureau on their annual air emissions inventories. One facility reported burning a total of 29,864 tons of refuse-derived fuel in 2023 (Feucht 2024). The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO₂ emissions from MSW combustion using SIT (ICF 2024a). These state-specific proportion values are from the 2022 Iowa Statewide Waste Characterization Study (SCS 2022). Earlier versions of the study (MSW 2011, SCS 2017) were used to calculate emissions from 2010 – 2020. The 2017 Iowa Statewide Waste Characterization Study (SCS 2017) was used to estimate the proportion of synthetic fibers as the 2022 study did not completely account for this material. The state-specific proportions of discards used are shown in Table 22.

Table 22: Proportions of Discards used in the Solid Waste Module

Material	SIT Default Value	2011 Iowa Study	2017 Iowa Study	2022 Iowa Study
Plastics	9.8 – 20.4%	16.7%	18.3%	15.3%
Synthetic Rubber	1.9 – 2.8%	1.0%	1.2%	1.6%
Synthetic Fibers	2.9 – 8.0%	4.1%	4.5%	Not recorded

Plastics and synthetic rubber materials may be further divided in the SIT into subcategories of plastics and rubber (e.g. polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), etc.), but the subcategories in the SIT do not match the subcategories in the waste characterization study.

Composting

There is limited composting of organic waste in Iowa and the emissions are considered de minimus. Therefore, they are not included in this report.

Results

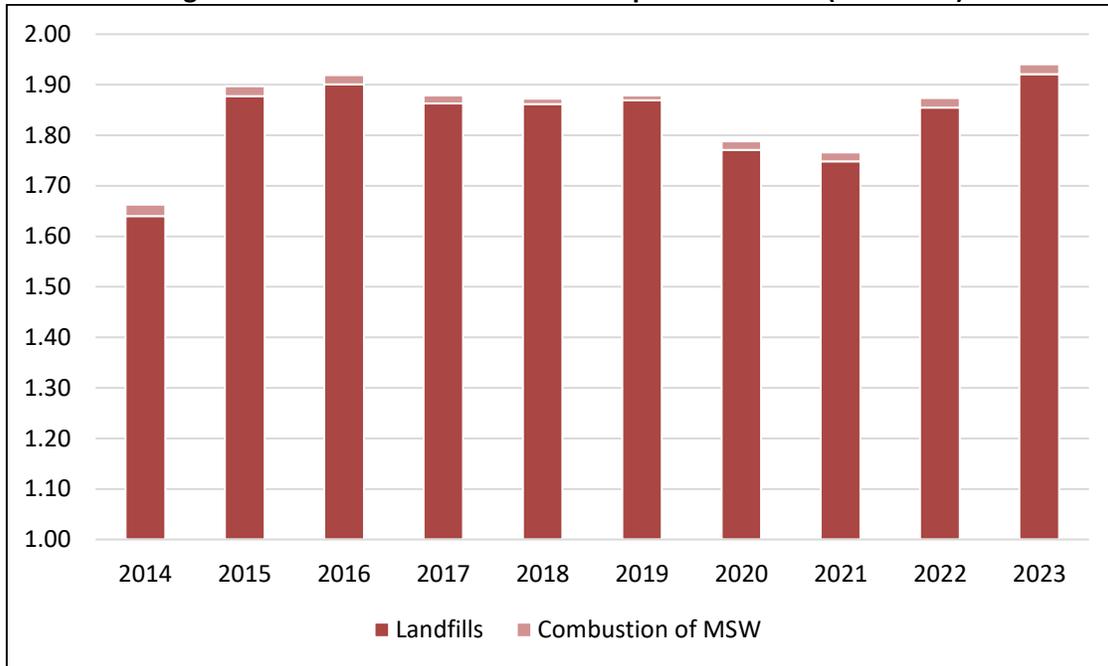
Total GHG emissions from the solid waste category were 1.94 MMtCO₂e in 2023, an increase of 3.56% from 2022 as shown in Table 23 and Figure 10. Solid waste emissions account for 1.54% of total statewide GHG emissions. Emissions from waste disposed in landfills, the largest category of emissions, increased by 3.58%. Additionally, emissions from the combustion of MSW increased by 1.27%. It is important to note that the relationship between emissions and the cumulative amount of waste is not linear as emissions vary due to the length of time the waste is in the landfill and because the decomposition rate of the waste fluctuates according to the amount of waste in the landfill, the climate, the quantity of CH₄ that is recovered and used as renewable natural gas or flared, and varying oxidation rates.

Table 23: GHG Emissions from Municipal Solid Waste (MMtCO₂e)¹⁸

Sector	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
MSW Landfills	1.64	1.88	1.90	1.86	1.86	1.87	1.77	1.75	1.85	1.92
MSW Combustion	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Total	1.66	1.90	1.92	1.88	1.87	1.88	1.79	1.77	1.87	1.94

¹⁸ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 10: GHG Emissions from Municipal Solid Waste (MMtCO₂e)



Uncertainty¹⁹

MSW Combustion

There are several sources of uncertainty in this sector, including combustion and oxidation rates, average carbon contents, and biogenic content.

- The combustion rate is not exact and varies by the quantity and composition of the waste.
- The oxidation rate varies depending on the type of waste combusted, moisture content, etc.
- The SIT uses average carbon contents instead of specific carbon contents for other plastics, synthetic rubber, and synthetic fibers.
- Non-biogenic CO₂ emissions vary depending on the amount of non-biogenic carbon in the waste and the percentage of non-biogenic carbon that is oxidized.

The SIT assumes that all carbon in textiles is non-biomass carbon and the category of rubber and leather is almost all rubber. This may result in CO₂ emissions being slightly over-estimated (ICF 2024b).

¹⁹ This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2024b).

Chapter 8 – Waste: Wastewater Treatment

This chapter includes GHG emissions from the treatment of municipal and industrial wastewater. The pollutants from this sector are methane (CH₄) and nitrous oxide (N₂O). CH₄ is emitted from the treatment of wastewater, both industrial and municipal. CH₄ is produced when organic material is treated in an anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N₂O is produced through nitrification followed by incomplete denitrification of both municipal and industrial wastewater containing both organic and inorganic nitrogen species. Production and subsequent emissions of N₂O is a complex function of biological, chemical, and physical factors, and emission rates depend on the specific conditions of the wastewater and the wastewater collection and treatment system. Human sewage makes up a significant portion of the raw material leading to N₂O emissions (ICF 2024b).

Method

Municipal Wastewater

GHG emissions from municipal wastewater are calculated in the SIT by multiplying a series of emission factors by the annual Iowa population, which was updated for 2022 (U.S. Census 2023). For example, to calculate CH₄ emissions, the state population was multiplied by the quantity of biochemical oxygen demands (BOD) per person emission factor, by the fraction that is treated anaerobically, and by the quantity of CH₄ produced per metric ton. It does not account for any digester methane that is collected and combusted instead of fossil fuels in equipment such as boilers, generators, or flares.

SIT default emission factors and assumptions were used to calculate both CH₄ and N₂O emissions, except that N₂O was calculated using the most recent protein (kg/person-year) value (44.4) from Table 7-34 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022* (EPA 2024b). Because the 2023 protein value was not available at the time of publication, the 2022 value was used as a surrogate for 2023.

Starting in 2020, the inventory has included the portion of municipal wastewater sludge from major wastewater facilities that was land applied. DNR collects data on the annual volume of wastewater sludge that is applied to land to condition soil by municipal wastewater treatment facilities. Major wastewater treatment facilities have a design capacity greater than or equal to 1 million gallons per day. Smaller facilities do land apply municipal wastewater sludge, but this data is not reported to the DNR so the quantity is unknown (Chennupati 2022). In 2023, 41,294 metric tons of municipal wastewater sludge was applied to land to condition soil (DNR 2024). The land application of sewage sludge was already accounted for in the agriculture chapter, so this change prevents double counting of emissions.

The Iowa fraction of population without septic systems, 76%, from EPA's *Onsite Wastewater Treatment Systems Manual* (EPA 2002), was also used to estimate N₂O emissions. This value taken from the *1990 Census of Housing* and is lower than the SIT default value of 79%. The US Census Bureau does not have more recent data on the fraction of the Iowa population without septic systems.

Industrial Wastewater

In 2015, the DNR refined its method for calculating emissions from industrial wastewater. The DNR previously calculated emissions using the SIT and statewide red meat production numbers from the USDA. This method

had a great deal of uncertainty as it only calculated emissions from wastewater at meat processing facilities and because it assumed a set amount of emissions from each metric ton of meat processed.

The EPA began requiring industrial wastewater facilities that emit 25,000 metric tons CO₂e or more to report to the federal greenhouse gas reporting program (GHGRP) starting with year 2011 emissions. In Iowa, this includes emissions from food processing facilities and ethanol production facilities. The emissions reported to EPA have a higher level of accuracy than the SIT method because they are based on the unique characteristics and wastewater organic content of each facility. In 2023, one ethanol production facility and five food processing facilities emitted more than 25,000 metric tons CO₂e or more (EPA 2024a). The number of food processors reporting emissions in 2023 did not change from 2022. Two fewer ethanol facilities reported emissions of more than 25,000 metric tons CO₂e in 2023 than 2022.

Results

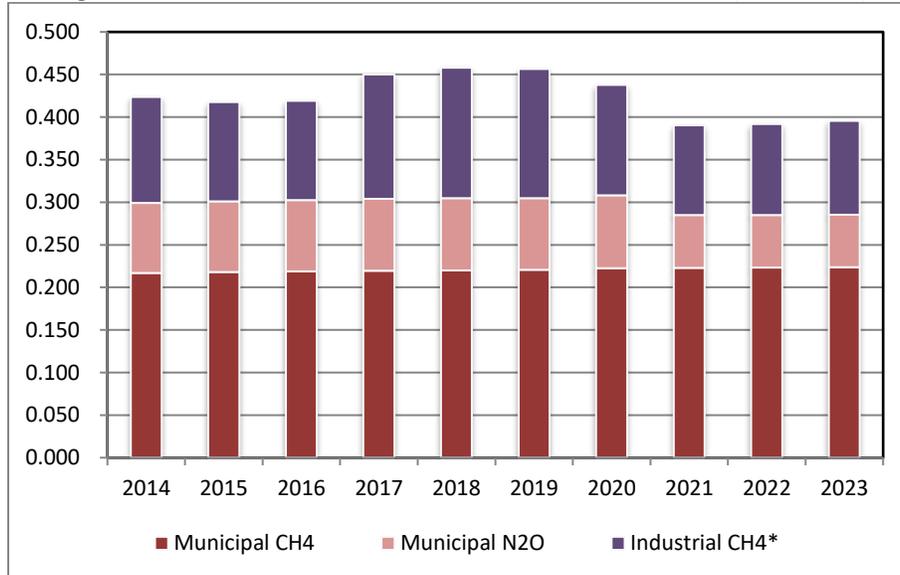
Wastewater emissions account for 0.31% of the total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.396 MMtCO₂e in 2023, a 0.98% increase from 2022 and a 6.54% decrease from 2014 as shown in Table 25. This is due to a decrease in the amount of wastewater produced by industrial meat processing facilities and ethanol plants corresponding to a decrease in the number of facilities that reported emissions, as well as more accurate calculations of emissions from municipal sewage sludge. CH₄ and N₂O from municipal wastewater treatment accounted for 72.11% of total wastewater treatment GHG emissions as shown in Figure 11.

Table 25: GHG Emissions from Wastewater (MMtCO₂e)²⁰

Sector	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Municipal CH ₄	0.217	0.218	0.219	0.219	0.220	0.221	0.223	0.223	0.223	0.224
Municipal N ₂ O	0.082	0.083	0.084	0.084	0.085	0.084	0.085	0.062	0.062	0.061
Industrial CH ₄	0.124	0.116	0.117	0.146	0.153	0.152	0.130	0.105	0.107	0.110
Total	0.423	0.417	0.419	0.450	0.458	0.456	0.438	0.390	0.392	0.396

²⁰ DNR generally uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed show the difference in emissions from year to year.

Figure 11: GHG Emissions from Wastewater Treatment (MMtCO₂e)



*Does not include emissions from production of fruits and vegetables, pulp and paper.

Uncertainty²¹

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH₄ emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the low-specific percentage of the population without septic systems was used to calculate emissions, the value is from 1990. There can also be variation in the per-capita BOD production associated with food consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors due to differences in wastewater treatment facilities (ICF 2024a).

N₂O emissions are dependent on nitrogen (N) inputs into the wastewater and the characteristics of wastewater treatment methods. Estimates of U.S. population, per capita protein consumption data, and the fraction of nitrogen in protein are believed to be accurate. However, the fraction that is used to represent the ratio of non-consumption nitrogen also contributes to the overall uncertainty of these calculations, as does the emission factor for effluent, which is the default emission factor from IPCC (1997). Different disposal methods of sewage sludge, such as incineration, landfilling, or land-application as fertilizer also add complexity to the GHG calculation method (ICF 2024a).

Industrial Wastewater

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 mtCO₂e or more are required to report to the federal greenhouse gas reporting program. Future improvements to the inventory could include identifying all of the industrial wastewater facilities that are not required to report to the federal program and developing a method to calculate their emissions.

²¹ This information is largely excerpted from the *SIT Wastewater Module* (ICF 2024a).

Biogas

Three wastewater facilities in Iowa produce methane in digesters, clean the resulting biogas and inject it into the natural gas pipeline system. Combustion of this biogas is not included in the amount of natural gas combusted in the state measured in the energy sector (Chapter 3 – Fossil Fuel Consumption). These facilities collect biogas from municipal and industrial customers. The methane emissions from industrial customers below 25,000 metric tons CO₂e are not included in this report so are not double counted. However, it is likely that the methane emissions from municipal customers serviced by these three wastewater facilities may be overestimated.

Chapter 9 - Land Use, Land Use Change, and Forestry (LULUCF)

This chapter addresses carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) emissions from liming of agricultural soils and fertilization of settlement soils,²² as well as carbon stored in forests, urban trees, agricultural soils, and landfills. This carbon storage is also called carbon sequestration or a carbon sink.

Human activities such as cutting forests to create cropland, draining wet lands, reverting pastures to grassland, and replanting logged forests are land use, land use change and forestry (LULUCF) activities that affect the balance between the emission and uptake of GHGs, affecting their atmospheric concentration. This balance is known as GHG flux. CO₂ is also emitted from applying lime to agricultural soils and applying urea as a fertilizer. N₂O is emitted when fertilizers are applied to settled soils such as landscaping, lawns, and golf courses. CH₄ and N₂O are also emitted from forest fires (ICF 2024b).

Method

Forest Carbon Flux

CO₂ is taken in by plants and trees and converted to carbon in biomass during photosynthesis. “Tree biomass is approximately 50% carbon. As trees grow larger, they take in more carbon from the atmosphere; however, when trees die and begin to decay, decomposition releases that carbon back into the atmosphere Wood products also work to store carbon.” (Edwards 2020). The calculated annual forest carbon flux includes sequestration/emissions in the following forest categories:

- Carbon in live trees and saplings above ground on forest land
- Carbon in understory above ground on forest land
- Carbon in live trees and saplings below ground on forest land
- Carbon in understory below ground on forest land
- Carbon in standing dead trees on forest land
- Carbon in down dead trees on forest land
- Carbon in litter (shed vegetation decomposing above the soil surface) on forest land
- Soil organic carbon on forest land

In previous years, the DNR used data from the USDA Forest Inventory Data Online (2010 – 2015) or the Design and Analysis Toolkit for Inventory and Monitoring (2016 – 2018) to calculate forest carbon flux. However, in October 2020, EPA updated the SIT methodologies to calculate forest carbon flux (IPC 2024b). The new methodologies are consistent with those used by EPA in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2022* (EPA 2023) and produced substantially different results than the former method used prior to 2019. EPA updated the SIT methodologies again in 2023. Agricultural Soil Flux now includes carbon flux from above and belowground biomass, deadwood and litter, as well as organic and mineral soils. Land Converted to Forest Land and Forest Land Converted to Land were also updated to include carbon flux from wetlands. Because 2022 or 2023 forest carbon flux data is not available, 2021 was used as a proxy for 2022 and 2023.

²² Settled soils such as landscaping, lawns, and golf courses (ICF 2024b).

Liming of Agricultural Soils

CO₂ is emitted when acidic agricultural soils are neutralized by adding limestone or dolomite. The Iowa Limestone Producers Association (ILPA) provided the DNR with the total annual amount of limestone produced for agricultural use as reported by their members (Stassen 2024). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (IDOT) tracks general information for active aggregate sources used for construction, including whether the material is limestone or dolomite. They do not track that information for limestone produced for agricultural purposes. The IDOT indicated that some areas of the state have 100% dolomite, some have 100% limestone, and some areas are mixed (Reyes 2011). Therefore, the DNR assumed that 50% of the material produced in Iowa for agricultural use is dolomite and 50% is limestone. Future improvements to the inventory may include calculating the ratio of limestone to dolomite in the state. In 2018, EPA moved liming of agricultural soils from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included liming in this chapter.

Urea Fertilization

2023 urea emissions were calculated using the amount of urea applied annually (IDALS 2023). EPA has moved urea fertilization from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included urea fertilization in this chapter.

Urban Tree Flux

Carbon sequestration in this sector was calculated using the total urban area and percent of urban area with tree cover provided in the SIT module (ICF 2024). The SIT extrapolates the 2011 – 2020 values from urban tree coverage measures in 1990, 2000, and 2010. In 2020, some cities in Iowa experienced a significant reduction in their urban tree cover due to a derecho storm. Iowa DNR and Trees Forever estimate that Iowa lost 12.9% of its urban tree cover August 10-11, 2020. While the report used different calculation methods than this inventory, they estimated that the loss of urban trees from the derecho will reduce the future amount of carbon dioxide sequestered per year by 22,870.8 tons (IDNR and Trees Forever 2021).

Additionally, the Iowa has lost many of its ash trees to emerald ash borer (EAB) infestations. The SIT estimates that 27% of Iowa's urban areas have tree cover, but the DNR conservatively estimates that the EAB and 2020 derecho have reduced Iowa's urban tree cover to 15.5% (Hanigan 2022).

Settlement Soils

Approximately 10% of the fertilizers applied to soils in the United States are applied to soils in settled areas such as landscaping, lawns, and golf courses (ICF 2024b). N₂O emissions from settlement soils were calculated using 10% of the total annual growing year synthetic fertilizer value from the SIT Agriculture module. For more information on how the 2023 values were derived, please see *Chapter 2-Agriculture* of this report.

Non-CO₂ Emissions from Forest Fires

CH₄ and N₂O emissions from forest fires in Iowa were not estimated because the majority of wildfires and prescribed burns in Iowa that are reported to DNR occur on grasslands (Kantak 2014). In addition, the SIT calculation method uses combustion efficiencies and emission factors that are provided for primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forest, eucalypt forest, other temperate forests, shrub lands, and savanna woodlands, which are not reflective of Iowa vegetation.

Yard Trimmings and Food Scraps Stored in Landfills

GHG estimations from this sector were refined by applying the estimated percentages of yard trimmings and food waste in municipal solid waste from the 2022 Iowa Statewide Waste Characterization Study (MSW 2022) to the total amount of municipal solid waste sent to landfills in 2022 (DNR 2023). While the DNR was able to use more accurate Iowa values for the annual amounts of yard trimmings and food scraps stored in landfills, the DNR used the SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon because Iowa-specific data was not available.

Agricultural Soil Carbon Flux

This is the third year that DNR has included agricultural soil carbon flux in the Iowa GHG inventory. Carbon is continuously cycled through soils in both cropland and grassland (EPA 2024). The amount of carbon stored varies depending on crop type, management practices (e.g., rotation, tillage, drainage, irrigation), and soil and climate variables. Carbon may be emitted when soils are tilled. However, carbon may also be sequestered when soil conservation practices are used (no-till or reduced tillage), when cropland is enrolled in the Conservation Reserve Program, or when cropland is converted to grass, trees, or wetlands. The net change in agricultural soil carbon is the change in the amount of carbon stored in soils over time (ICF 2024b). In the past, the SIT did not include the ability to calculate emissions from soil carbon flux from tillage practices, but EPA recently updated the SIT to calculate agricultural soil carbon flux using the same methodologies as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2022* (EPA 2024).

Adjustments

2013-2021 sequestration from Forest Carbon Flux was recalculated using updated net sequestration and emissions values from forest land including above and belowground biomass, deadwood and litter, as well as organic and mineral soils. Land Converted to Forest Land and Forest Land Converted to Land were also updated to include carbon flux from wetlands.

Table 26: Recalculated Emissions from Forest Carbon Flux (MMtCO₂e)

Forest Carbon Flux	2021	2022
Previous Value	-3.24	-3.24
Updated Value	-3.57	-3.57

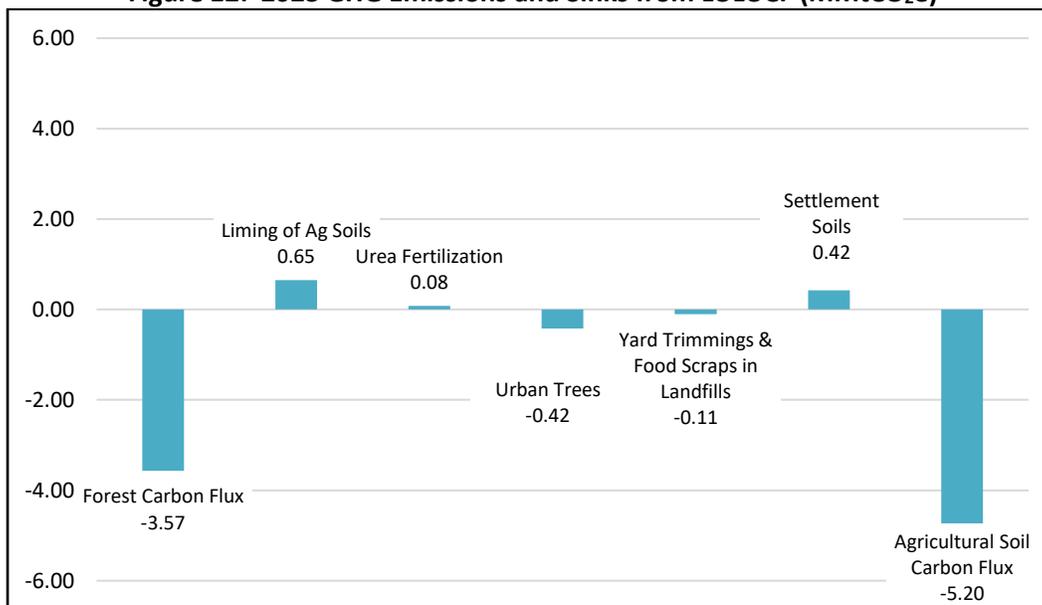
Results

Overall, sources in the LULUCF sector stored slightly less carbon in 2023 than they stored in 2022, storing 8.15 MMtCO₂e as shown in Table 27 and Figure 12. This is a decrease of 1.62% from 2022 and an increase of 22.13% from 2014. Emissions of CO₂ are shown above the x-axis in Figure 12 and carbon sinks are shown below the x-axis.

Table 27: GHG Emissions and Sinks from LULUCF (MMtCO₂e)²³

Sector	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Forest Carbon Flux	-3.57	-3.57	-3.58	-3.57	-3.57	-3.57	-3.56	-3.57	-3.57	-3.57
Liming of Ag Soils	0.41	0.34	0.46	0.45	0.40	0.28	0.54	0.56	0.53	0.65
Urea Fertilization	0.15	0.16	0.19	0.18	0.13	0.08	0.08	0.07	0.07	0.08
Urban Trees	-0.46	-0.47	-0.47	-0.48	-0.48	-0.49	-0.44	-0.42	-0.42	-0.42
Yard Trimmings & Food Scraps Stored in Landfills										
N ₂ O from Settlement Soils	0.49	0.40	0.41	0.47	0.42	0.41	0.40	0.44	0.42	0.42
Agricultural Soil Carbon Flux	-3.60	-4.23	-5.45	-5.58	-4.85	-4.71	-5.64	-5.20	-5.20	-5.20
Total	-6.68	-7.47	-8.53	-8.60	-8.05	-8.11	-8.74	-8.24	-8.29	-8.15

Figure 12: 2023 GHG Emissions and Sinks from LULUCF (MMtCO₂e)



Uncertainty

Uncertainty in the LULUCF sector is due to the lack of current Iowa-specific data and emission factors used to calculate emissions and/or sinks from urban trees and settlement soils. Emissions from categories such as urea fertilization, liming of agricultural soils, and yard trimmings and food scraps stored in landfills are more certain because Iowa-specific activity data was used. However, uncertainty was also introduced by:

- Using growing year synthetic fertilizer data for settlement soils instead of calendar year data,
- Assuming the national average of 10% of synthetic fertilizer used on settlement soils applies to Iowa,
- Assuming the ratio of limestone to dolomite in Iowa is 50%,
- Using SIT default values for content of yard trimmings (e.g. % grass, % leaves, and % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon, and
- Assuming Iowa’s urban tree cover is 15.5%. when it could be lower.

²³ Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Chapter 10 – Electricity Consumption

This chapter includes indirect emissions from electricity consumed at the point of use (e.g. residential electric hot water heaters, televisions, appliances, etc.) and does not include direct emissions generated at the electric power generating station (*see Chapter 3 – Fossil Fuel Combustion*).

Electricity consumed by lowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2024b). Therefore, GHG emissions from electricity consumption are included in this inventory as an informational item only and are not included in the total statewide GHG emissions to avoid any possible double counting. However, trends in electricity consumption are valuable because they are indicators of consumer behavior and trends in energy efficiency.

Method

GHG emissions were calculated using the Electricity Consumption SIT module (ICF 2024a).

Residential, Commercial, and Industrial

2023 emissions were calculated from the electricity consumption values reported by the EIA as “Annual sales to ultimate customers by state and sector” (EIA 2024a).

Transportation

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the Iowa Department of Transportation (IDOT 2024b), 15,159 electric vehicles were registered in Iowa in 2023. This is an increase of 41.51% from 2022, but is 0.40% of the total 3.75 million vehicles registered in the state in 2023 (IDOT 2024a3). Emissions were calculated assuming that each electric vehicle consumes 4,250 kWh of electricity per year (IEDA 2016). This does not include emissions from electric propulsion, other electric batteries, or non-highway electric vehicles such as golf carts.

Adjustments

2021 and 2022 emissions have been recalculated since the DNR’s 2022 GHG Inventory Report was published in December 2023. EPA updated the emissions factors and transmission losses in the SIT for the years 2021 and 2022 so DNR recalculated the emissions values as shown in Table 28. Previously, the DNR used the emissions factors and transmission losses from the year 2020 as a proxy for the factors and losses of 2021-2022.

Table 28: GHG Emissions from Electricity Consumption (MMtCO₂e)

Category	2021		2022	
	Published Dec. 2023	Updated Value	Published Dec. 2023	Updated Value
Residential	4.32	5.39	4.48	5.59
Commercial	3.58	4.46	3.67	4.59
Industrial	7.69	9.60	7.82	9.76
Transportation	0.01	0.01	0.01	0.01
Total	15.60	19.46	15.98	19.95

Results

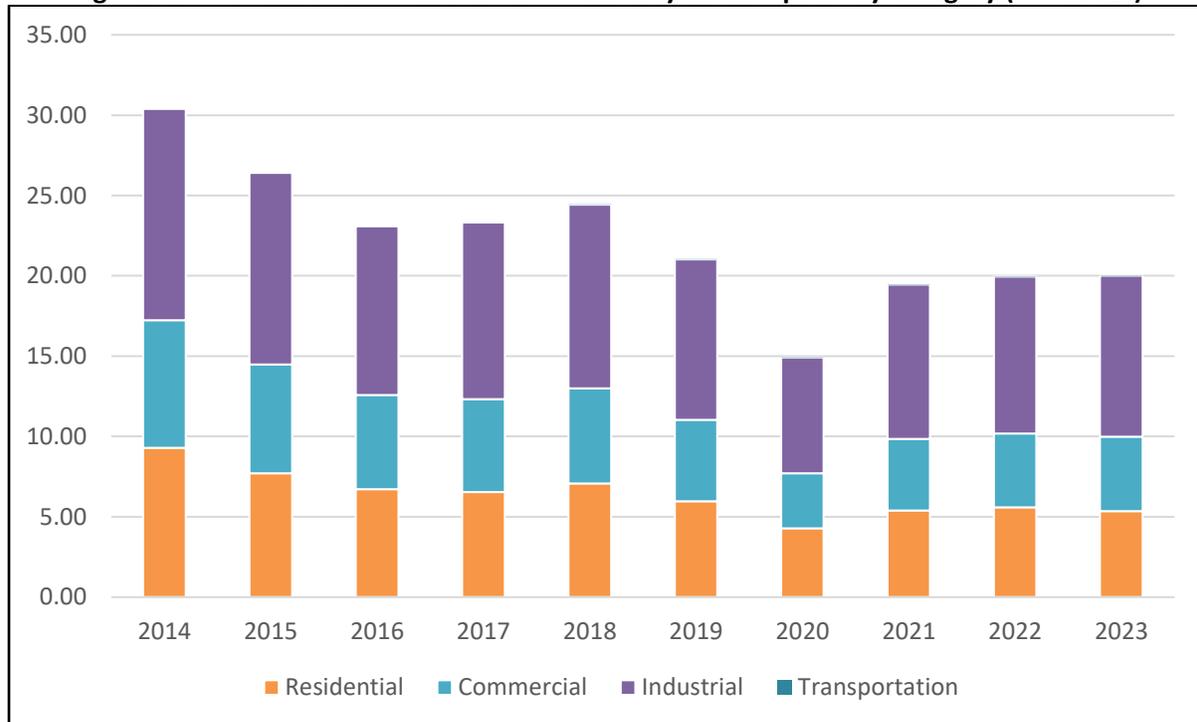
Indirect GHG emissions from electricity consumption were 20.01 MMtCO₂e in 2023, increasing 0.31% since 2022, due to projected increases in electricity consumption in all categories (EIA 2024a), as shown in Table 30 and Figure 13. Industrial users consumed the largest percentage of electricity, 50.02%, as shown in Figure 14.

Table 30: GHG Emissions from Electricity Consumption (MMtCO₂e)²⁴

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Residential	9.29	7.72	6.72	6.54	7.08	5.97	4.29	5.39	5.59	5.36
Commercial	7.94	6.76	5.86	5.79	5.92	5.07	3.42	4.46	4.59	4.63
Industrial	13.16	11.92	10.51	11.00	11.42	9.98	7.21	9.60	9.76	10.01
Transportation	*not calculated	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Total	30.39	26.41	23.09	23.32	24.43	21.03	14.93	19.46	19.95	20.01

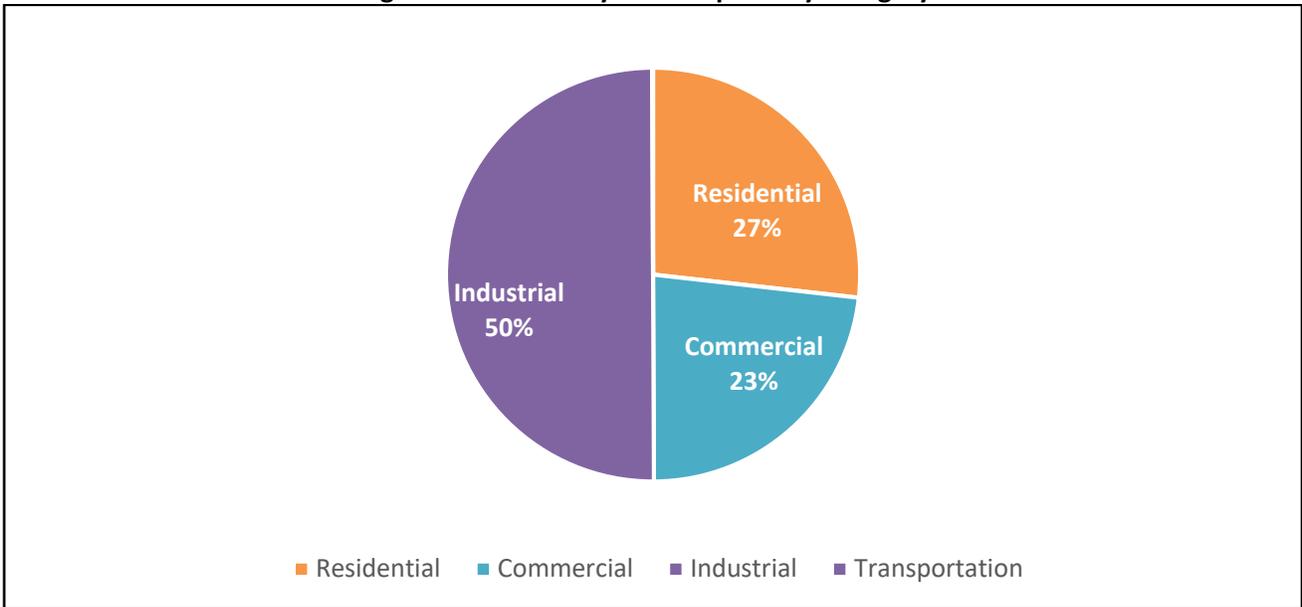
* 2015 was the first time that DNR calculated indirect emissions from electricity consumption.

Figure 13: Indirect GHG Emissions from Electricity Consumption by Category (MMtCO₂e)



²⁴ Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 14: Electricity Consumption by Category²⁵



²⁵ Emissions from transportation round to 0%.

Forecasting

Iowa Code 455B.104 requires that the DNR forecast trends in GHG emissions.

Method

The DNR projected emissions out to 2030 using the SIT Projection Tool (ICF 2024). The Projection Tool predicts that Iowa's population decreases every year from 2020 – 2030. This is contrary to the most recent population projections available from the U.S. Census. Consequently, the DNR replaced the Projection Tool default population projection with the 2024-2050 population projections from Woods & Poole Economics (Woods & Poole, 2024).

The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2022, using a combination of data sources and national projections for activity data. DNR used the Projection Tool to forecast 2023 emissions in order to compare actual 2023 emissions to the forecasted 2023 emissions.

Results

The DNR's calculated 2023 GHG inventory and projected emissions from the SIT Projection Tool for 2023, 2025, and 2030 for each category are shown in Table 31. Forecasts for all years up to 2050 are available from the DNR upon request. The 2023 "forecast" was produced to help gauge the reasonableness of the projections. The projected emissions for 2023 were 10.76 tons lower than actual gross emissions in 2023. This was mainly due to a -6.23 ton difference in projected emissions from power plants and -3.69 ton difference in projected emissions from combustion of fossil fuels in the RCI sector.

Table 31: Projected Gross GHG Emissions 2023 – 2030 (MMtCO₂e)

Sector	Calculated	Projected		
	2023	2023	2025	2030
Agriculture	36.20	36.37	37.18	38.85
Power Plants	20.21	13.97	11.77	5.37
RCI Fossil Fuel Use	34.59	30.89	28.48	28.95
Industrial Processes	7.82	8.05	9.22	10.66
Natural Gas T & D	1.66	1.39	1.41	1.41
Transportation	23.13	21.48	20.90	19.90
Waste	2.34	3.03	3.08	3.20
Total	125.95	115.19	112.04	108.35

Factors that May Affect Future Emissions

While the DNR cannot predict with certainty what the effects on future emissions will be, the DNR has identified two factors that may affect future GHG emissions:

1. Emissions from Power Plants

Emissions from power plants are difficult to forecast as the amount and fuel source of electricity generated is influenced by many factors such as:

- the economy,
- weather,
- future environmental regulations,

- electricity demand by customers,
- how electricity generation is dispatched by the grid operator, and
- other market forces.

2. Energy Consumption

Greenhouse gas emissions are also affected by energy consumption. The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* (EIA 2024) on December 10, 2024, stating that “...our forecast for 2025 emissions is 2% (or around 100 million metric tons) higher than it was forecast in our January 2024 outlook. The outlook for more emissions in 2025 is mostly associated with an upward revision in coal-fired electricity generation. Compared with our January forecast, we expect more coal generation in 2025 due to an upward revision in overall electricity demand associated with rising electricity consumption from data centers. Increased petroleum product consumption, mostly motor gasoline, also increased our 2025 emissions estimates. We attribute this upward revision in consumption partially to an upward revision in disposable income, amid other factors influencing supply and demand for gasoline.”²⁶ It should be noted that the STEO addresses national emissions, not lowa-specific emissions, and that the SIT Projection Tool contradicts the STEO by projecting that Iowa GHG emissions from power plants will decrease 15.74% from 2023 – 2025.

Other Uncertainty

As with many forecasts, numerous factors affect the significant level of uncertainty associated with emissions projections. As noted above, these factors include the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, and other variables. Although the SIT Projection Tool provides a useful first look at projected future emissions, it has several specific areas of uncertainty:

1. Agricultural emissions are highly dependent on the weather and crop and livestock prices, which are not addressed by the Projection Tool.
2. Emissions from electric power plants and RCI fuel combustion are also highly dependent on weather and the number of heating and cooling days per year.
3. Emissions from electric power plants also may fluctuate due to differences in how electricity generation is dispatched by MISO, electricity demand by customers, and other market forces.

²⁶ U.S. EIA, [Short-Term Energy Outlook](#), December 2024.

References

Unless otherwise noted, all emails referenced were sent to Marnie Stein or Krysti Mostert, Air Quality Bureau, Iowa Department of Natural Resources in Des Moines, Iowa.

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Appendix A – Iowa GHG Emissions 2014 - 2023 by Sector^{27, 28}

Emissions (MMtCO ₂ e)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Agriculture	38.18	38.89	39.31	40.32	36.59	36.05	35.70	36.60	36.20	36.20
Enteric Fermentation	9.12	9.31	9.41	9.39	9.69	9.54	9.30	8.74	9.00	8.69
Manure Management	11.99	12.13	12.01	12.89	8.91	9.38	9.31	8.93	9.02	9.32
Agricultural Soil Management	17.07	17.45	17.89	18.05	17.99	17.13	17.09	18.92	18.17	18.18
Fossil Fuel Combustion	66.27	61.02	54.80	58.68	62.95	61.65	53.83	58.12	56.23	54.80
Electric Generating Facilities	33.43	29.45	25.32	26.61	30.86	24.56	17.07	24.26	20.70	20.21
Residential, Commercial, Industrial	32.84	31.56	29.48	32.08	32.10	37.09	36.76	33.86	35.53	34.59
Industrial Processes	5.42	5.49	5.57	7.40	7.38	7.31	7.36	7.57	7.92	7.82
Ammonia & Urea Production	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88	3.24	3.20
Cement Manufacture	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31	1.28	1.28
Electric Power Transmission and Distribution Systems	0.08	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
Iron and Steel Production	0.18	0.16	0.19	0.20	0.19	0.18	0.20	0.14	0.11	0.12
Lime Manufacture	0.17	0.13	0.15	0.18	0.16	0.17	0.18	0.16	0.12	0.11
Limestone and Dolomite Use	0.41	0.42	0.38	0.34	0.26	0.31	0.28	0.81	0.81	0.81
Nitric Acid Production	0.73	0.66	0.67	0.63	0.65	0.70	0.59	0.72	0.82	0.76
ODS Substitutes	1.56	1.69	1.58	1.71	1.47	1.4981	1.39	1.43	1.43	1.43
Semiconductor Manufacturing	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF ²⁹	-6.68	-7.47	-8.53	-8.60	-8.05	-8.11	-8.74	-8.24	-8.29	-8.15
Forest Carbon Flux	-3.57	-3.57	-3.58	-3.57	-3.57	-3.57	-3.56	-3.57	-3.57	-3.57
Liming of Agricultural Soils	0.41	0.34	0.46	0.45	0.40	0.28	0.54	0.56	0.53	0.65
Urea Fertilization	0.15	0.16	0.19	0.18	0.13	0.08	0.08	0.07	0.07	0.08
Urban Trees	-0.46	-0.47	-0.47	-0.48	-0.48	-0.49	-0.44	-0.42	-0.42	-0.42
Yard Trimmings and Food Scraps Stored in Landfills	-0.10	-0.10	-0.09	-0.08	-0.10	-0.10	-0.11	-0.11	-0.11	-0.11
Fertilization of Settlement Soils	0.49	0.40	0.41	0.47	0.42	0.41	0.40	0.44	0.42	0.42
Agriculture Soil Carbon Flux	-3.60	-4.23	-5.45	-5.58	-4.85	-4.71	-5.64	-5.20	-5.20	-5.20

²⁷ Totals may not equal the exact sum of subtotals in this table due to independent rounding.

²⁸ Emissions values that have been adjusted since the previous inventory are in bold and are described in detail in this document. In addition, all values for 2014-2022 were adjusted to the AR5 GWP values; those changes are not shown in bold. See Chapter 1 for more details.

²⁹ Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Emissions (MMtCO₂e)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Natural Gas Transmission & Distribution	1.5715	1.5664	1.5761	1.5826	1.5762	1.5862	1.5909	1.6497	1.6568	1.6622
Transmission	0.8807	0.8812	0.8811	0.8813	0.8808	0.8783	0.8783	0.9451	0.9453	0.9437
Distribution	0.6908	0.6852	0.6950	0.7013	0.6954	0.7079	0.7126	0.7047	0.7115	0.7184
Transportation	19.61	20.09	20.20	20.42	19.99	20.35	18.80	20.71	22.70	23.13
Waste	2.09	2.31	2.34	2.33	2.33	2.33	2.23	2.16	2.27	2.34
Solid Waste	1.66	1.90	1.92	1.88	1.87	1.88	1.79	1.77	1.87	1.94
Wastewater	0.42	0.42	0.42	0.45	0.46	0.46	0.44	0.39	0.39	0.40
Gross Emissions	133.14	129.37	123.80	130.74	130.82	129.28	119.50	126.81	126.97	125.95
Sinks	-6.68	-7.47	-8.53	-8.60	-8.05	-8.11	-8.74	-8.24	-8.29	-8.15
Net Emissions	126.47	121.90	115.27	122.14	122.77	121.17	110.77	118.57	118.68	117.79
% Change from Previous Year (Gross)	--	-2.84%	-4.30%	5.61%	0.06%	-1.18%	-7.56%	6.11%	0.12%	-0.80%
% Change from 2014 (Gross)	--	-3.03%	-7.50%	-1.93%	-1.86%	-3.10%	-10.94%	-5.08%	-4.95%	-5.77%

Appendix B – Iowa GHG Emissions 2014 - 2023 by Pollutant³⁰

Emissions (MMtCO ₂ e)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Gross CO ₂	88.22	83.52	77.70	83.61	87.53	86.44	77.44	83.63	83.97	82.95
Net CO ₂	81.06	75.66	68.76	74.54	79.05	77.92	68.31	74.96	75.27	74.38
Stationary Fossil Fuel Combustion	65.85	60.64	54.51	58.35	62.58	61.31	53.56	57.81	55.93	54.51
Transportation	19.32	19.81	19.93	20.25	19.74	20.09	18.56	20.47	22.44	22.88
Industrial Processes	3.02	3.05	3.24	5.00	5.19	5.03	5.30	5.33	5.59	5.55
Solid Waste	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02
LULUCF ³¹	-7.17	-7.87	-8.94	-9.07	-8.47	-8.52	-9.13	-8.67	-8.70	-8.57
CH ₄	23.33	24.39	24.33	25.23	21.57	21.89	21.47	20.59	21.04	21.10
Stationary Fossil Fuel Combustion	0.20	0.17	0.11	0.16	0.18	0.18	0.14	0.16	0.15	0.15
Transportation	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Natural Gas and Oil Transmission and Distribution	1.57	1.57	1.58	1.58	1.58	1.59	1.59	1.65	1.66	1.66
Enteric Fermentation	9.12	9.31	9.41	9.39	8.69	9.54	9.30	8.74	9.00	8.69
Manure Management	10.43	11.10	10.97	11.85	7.86	8.32	8.28	7.93	8.02	8.32
Solid Waste	1.64	1.88	1.90	1.86	1.86	1.87	1.77	1.75	1.85	1.92
Wastewater	0.34	0.33	0.34	0.37	0.37	0.37	0.35	0.33	0.33	0.33
N ₂ O	20.42	20.08	20.51	20.59	20.61	19.77	19.52	21.51	20.85	20.81
Stationary Fossil Fuel Combustion	0.23	0.20	0.18	0.17	0.19	0.16	0.13	0.16	0.14	0.14
Transportation	0.25	0.25	0.24	0.14	0.22	0.23	0.21	0.21	0.23	0.23
Industrial Processes	0.73	0.66	0.67	0.63	0.65	0.70	0.59	0.72	0.82	0.76
Manure Management	1.56	1.03	1.04	1.04	1.05	1.06	1.03	1.00	1.01	1.01
Agricultural Soil Management	17.07	17.45	17.89	18.05	17.99	17.13	17.09	18.92	18.17	18.18
N ₂ O from Settlement Soils	0.49	0.40	0.41	0.47	0.42	0.41	0.40	0.44	0.42	0.42
Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.06	0.06	0.06
HFC, PFC, and SF ₆	1.66	1.77	1.66	1.78	1.54	1.58	1.47	1.51	1.51	1.51
Industrial Processes	1.66	1.77	1.66	1.78	1.54	1.58	1.47	1.51	1.51	1.51
Gross Emissions	133.63	129.76	124.21	131.21	131.25	129.69	119.90	127.24	127.38	126.37
Sinks	-7.17	-7.87	-8.94	-9.07	-8.47	-8.52	-9.13	-8.67	-8.70	-8.57
Net Emissions (Sources and Sinks)	126.47	121.90	115.27	122.14	122.77	121.17	110.77	118.57	118.68	117.79

³⁰ Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that have been adjusted since the previous inventory are in bold and are described in detail in this document. In addition, all values for 2014-2022 were adjusted to the AR5 GWP values; those changes are not shown in bold. See Chapter 1 for more details.

³¹ Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

