IOWA DEPARTMENT OF NATURAL RESOURCES

2022 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

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Iowa Department of Natural Resources
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Des Moines, IA 50319

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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
$MMtCO_2e$	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_2O	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 *2022 Iowa Statewide Greenhouse Gas Emissions Inventory Report*. Total Iowa GHG emissions from 2013 – 2022 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 – 2020, 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	6/1/23	CH_4, N_2O
Energy	CO_2FFC	6/1/23	CO_2
	Stationary Combustion	6/1/23	CH_4, N_2O
Industrial Processes	IP	6/1/23	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission & Distribution	Natural Gas and Oil	6/1/23	CH_4
Transportation	Mobile Combustion	6/1/23	CO_2, CH_4, N_2O
Waste	Solid Waste	6/1/23	CO_2, CH_4
	Wastewater	6/1/23	CH_4, N_2O
Land Use, Land Use Change, and Forestry	LULUCF	6/1/23	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	6/1/23	CO_2
Future Emissions	Projection Tool	1/31/22	CO_2, CH_4, N_2O, 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 (CO_2e) that allows for better comparison of the impact of the different greenhouse gases. CO_2e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting values. CO_2e was calculated using Equation 1.

Equation 1:

$$tons\ CO_2e = \sum_{i=0}^{n} GHG_i\ x\ GWP_i$$

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) (IPCC 2007). The values used are shown in Table 2.

Table 2: Global Warming Potentials

Pollutant	**GWP used by DNR (IPCC AR4 2007)**
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Sulfur Hexafluoride (SF_6)	22,600
Hydrofluorocarbons (HFC)	Vary by pollutant – For a complete list, refer to DNR's Greenhouse Gas Emissions Estimation Guidance.
Perfluorocarbons (PFC)	

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 (CH_4) and nitrous oxide (N_2O). Table 3 summarizes the source of GHG emissions in each sector. N_2O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2022).

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_2O	Decomposition of manure during storage and treatment of livestock manure.
Agricultural Soils	Residues, legumes, and histosols	N_2O	Biological nitrogen fixation by crops, crop residues remaining on fields, and cultivation of high organic content soils (histosols).
	Fertilizers	N_2O	Application of manure, fertilizers, etc. to soils and leaching/runoff of nitrogen into ground or surface water.
	Animals	N_2O	Animal excretions directly on to soils such as pastures.
Agricultural Burning		CH_4, N_2O	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 June 1, 2023 (ICF 2023a and 2023b).

Enteric Fermentation

The SIT calculates CH_4 emissions from enteric fermentation by multiplying various livestock populations by an annual CH_4 emission factor (kilograms CH_4 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 CH_4 and N_2O emissions from manure when it is being stored and treated in a manure management system. In general, CH_4 emissions increase in more anaerobic (lacking oxygen) conditions while N_2O 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	2022	2022 Iowa Agricultural Statistics Bulletin (USDA 2022)
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	2017 census value used as proxy for 2018-2022	USDA-NASS Quick Stats (USDA 2023)
Horses		
Turkeys		
Chickens	2021 census value used as proxy for 2022	2022 Iowa Agricultural Statistics Bulletin (USDA 2022)
Hens		

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

N_2O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2023). N_2O 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 N_2O 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 N_2O (EPA 2023).

Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2023) were used to calculate N_2O 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.

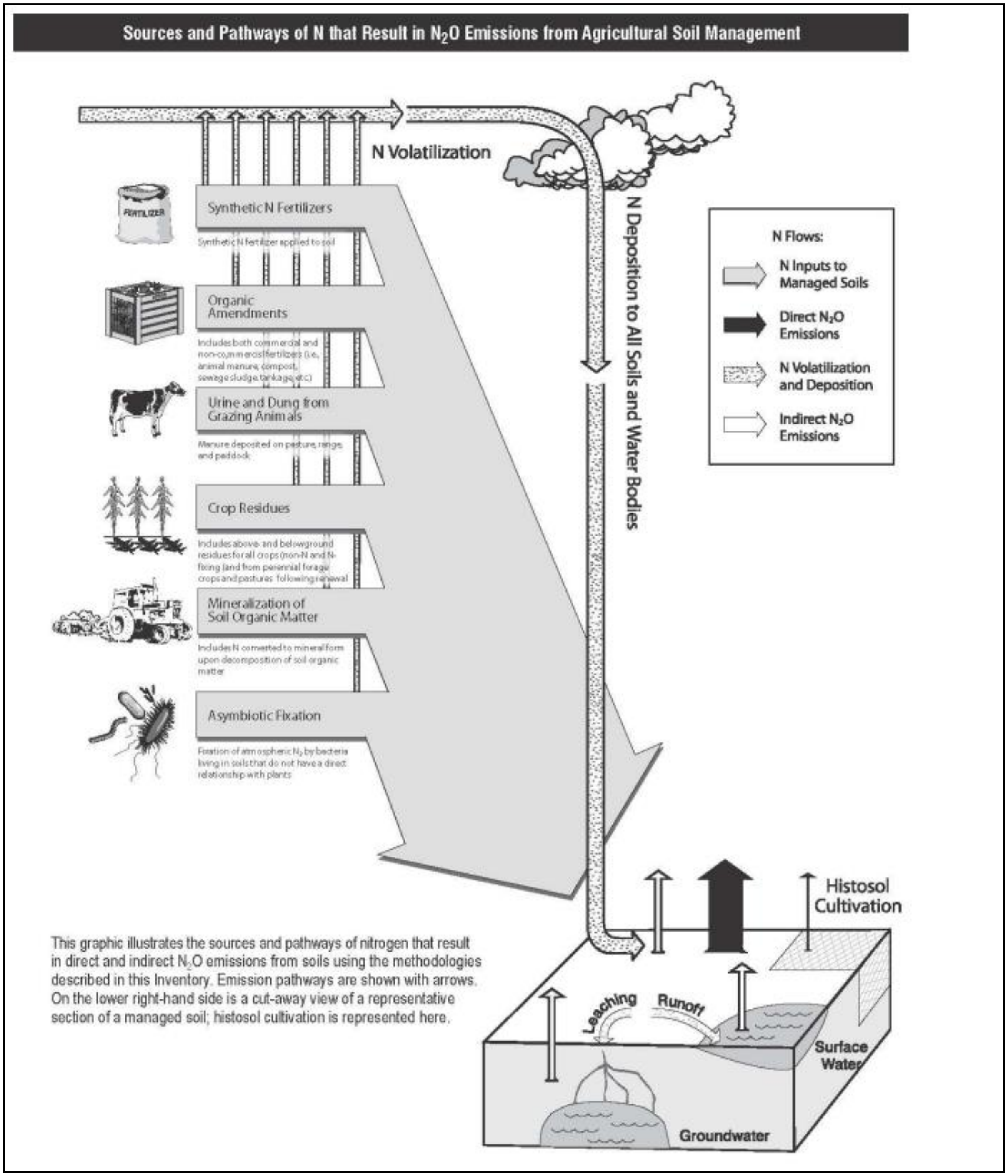
Soil Cultivation - Nitrous Oxide (N_2O)

N_2O 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 2023) 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 N_2O Emissions in Ag Soils (EPA 2023)



Fertilizer Utilization
The DNR calculated fertilizer emissions for 2022 using fertilizer tonnages from the *Fertilizer Tonnage Distribution in Iowa 2022 Crop Year* (IDALS 2022). The IDALS fertilizer data is provided per the 2022 growing season, which is from July 2021 – June 2022.

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 2023). 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 2023c). 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 2021 GHG Inventory Report was published in December 2022, the 2021 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:

- 2021 populations of bulls, steer stockers, heifer stockers, market swine and breeding swine were updated to match revised values in the 2022 Iowa Annual Statistics Bulletin (USDA 2022).
- Tons of soybeans produced, acres of soybeans harvested, and acres of corn harvested in 2021 were updated to match revised values in the USDA's Quick Stats database (USDA 2023).

Table 5: Recalculated Agricultural Emissions (MMtCO_2e)

Category	2021 Value (Published Dec. 2022)	2021 Updated Value
Enteric Fermentation	8.11	8.09
Manure Management	8.28	9.13
Agricultural Soils	19.64	21.62
Total	**36.03**	**38.84**

Results
GHG emissions from agriculture increased 0.60% from 2021 – 2022 and increased 9.23% from 2013 – 2022. Gross GHG emissions from agriculture were 39.07 MMtCO_2e in 2022, or 31.46% of Iowa's total gross 2022 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 (55.59%) are from soils as shown in Figure 2 and Table 6.

Figure 2: Gross GHG Emissions from Agriculture ($MMtCO_2e$)

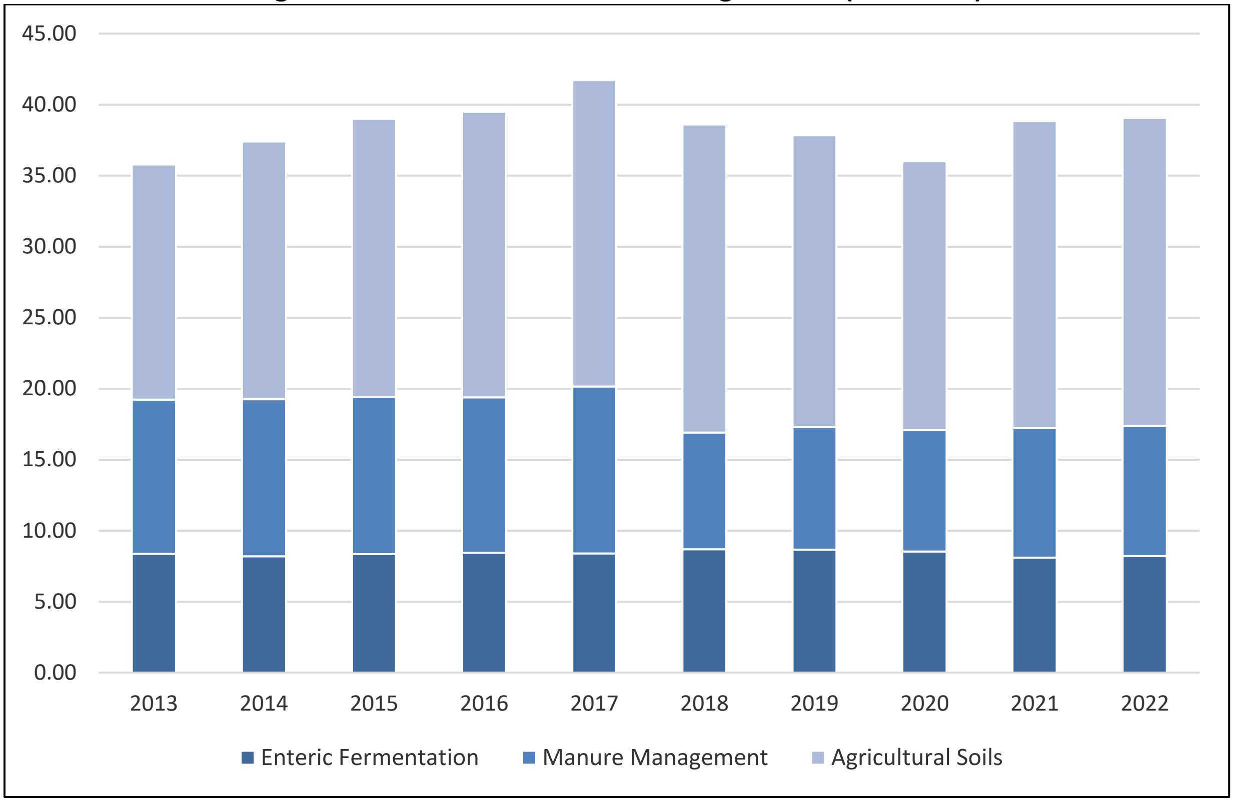


Table 6: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[4]

Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Enteric Fermentation	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	8.09	8.22
Manure Management	10.85	11.06	11.07	10.96	11.75	8.20	8.62	8.55	9.13	9.14
Agricultural Soils	16.55	18.14	19.58	20.09	21.56	21.70	20.57	18.91	21.62	21.72
Total	**35.77**	**37.39**	**39.00**	**39.49**	**41.71**	**38.60**	**37.85**	**36.00**	**38.84**	**39.07**

Enteric Fermentation

CH_4 emissions from enteric fermentation were 8.22 $MMtCO_2e$ in 2022, increasing 1.56% from 2021. This can be attributed to a 2.41% increase 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 CH_4 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: 2022 Iowa Animal Populations (USDA 2023)[5]

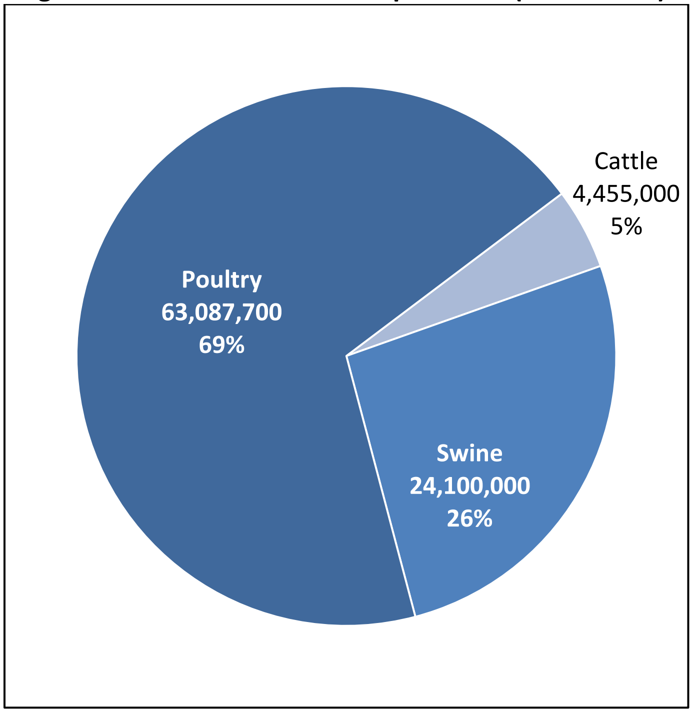


Table 7: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2023a)
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 CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 0.06% from 2021 and accounted for 23.39% of agricultural GHG emissions in 2022.

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 decreased in 2022 while there was a smaller decrease in production of corn, as shown in Table 8. Production of alfalfa and oats also decreased and updated data was not available for wheat, rye, pea, and sorghum production. While crop production decreased, total synthetic fertilizer use increased from 778 million kg N to 998 million kg N, an increase of 28.27%. This led to an overall increase in N_2O emissions from agricultural soils of 0.47% from the previous year. N_2O emissions from agricultural soils accounted for 55.59% of all agricultural GHG emissions and 17.48 of total gross statewide GHG emissions in 2022.

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

Figure 4: 2021 - 2022 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)

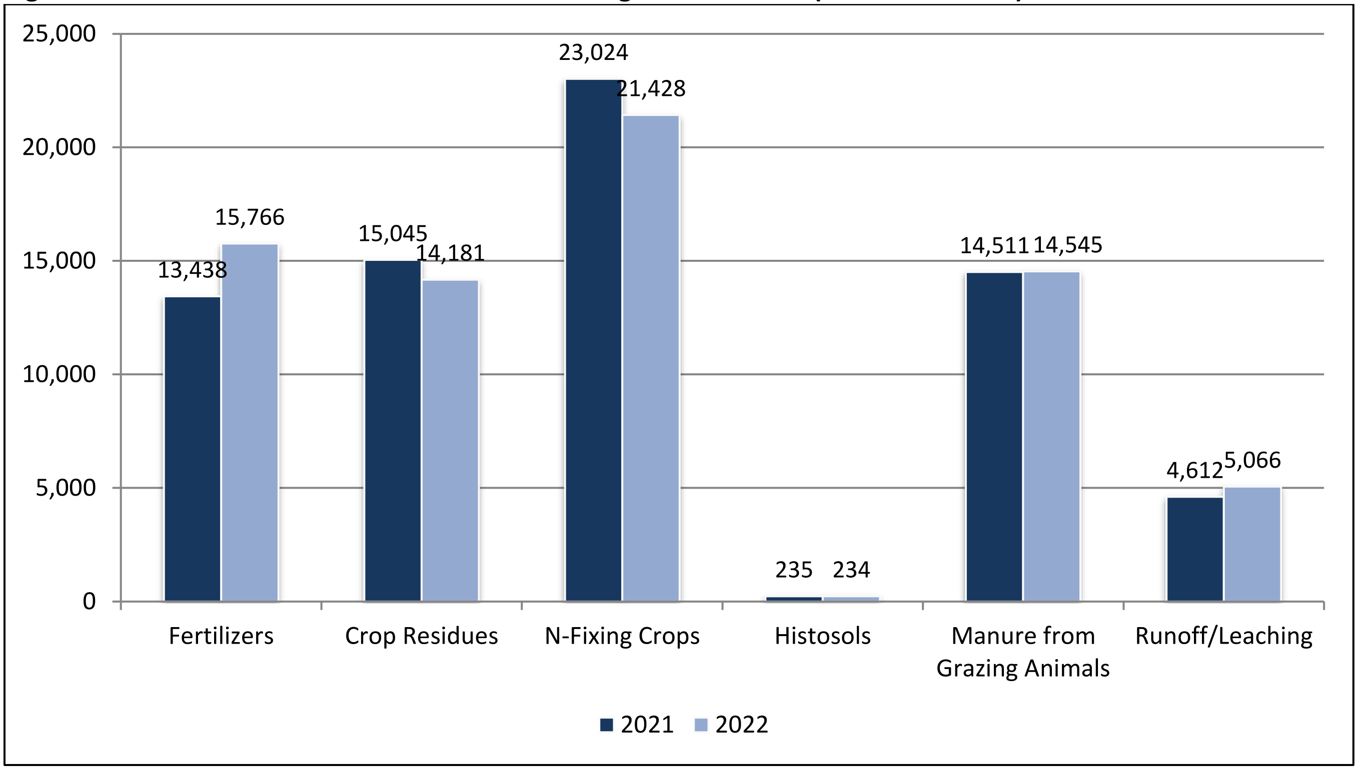


Table 8: Iowa Crop Production 2021 – 2022 (USDA 2023)

Crop	2021 (1000 Bushels)	2022 (1000 Bushels)
Barley	54	54
Corn for Grain	2,539,800	2,470,000
Oats	4,004	3,200
Rye	247	247
Sorghum for Grain	25	25
Soybeans	631,890	586,755
Wheat	348	348
Total	**3,176,368**	**3,060,629**
Crop	**2021 (1000 tons)**	**2022 (1000 tons)**
Alfalfa	3,185	3,091
Crop	**2021 (1000 CWT)**	**2022 (1000 CWT)**
Peas, Dry Edible	11	11

Uncertainty[6]

Enteric Fermentation

The quantity of methane (CH_4) 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

[6] This information is largely excerpted from the *SIT Agriculture Module* (ICF 2023a).

type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2023a).

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 CH_4 and N_2O emission factors used for these systems. In addition, there is uncertainty in the maximum CH_4 producing potential (B_0) 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 B_0 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 B_0 for all animal types and feeding circumstances (ICF 2023a).

Agricultural Soils
The N_2O 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 N_2O 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 N_2O 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 CO_2FFC module for carbon dioxide (CO_2) emissions and the Stationary Combustion module for CH_4 and N_2O emissions (ICF 2023a-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 – 2020 from U.S. Energy Information Administration (EIA) State Energy Data System (SEDS) (EIA 2023b). Because Iowa-specific 2022 energy consumption data will not be published by the EIA until June 2024, the DNR projected 2022 energy consumption using projections provided by EPA in the SIT Projection Tool (ICF 2023a). These projections are based on the EIA's *Annual Energy Outlook (AEO) 2021 with Projections to 2050* (EIA 2022a) 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 2023) or EPA's federal GHG Reporting Program (EPA 2023) were used as follows:

2005 – 2009

CO_2 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 CO_2 emissions reported by facilities to CAMD are actual measured emissions values from continuous emission monitoring systems (CEMS) located on electric generating units.

2010 - 2022

Power plants became subject to the federal GHG reporting program starting with calendar year 2010. Facilities are required to report CO_2, CH_4, and N_2O emissions. This CO_2 data is also from CEMS and is more accurate than EIA data. In addition, the CH_4 and N_2O emissions are calculated using facility-specific fuel heating values. The CO_2 data reported to the federal GHG reporting program is consistent with the CO_2 emissions reported by the same facilities to CAMD.

Adjustments

The DNR previously forecasted 2021 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2021 energy data was released by EIA in June 2023 (EIA 2023b), so the DNR used the data to recalculate 2021 emissions as shown in Table 10.

Table 10: Recalculated RCI Emissions ($MMtCO_2e$)

Category	2021 Value (Published Dec. 2022)	2021 Updated Value
Residential	5.16	5.07
Commercial	4.09	3.93
Industrial	25.20	24.86
Total	**34.45**	**33.86**

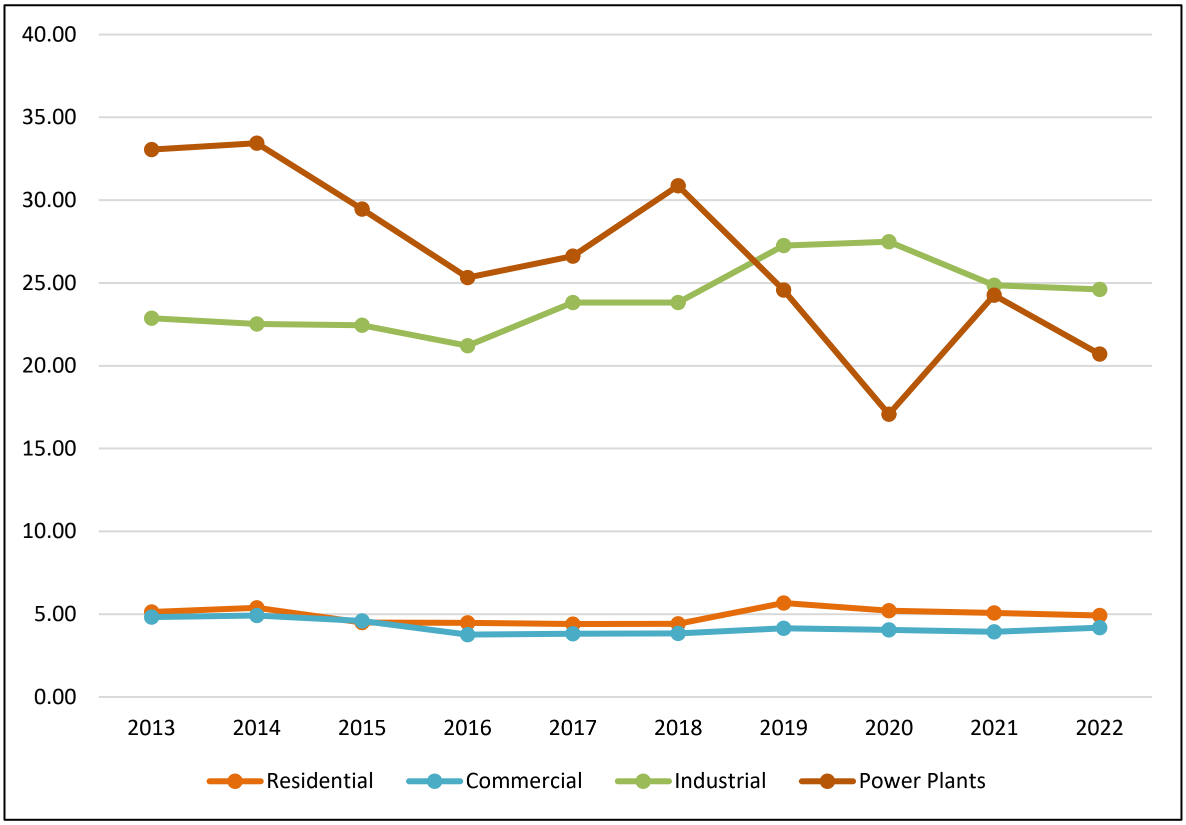
Results

Total GHG emissions from fossil fuel consumption in 2022 were 54.41 $MMtCO_2e$, a decrease of 3.71% from 2021 and a decrease of 17.41% from 2013 levels as shown in Table 11 and Figure 5. Emissions from commercial fuel use increased 6.40% from the previous year, while emissions from residential and industrial fuel use decreased. Markedly, emissions from power plants decreased by 14.68% from 2021 to 2022. With the exception of 2020, the 2022 emissions from power plants were the lowest since Iowa began calculating emissions in 2005.

Table 11: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)[7]

Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	5.12	5.38	4.49	4.48	4.41	4.42	5.67	5.22	5.07	4.92
Commercial	4.83	4.92	4.60	3.77	3.82	3.83	4.14	4.05	3.93	4.18
Industrial	22.87	22.52	22.44	21.21	23.82	23.83	27.26	27.49	24.86	24.61
Power Plants	33.06	33.44	29.46	25.33	26.62	30.86	24.57	17.07	24.27	20.71
Total	**65.88**	**66.26**	**61.00**	**54.78**	**58.67**	**62.93**	**61.64**	**53.83**	**58.12**	**54.41**

Figure 5: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)



As noted above, emissions from fossil-fuel fired power plants in 2022 decreased from 2021 and were the second lowest within the 2013-2022 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.

CO_2 Uncertainty[8]

The amount of CO_2 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 CO_2 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 CO_2 emissions to a small extent.

CH_4 and N_2O Uncertainty[9]

The amount of CH_4 and N_2O 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 CH_4 and N_2O 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 CO_2, 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 CO_2FFC Module* (ICF 2023a).
[9] This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2023b).

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_2O
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
CO_2 is released during the manufacture of ammonia. The chemical equations to calculate the release of CO_2 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 CO_2 emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO_2. Other emissions of CO_2 can occur during condensate stripping or regeneration of the scrubbing solution. CO_2 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 (CO_2) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO_2. The CO_2 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 (SF_6) is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2023b).

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 2023b). 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, CO_2 emissions result primarily from the consumption of carbon electrodes and from the consumption of supplemental materials used to augment the melting process (EPA 2023b).

Lime Manufacture
Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO_2. The CO_2 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 (N_2O) 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 SF_6 may also be used (ICF 2023b).

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 2023b). 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.

<u>Method</u>
The 2022 emissions from industrial processes were calculated using either the SIT (ICF 2023a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2023a) as shown in Table 13.

Table 13: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2022	40 CFR 98 Subpart G	GHGRP (EPA 2023a)
Cement Production	2022	40 CFR 98 Subpart H	GHGRP (EPA 2023a)
Electric Power Transmission & Distribution	2021 as proxy for 2022	SIT	National GHG Inventory (EPA 2023b)
Iron and Steel Production	2022	40 CFR 98 Subpart Q	GHGRP (EPA 2023a)
Lime Manufacture	2022	40 CFR 98 Subpart S	GHGRP (EPA 2023a)
Limestone and Dolomite Use	2020 as proxy for 2021 - 2022	SIT	(USGS 2021)
Nitric Acid Production	2022	40 CFR 98 Subpart V	GHGRP (EPA 2023a)
ODS Substitutes	2021 as proxy for 2022	SIT	National GHG Inventory (EPA 2023b)
Semiconductor Manufacturing	2020 as a proxy for 2021-2022	SIT	SIT defaults
Soda Ash Use	2020 as a proxy for 2021-2022	SIT	(USGS 2022)

Categories Calculated using the SIT

Because current emissions data was not available for electric power transmission and distribution, the 2021 national emissions were used as a proxy for 2022. The 2021 value was calculated by determining the ratio between 2021 Iowa retail sales to 2021 national retail sales (EIA 2023), and applying that ratio to 2021 national emissions of SF_6. The 2021 retail sales ratio was used to calculate 2021 emissions

Emissions in 2020 from the use of limestone and dolomite in industrial processes were used as a proxy for 2021 – 2022 emissions. The 2020 value was calculated by multiplying Iowa's 2020 consumption by the ratio of national consumption for industrial uses to total national consumption.

Emissions in 2021 from ODS substitutes were used as proxy for 2022. The 2021 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 2023).

Emissions in 2022 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 2023).

Emissions in 2022 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 2023).

<u>Adjustments</u>

Emissions from limestone and dolomite use were adjusted for the years 2020 and 2021 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 ($MMtCO_2e$)[10]

	2020	2021
Previous Value (Published Dec. 2021)	0.21	0.21
Updated Value	0.31	0.31

Emissions from electric power transmission and distribution as well as ODS substitutes were recalculated using updated national emissions data for 2021. Changes are shown in Table 15 below.

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

Subcategory	2021 Value (Published Dec. 2022)	2021 Updated Value
Electric Power T & D	0.06	0.05
ODS Substitutes	1.62	1.54

Results

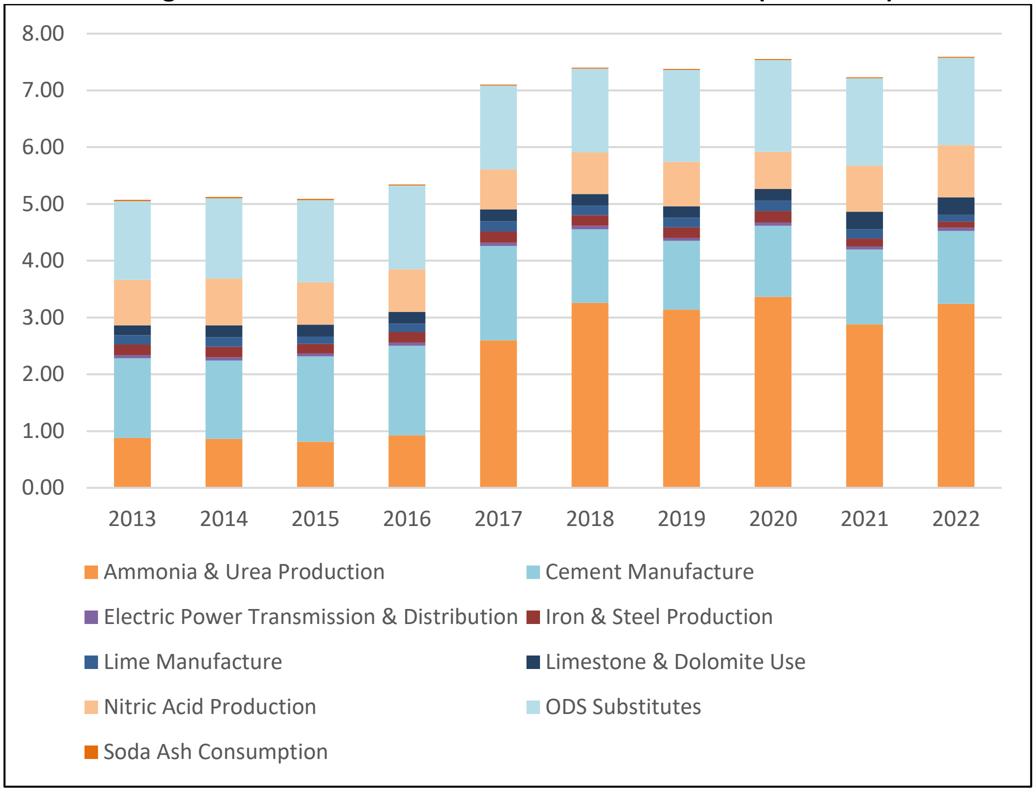
GHG emissions from industrial processes in 2022 were 7.59 $MMtCO_2e$, or 6.11% of total statewide GHG emissions. Emissions from this sector increased 5.00% from 2021 as shown in Table 16 and Figure 6, primarily due to increases in emissions in nitric acid production (0.11 $MMtCO_2e$) and ammonia and urea production (0.36 $MMtCO_2e$). The decrease was offset by decreases in cement manufacture, lime manufacture, and iron and steel production (cumulatively -0.11 $MMtCO_2e$).

Table 16: GHG Emissions from Industrial Processes ($MMtCO_2e$)[11]

Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ammonia & Urea	0.88	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88	3.24
Cement Manufacture	1.41	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31	1.28
Electric Power T&D	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.05
Iron & Steel Production	0.19	0.18	0.16	0.19	0.20	0.19	0.18	0.20	0.14	0.11
Lime Manufacture	0.16	0.17	0.13	0.15	0.18	0.16	0.17	0.18	0.16	0.12
Limestone & Dolomite Use	0.18	0.21	0.21	0.21	0.21	0.21	0.21	0.31	0.31	0.31
Nitric Acid Production	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.66	0.81	0.92
ODS Substitutes	1.39	1.42	1.45	1.47	1.47	1.47	1.61	1.62	1.54	1.54
Semiconductor Manufacturing	0.00	0.00	0.00	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
Total	**5.07**	**5.12**	**5.09**	**5.34**	**7.10**	**7.40**	**7.38**	**7.55**	**7.23**	**7.59**

[10] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[11] Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2013– 2022 rounded to 0.001 $MMtCO_2e$ or less.

Figure 6: GHG Emissions from Industrial Processes ($MMtCO_2e$)



<u>Uncertainty</u>

Uncertainty occurs in categories where SIT default activity data was used instead of Iowa-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 2023a).

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 (CH_4) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO_2) 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. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2023b).

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 2023). 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 two years, and has assumed the number of stations has not changed since 2020 (Zayudis 2023).

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. CH_4 is emitted from leaks, meters, regulators, and accidents (ICF 2023b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2023). 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 1.4793 $MMtCO_2e$[13] in 2022, an increase of 0.43% from 2021 and an increase of 5.66% from 2013 as shown in Table 17 and Figure 7. GHG emissions from this sector account for 1.19% of 2022 statewide GHG emissions.

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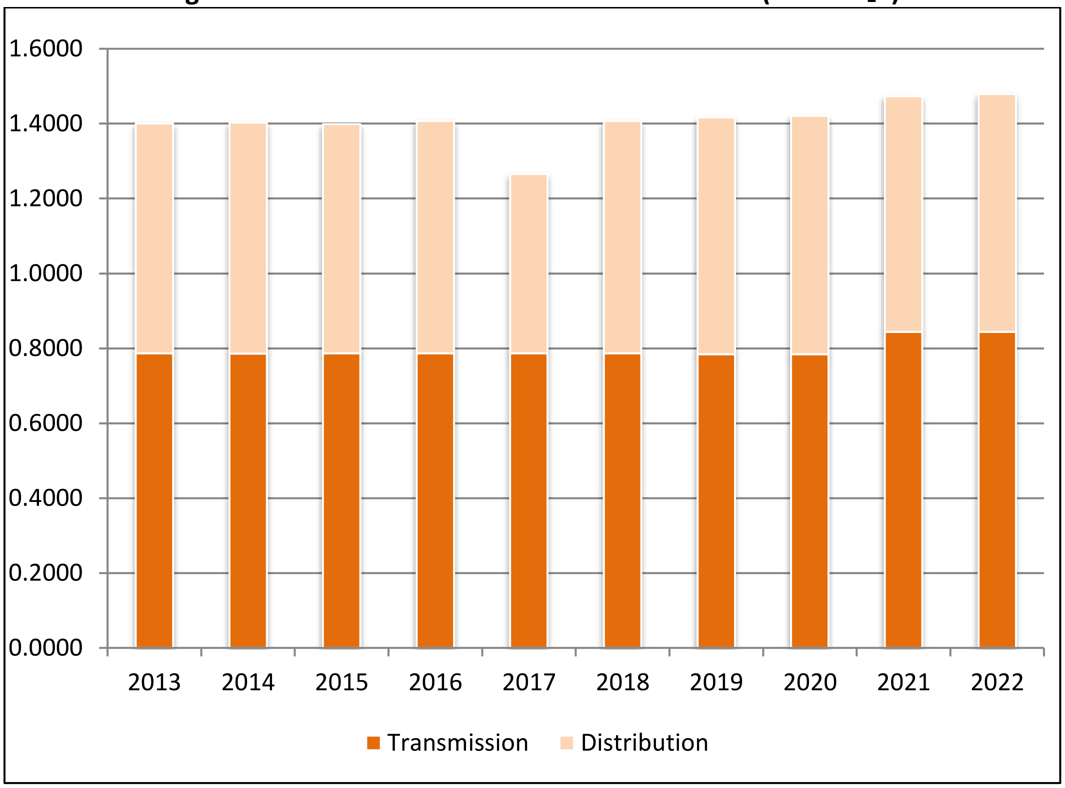
[13] DNR generally uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

Table 17: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)

Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Transmission	0.7865	0.7864	0.7868	0.7867	0.7868	0.7864	0.7842	0.7845	0.8438	0.8440
Distribution	0.6135	0.6168	0.6118	0.6205	0.4789	0.6209	0.6321	0.6363	0.6292	0.6353
Total	**1.4000**	**1.4031**	**1.3986**	**1.4073**	**1.2657**	**1.4073**	**1.4163**	**1.4208**	**1.4730**	**1.4793**

Figure 7: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)



<u>Uncertainty</u>[14]

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 2023a).

[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 2023a), which was updated by EPA in 2022 to calculate CO_2, CH_4, and N_2O 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 N_2O emissions factors in the 2021 SIT Mobile Combustion module, which are significantly higher than the factors used in the past.

Highway Vehicles (CH_4 and N_2O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH_4 and N_2O 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 2023). 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-73 and A-74 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021* (EPA 2023). The classes and the national distribution percentages are shown in Table 18.

Table 18: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2021 (EPA 2023)	2022 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.43%	2,777
Heavy duty gas vehicle	HDGV	0.91%	300
Light duty diesel truck	LDDT	2.03%	669
Light duty diesel vehicle	LDDV	0.26%	86
Light duty gasoline truck	LDGT	49.65%	16,352
Light duty gasoline vehicle	LDGV	37.63%	12,394
Motorcycle	MC	0.63%	209
Total		**100.00%**	**33,938**

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-81 in the most recent national inventory (EPA 2023).
4. 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-84, A-85, and A-86 in Annex 3 of the most recent national inventory (EPA 2023).

Non-highway Vehicles (CH_4 and N_2O)

Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH_4 and N_2O 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	2021 used as proxy for 2022	EIA SEDS (EIA 2023)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2021 used as proxy for 2022	FHWA 2023
Heavy Duty Utility			
Tractors			
Construction			
Construction	Distillate Fuel	2020 used as proxy for 2021-2022	EIA Adjusted Sales (EIA 2022)
Locomotives			
Tractors			
Heavy Duty	Distillate Fuel	2020 used as proxy for 2021-2022	SIT default value
Small Utility	Gasoline		
Alternative Fuel Vehicles	Gasoline		

Adjustments

Emissions from non-highway vehicles were recalculated for 2021 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 and 2022 because updated fuel usage was not available.

Table 20: Recalculated Emissions from Transportation (MMtCO_2e)[15]

Pollutant	2021 Value (Published Dec. 2022)	2021 Updated Value
CO_2	20.49	20.47
CH_4	0.03	0.03
N_2O	0.24	0.24
Total	**20.76**	**20.73**

Results

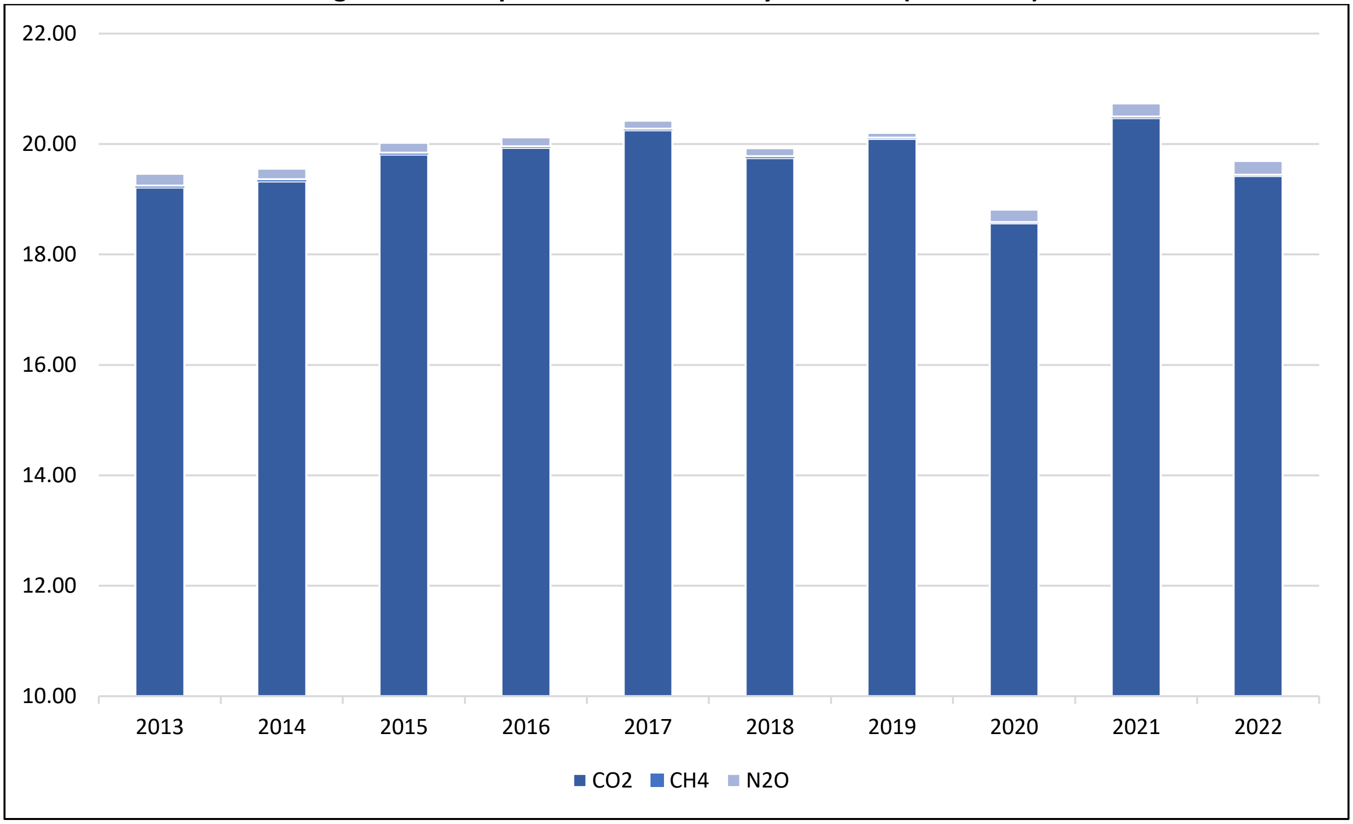
Total GHG emissions from transportation were 19.70 MMtCO_2e in 2022 as shown in Table 21. This is a decrease of 5.01% from 2021 due to a 0.85% decrease in VMT from 2021 - 2022 as well as a change in the EPA model used to estimate vehicle emissions by vehicle class. CO_2 accounts for nearly all the Iowa transportation GHG emissions (98.57%) as shown in Figure 8. The majority of the transportation emissions (53.94%) are from gasoline highway vehicles as shown in Figure 9.

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

Table 21: GHG Emissions from Transportation ($MMtCO_2e$)[16]

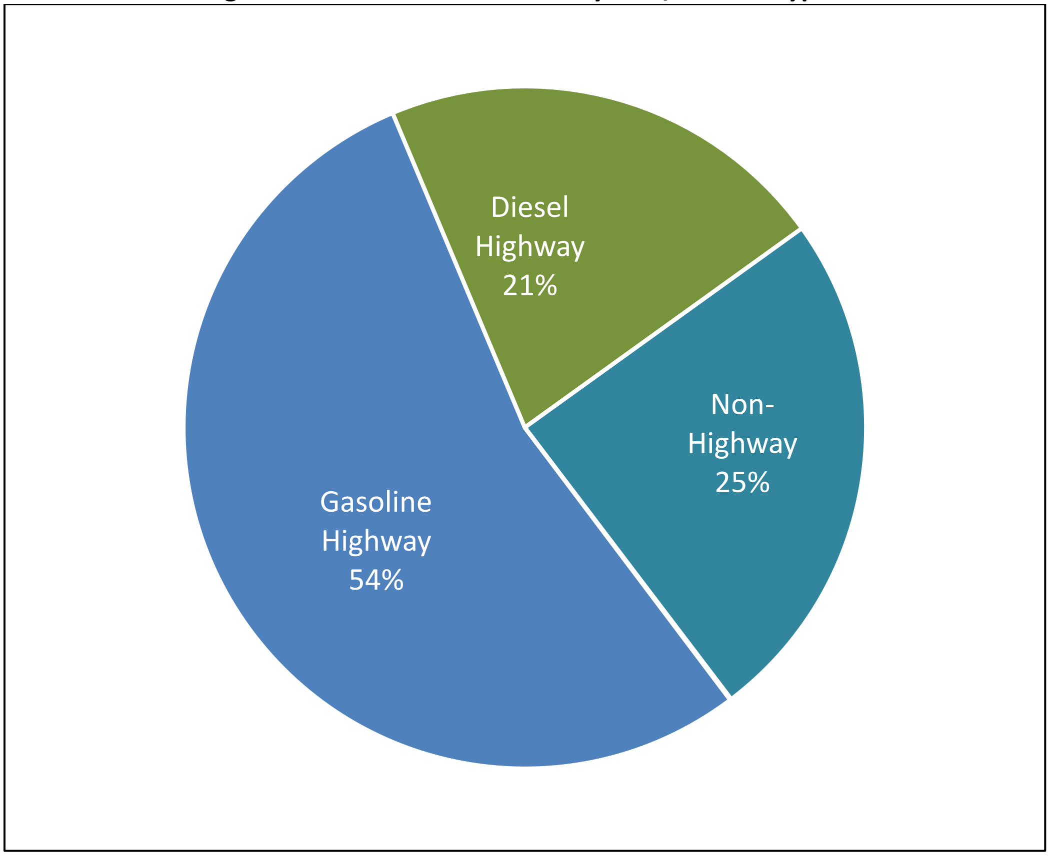
Pollutant	2013	2014	2015c	2016c	2017c	2018	2019	2020	2021	2022
CO_2	19.21	19.32	19.81	19.93	20.25	19.74	20.09	18.56	20.47	19.42
CH_4	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N_2O	0.21	0.19	0.18	0.16	0.14	0.14	0.09	0.23	0.24	0.25
Total	**19.46**	**19.55**	**20.02**	**20.12**	**20.42**	**19.92**	**20.20**	**18.81**	**20.73**	**19.70**

Figure 8: Transportation Emissions by Pollutant ($MMtCO_2e$)



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

Figure 9: 2022 GHG Emissions by Fuel/Vehicle Type[17]



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 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 2023b).

[17] Emissions from alternative vehicles round to 0%.

Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH_4) emissions from municipal solid waste landfills and carbon dioxide (CO_2) and nitrous oxide (N_2O) emitted from the combustion of municipal solid waste to produce electricity. CH_4 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 CH_4 that is recovered and flared, and
- The quantity of CH_4 oxidized in landfills instead of being released into the atmosphere.

Fluctuations in CH_4 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 2023b).

Method

Municipal Solid Waste (MSW) Landfills

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2023a), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO_2e or more to report their emissions. This included twenty-six Iowa landfills in 2022. 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).

Combustion of Municipal Solid Waste

The amount of CH_4 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 29,490 tons of refuse-derived fuel in 2022 (Curtis 2023). The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO_2 emissions from MSW combustion using SIT (ICF 2023a). 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.

Adjustments
Emissions from MSW combustion were updated in 2021. Previously reported emissions were calculated using an incorrect value for municipal solid waste combusted. Changes are shown in Table 23 below.

Table 23: Recalculated Emissions from Combustion of Municipal Solid Waste ($MMtCO_2e$)[18][19]

Pollutant	2021 Value (Published Dec. 2022)	2021 Updated Value
CO_2	0.0016	0.0039
N_2O	0.0000	0.0001
Total	**0.0017**	**0.0040**

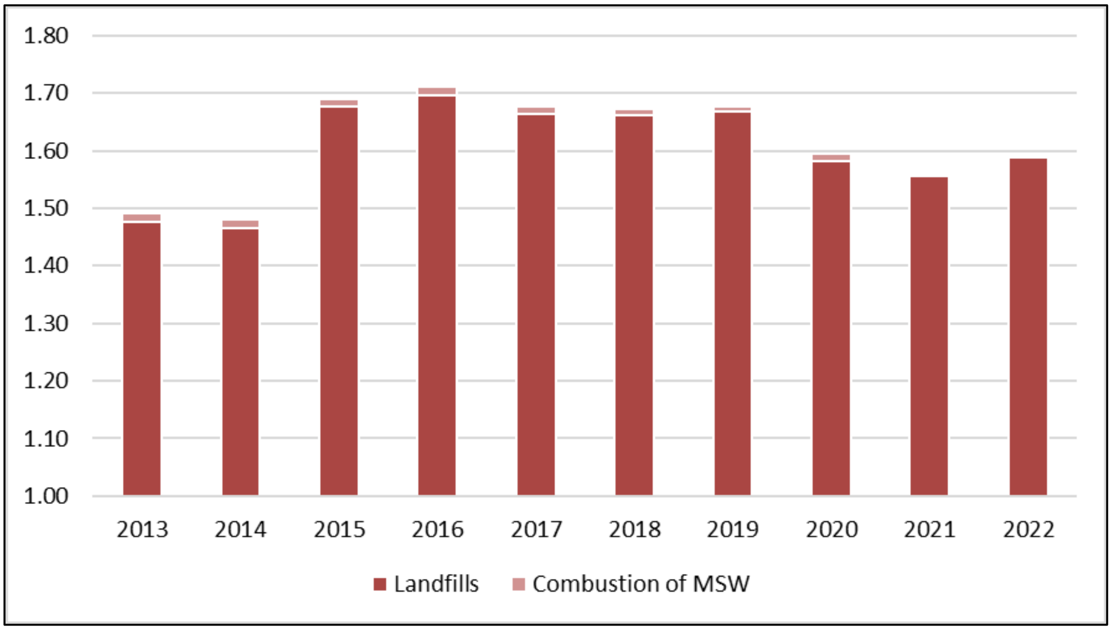
Results
Total GHG emissions from the solid waste category were 1.591 $MMtCO_2e$ in 2022, an increase of 1.96% from 2021 as shown in Table 24 and Figure 10. Solid waste emissions account for 1.28% of total statewide GHG emissions. Emissions from waste disposed in landfills, the largest category of emissions, increased by 1.98%. Additionally, emissions from the combustion of MSW decreased by 4.57%. 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 CH_4 that is recovered and used as renewable natural gas or flared, and varying oxidation rates.

Table 24: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$)[20, 21]

Sector	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW Landfills	1.48	1.46	1.68	1.70	1.664	1.662	1.669	1.581	1.557	1.588
MSW Combustion	0.02	0.02	0.01	0.01	0.013	0.009	0.008	0.014	0.004	0.004
Total	**1.49**	**1.48**	**1.69**	**1.71**	**1.676**	**1.671**	**1.677**	**1.595**	**1.561**	**1.591**

[18] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[19] DNR generally uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed to show the difference in emissions from the initial and updated 2021 emissions values.
[20] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[21] DNR generally uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed to show the difference in emissions from 2021 to 2022.

Figure 10: GHG Emissions from Municipal Solid Waste (MMtCO$_2$e)[22]



<u>Uncertainty[23]</u>

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 CO_2 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 CO_2 emissions being slightly over-estimated (ICF 2023b).

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[22] Combustion of MSW emissions in 2021 and 2022 were 0.004 MMtCO$_2$e and are too small to appear on the chart due to scale differences.

[23] This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2023b).

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 (CH_4) and nitrous oxide (N_2O). CH_4 is emitted from the treatment of wastewater, both industrial and municipal. CH_4 is produced when organic material is treated in an anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N_2O 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 N_2O 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 signification portion of the raw material leading to N_2O emissions (ICF 2023b).

<u>Method</u>

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 CH_4 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 CH_4 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 CH_4 and N_2O emissions, except that N_2O was calculated using the most recent protein (kg/person-year) value (44.6) from Table 7-34 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021* (EPA 2023b). Because the 2022 protein value was not available at the time of publication, the 2021 value was used as a surrogate for 2022.

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 2022, 40,497 metric tons of municipal wastewater sludge was applied to land to condition soil (DNR 2023). 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 N_2O 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 CO_2e 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. Last year three ethanol production facilities and five food processing facilities emitted more than 25,000 metric tons CO_2e or more (EPA 2023a). The number of ethanol facilities and the number of food processors reporting emissions in 2022 did not change from 2021.

Adjustments

EPA changed the percentage of wastewater BOD anaerobically digested from 16.25% to 12.78%. This decrease in anaerobic digestion decreases the resulting calculated methane emissions. DNR updated the calculated Municipal CH_4 emissions from 2013-2021 using this value.

Table 25: Recalculated CH_4 Emissions from Municipal Wastewater (MMtCO_2e)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Previous Value (Published Dec. 2021)	0.247	0.249	0.250	0.251	0.252	0.252	0.253	0.255	0.256
Updated Value	0.195	0.196	0.197	0.197	0.198	0.198	0.199	0.199	0.201

Results

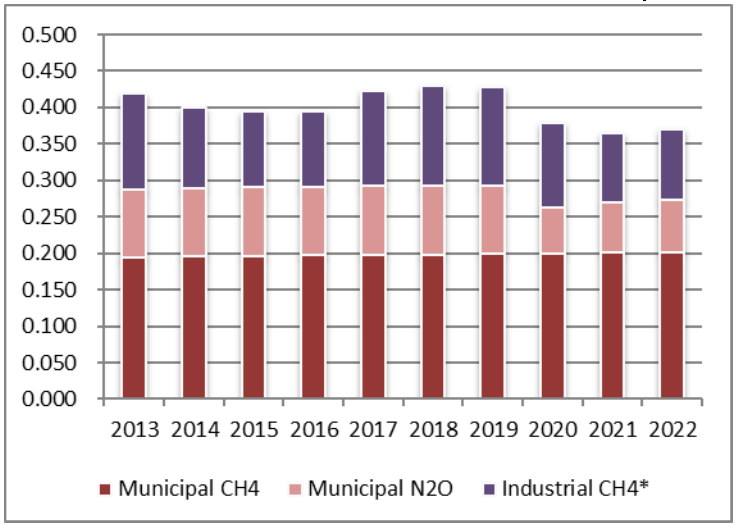
Wastewater emissions account for 0.30% of the total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.369 MMtCO_2e in 2022, a 1.25% increase from 2021 and a 11.96% decrease from 2013 as shown in Table 26. This is due to a decrease in the amount of wastewater produced 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. CH_4 and N_2O from municipal wastewater treatment accounted for 74.16% of total wastewater treatment GHG emissions as shown in Figure 11.

Table 26: GHG Emissions from Wastewater (MMtCO_2e)[24]

Sector	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Municipal CH_4	0.195	0.196	0.197	0.197	0.198	0.198	0.199	0.199	0.201	0.201
Municipal N_2O	0.093	0.093	0.094	0.094	0.094	0.094	0.094	0.063	0.069	0.072
Industrial CH_4	0.132	0.111	0.104	0.104	0.131	0.137	0.135	0.116	0.094	0.095
Total	**0.419**	**0.400**	**0.394**	**0.395**	**0.423**	**0.429**	**0.429**	**0.378**	**0.365**	**0.369**

[24] 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 ($MMtCO_2e$)



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

<u>Uncertainty</u>[25]

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 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 Iowa-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 2023a).

N_2O 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 2023a).

Industrial Wastewater

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 $mtCO_2e$ 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.

[25] This information is largely excerpted from the *SIT Wastewater Module* (ICF 2023a).

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

This chapter addresses carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from liming of agricultural soils and fertilization of settlement soils,[26] 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. CO_2 is also emitted from applying lime to agricultural soils and applying urea as a fertilizer. N_2O is emitted when fertilizers are applied to settled soils such as landscaping, lawns, and golf courses. CH_4 and N_2O are also emitted from forest fires (ICF 2023b).

Method

Forest Carbon Flux

CO_2 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 2023b). The new methodologies are consistent with those used by EPA in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2021* (EPA 2022) 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 2021 or 2022 forest carbon flux data is not available, 2020 was used as a proxy for 2021 and 2022.

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[26] Settled soils such as landscaping, lawns, and golf courses (ICF 2023b).

Liming of Agricultural Soils

CO_2 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 (Olson 2023). 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

2022 urea emissions were calculated using the amount of urea applied annually (IDALS 2022). 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 2023). 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 2023b). N_2O 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 2022 values were derived, please see *Chapter 2-Agriculture* of this report.

Non-CO_2 Emissions from Forest Fires

CH_4 and N_2O 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 2023). 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 2023b). 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 -2021* (EPA 2023).

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 27: Recalculated Emissions from Forest and Ag Soil Carbon Flux (MMtCO$_2$e)

Forest Carbon Flux	2013	2014	2015	2016	2017	2018	2019	2020	2021
Previous Value (Published Dec. 2022)	-2.57	-2.56	-2.59	-2.61	-2.63	-2.66	-2.66	-2.66	-2.66
Updated Value	-3.22	-3.23	-3.27	-3.28	-3.28	-3.26	-3.24	-3.24	-3.24
Ag Soil Carbon Flux									
Previous Value (Published Dec. 2022)	-6.62	-4.53	-5.21	-7.88	-7.59	-6.65	-6.65	-5.40	-5.40
Updated Value	-5.88	-3.48	-4.11	-5.32	-5.44	-4.71	-4.57	-5.50	-5.50

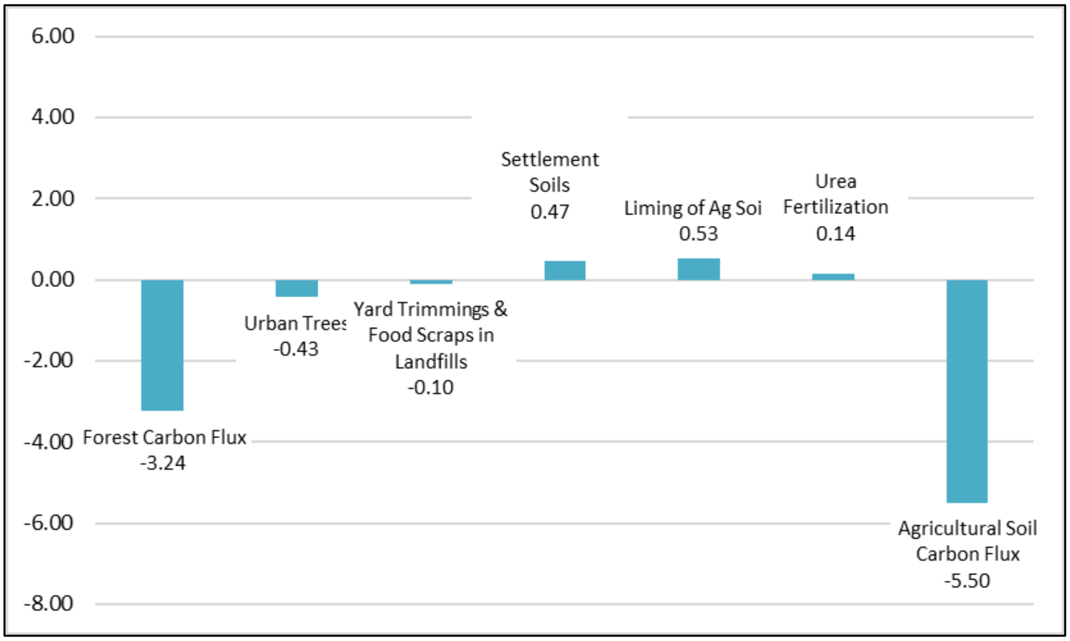
Results

Overall, sources in the LULUCF sector stored slightly more carbon in 2022 than they stored in 2021, storing 8.14 MMtCO$_2$e as shown in Table 28 and Figure 12. This is an increase of 0.06% from 2021 and decrease of 2.78% from 2013. Emissions of CO_2 are shown above the x-axis in Figure 12 and carbon sinks are shown below the x-axis.

Table 28: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[27]

Sector	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forest Carbon Flux	-3.22	-3.23	-3.27	-3.28	-3.28	-3.26	-3.24	-3.24	-3.24	-3.24
Liming of Ag Soils	0.47	0.41	0.34	0.46	0.45	0.40	0.28	0.54	0.56	0.53
Urea Fertilization	0.11	0.15	0.15	0.19	0.18	0.13	0.08	0.12	0.15	0.14
Urban Trees	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34	-0.49	-0.50	-0.43	-0.43
Yard Trimmings & Food Scraps Stored in Landfills	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08	-0.10	-0.10	-0.10
N_2O from Settlement Soils	0.57	0.52	0.49	0.51	0.53	0.48	0.50	0.31	0.49	0.47
Agricultural Soil Carbon Flux	-5.88	-3.48	-4.11	-5.32	-5.44	-4.71	-4.57	-5.50	-5.50	-5.50
Total	**-8.37**	**-6.07**	**-6.85**	**-7.89**	**-7.99**	**-7.38**	**-7.53**	**-8.37**	**-8.08**	**-8.14**

Figure 12: 2022 GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)



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 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.

[27] 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 Iowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2023b). 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 2023a).

Residential, Commercial, and Industrial

2022 emissions were calculated from the electricity consumption values reported by the EIA as "Annual sales to ultimate customers by state and sector" (EIA 2023a).

Transportation

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the US Department of Energy (DOE 2023), 6,200 electric vehicles were registered in Iowa as in 2022. This is an increase of 10.18% from 2021, but is 0.21% of the total 2.96 million light duty vehicles registered in the state in 2022 (DOE 2023). 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

2019, 2020, and 2021 emissions have been recalculated since the DNR's 2021 GHG Inventory Report was published in December 2022. EPA updated the emissions factors and transmission losses in the SIT for the years 2019, 2020, and 2021 so DNR recalculated the emissions values as shown in Table 29. Previously, the DNR used the emissions factors and transmission losses from the year 2018 as a proxy for the factors and losses of 2019-2021.

Table 29: GHG Emissions from Electricity Consumption ($MMtCO_2e$)

	2019		2020		2021	
Category	**Published Dec. 2021**	**Updated Value**	**Published Dec. 2021**	**Updated Value**	**Published Dec. 2021**	**Updated Value**
Residential	7.40	5.97	6.00	4.29	6.03	4.32
Commercial	6.28	5.07	4.78	3.42	5.00	3.58
Industrial	12.37	9.98	10.07	7.21	10.75	7.69
Transportation	0.01	0.00	0.01	0.01	0.01	0.01
Total	**26.05**	**21.03**	**20.86**	**14.93**	**21.79**	**15.60**

Results

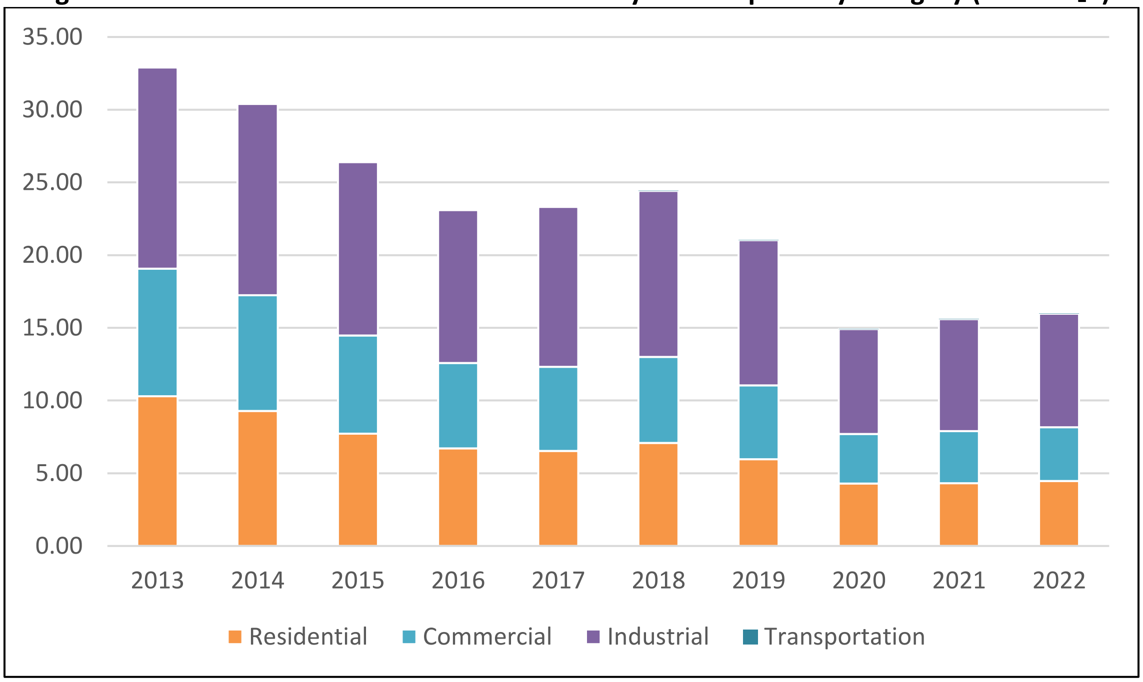
Indirect GHG emissions from electricity consumption were 15.98 $MMtCO_2e$ in 2022, increasing 4.45% since 2021, due to projected increases in electricity consumption in all categories (EIA 2023a) except transportation, as shown in Table 30 and Figure 13. Industrial users consumed the largest percentage of electricity, 49.33%, as shown in Figure 14.

Table 30: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[28]

Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	10.30	9.29	7.72	6.72	6.54	7.08	5.97	4.29	4.32	4.48
Commercial	8.77	7.94	6.76	5.86	5.79	5.92	5.07	3.42	3.58	3.67
Industrial	13.83	13.16	11.92	10.51	11.00	11.42	9.98	7.21	7.69	7.82
Transportation	*not calculated		0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Total	**32.90**	**30.39**	**26.41**	**23.09**	**23.32**	**24.43**	**21.03**	**14.93**	**15.60**	**15.98**

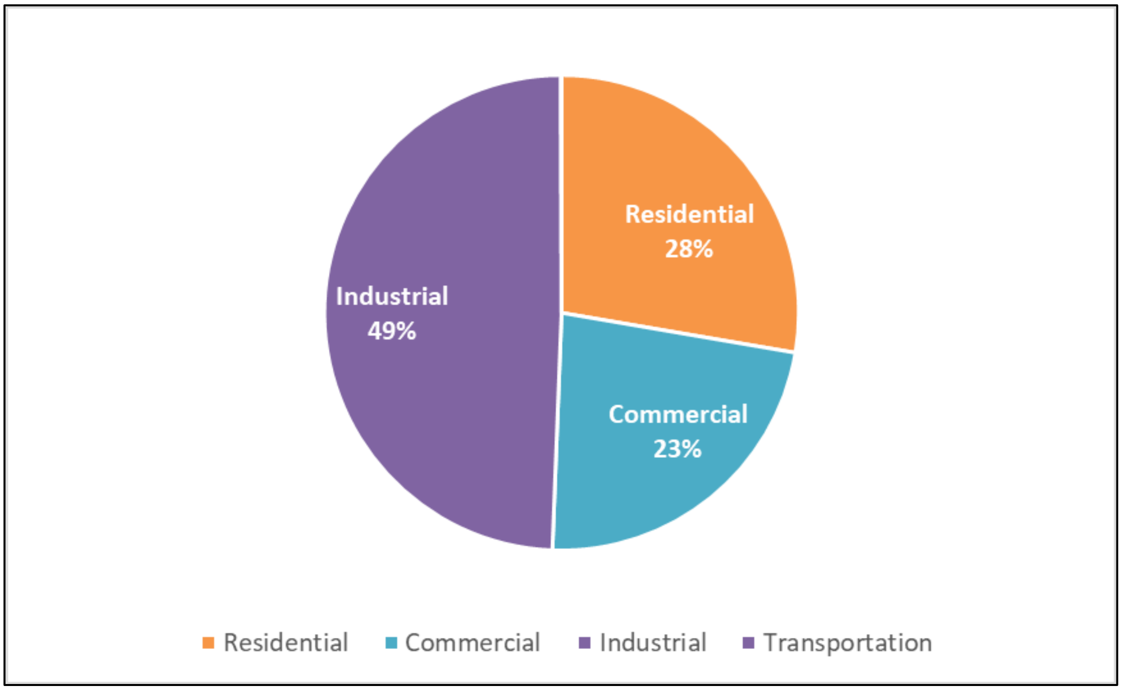
* 2015 was the first time that DNR calculated indirect emissions from electricity consumption.

Figure 13: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)



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

Figure 14: Electricity Consumption by Category[29]



[29] 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 2040 using the SIT Projection Tool (ICF 2022). EPA published a projection tool in 2023 using more recent data, but the tool uses global warming potentials from IPCC AR5 (IPCC 2014). Iowa has used the global warming potentials published in IPCC AR4 (IPCC 2007) for this report so the projections from the most recent SIT would not be comparable to this inventory.

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 populations with the actual Iowa population for 2007 -2022 (U.S. Census 2023) and the 2023-2050 population projections from Woods & Poole Economics (Woods & Poole, 2022).

The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2019, using a combination of data sources and national projections for activity data. The Projection Tool would ideally include data through 2022 to be consistent with the DNR's 2022 calculated GHG inventory, but this discrepancy is unavoidable. It would be preferable to forecast emissions using the DNR's 2022 calculated GHG inventory as the baseline, but it is not reasonable to fully update the data in the SIT Projection Tool to eliminate all such inconsistencies.

Results

The DNR's calculated 2022 GHG inventory and projected emissions from the SIT Projection Tool for 2022, 2025, 2030, 2035, and 2040 for each category are shown in Table 31 (intervening year forecasts are available from the DNR upon request). The 2022 "forecast" was produced to help gauge the reasonableness of the projections. While the total projected emissions were within 0.2 $MMtCO_2e$ of the calculated value, actual calculated emissions in individual sectors such as residential, commercial and industrial fuel use, industrial processes, and waste were more than 10% above or below the projected emissions.

Table 31: Projected Gross GHG Emissions 2022 – 2040 ($MMtCO_2e$)

	Calculated	Projected				
Sector	**2022**	**2022**	**2025**	**2030**	**2035**	**2040**
Agriculture	39.07	38.54	49.09	54.63	60.18	65.74
Power Plants	20.71	22.59	18.10	18.63	18.13	18.37
RCI Fossil Fuel Use	33.71	29.58	31.12	31.56	31.85	32.64
Industrial Processes	7.59	8.52	8.30	9.56	10.49	11.42
Natural Gas T & D	1.48	1.53	1.59	1.59	1.59	1.59
Transportation	19.70	20.55	20.05	19.32	18.93	18.88
Waste	1.96	2.74	3.30	3.45	3.60	3.71
Total	**124.22**	**124.06**	**131.55**	**138.74**	**144.77**	**152.63**

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. While emissions may continue to decrease as Iowa utilities shift away from burning coal to burning natural gas and installing renewable generation, 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.

   Emissions from power plants have increased or decreased by up to 40% from year to year in the last decade but have shown an overall downward trend, with the most recent three years being the lowest emissions recorded. The most recent data from EPA's Clean Air Markets Division shows that CO_2 emission from electric power generation during the first nine months of 2023 are 3% higher than CO_2 emissions from the first nine months of 2022 (CAMD 2023). It is reasonable to expect 2023 emissions from electric power generation to be approximately equal to 2022 emissions.

2. Economic Uncertainty
   Greenhouse gas emissions are affected by economic conditions. The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* (STEO) on December 12, 2023, stating that "Our labor market outlook affects our forecast of liquid fuels consumption. More employed workers generally leads to more vehicle miles traveled and, therefore, more gasoline consumption. In addition, the impact of tighter monetary policy and its eventual effect on the labor market is a source of uncertainty in our outlook. Further downward revisions to non-farm employment could lead us to revise our forecast of U.S. liquid fuels consumption lower." It should be noted that the STEO addresses national emissions, not Iowa-specific emissions (EIA 2023).

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.
4. In sectors where the Projection Tool predicts future emissions based on historical emissions (industrial processes, agriculture, and waste), it only uses emissions from 1990 – 2019 and does not consider 2020-2022 data.

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Appendix A – Iowa GHG Emissions 2013 - 2022 by Sector[30]

Emissions (MMtCO$_2$e)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agriculture	35.77	36.39	39.00	39.49	41.71	38.60	37.85	36.00	**38.84**	39.07
Enteric Fermentation	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	**8.09**	8.22
Manure Management	10.85	11.06	11.07	10.96	11.75	8.20	8.62	8.55	**9.13**	9.14
Agricultural Soil Management	16.55	18.14	19.58	20.09	21.56	21.70	20.57	18.91	**21.62**	21.72
Fossil Fuel Combustion	65.88	66.26	61.00	54.78	58.67	62.94	61.64	53.83	**58.13**	54.42
Electric Generating Facilities	33.06	33.44	29.46	25.33	26.62	30.87	24.57	17.07	24.27	20.71
Residential, Commercial, Industrial	32.82	32.82	31.54	29.45	32.05	32.07	37.07	36.76	**33.86**	33.71
Industrial Processes	5.07	5.12	5.09	5.34	7.10	7.40	7.38	7.55	**7.23**	7.59
Ammonia & Urea Production	0.88	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88	3.24
Cement Manufacture	1.41	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31	1.28
Electric Power Transmission and Distribution Systems	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.06	**0.05**	0.05
Iron and Steel Production	0.19	0.18	0.16	0.19	0.20	0.19	0.18	0.20	0.14	0.11
Lime Manufacture	0.16	0.17	0.13	0.15	0.18	0.16	0.17	0.18	0.16	0.12
Limestone and Dolomite Use	0.18	0.21	0.21	0.21	0.21	0.21	0.21	0.21	**0.31**	0.31
Nitric Acid Production	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.66	0.81	0.92
ODS Substitutes	1.39	1.42	1.45	1.47	1.47	1.47	1.61	1.62	**1.54**	1.54
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.02	0.02
LULUCF[31]	**-8.37**	**-6.07**	**-6.85**	**-7.89**	**-7.99**	**-7.38**	**-7.53**	**-8.37**	**-8.08**	-8.14
Forest Carbon Flux	**-3.22**	**-3.23**	**-3.27**	**-3.28**	**-3.28**	**-3.26**	**-3.24**	**-3.24**	**-3.24**	-3.24
Liming of Agricultural Soils	0.47	0.41	0.34	0.46	0.45	0.40	0.28	0.54	0.56	0.53
Urea Fertilization	0.11	0.15	0.15	0.19	0.18	0.13	0.08	0.12	0.15	0.14
Urban Trees	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34	-0.49	-0.50	-0.43	-0.43
Yard Trimmings and Food Scraps Stored in Landfills	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08	-0.10	-0.10	-0.10
Fertilization of Settlement Soils	0.57	0.52	0.49	0.51	0.53	0.48	0.50	0.31	0.49	0.47
Agriculture Soil Carbon Flux	**-5.88**	**-3.48**	**-4.11**	**-5.32**	**-5.44**	**-4.71**	**-4.57**	**-5.50**	**-5.50**	-5.50

[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.

[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.

Emissions ($MMtCO_2e$)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural Gas Transmission & Distribution	1.40	1.40	1.40	1.41	1.27	1.41	1.42	1.42	1.47	1.48
Transmission	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.84	0.84
Distribution	0.61	0.62	0.61	0.62	0.48	0.62	0.63	0.64	0.63	0.64
Transportation	19.46	19.55	20.02	20.12	20.42	19.92	20.20	18.81	**20.73**	19.70
Waste	**1.91**	**1.88**	**2.08**	**2.11**	**2.10**	**2.10**	**2.11**	**1.97**	**1.93**	1.96
Solid Waste	1.49	1.48	1.69	1.71	1.68	1.67	1.68	1.60	1.56	1.59
Wastewater	**0.42**	**0.40**	**0.39**	**0.40**	**0.42**	**0.43**	**0.43**	**0.38**	**0.37**	0.37
Gross Emissions	**129.49**	**131.62**	**128.60**	**123.25**	**131.27**	**132.36**	**130.59**	**119.60**	**128.33**	124.22
Sinks	**-8.37**	**-6.07**	**-6.85**	**-7.89**	**-7.99**	**-7.38**	**-7.53**	**-8.37**	**-8.08**	-8.14
Net Emissions	**121.12**	**125.55**	**121.75**	**115.36**	**123.28**	**124.98**	**123.06**	**111.22**	**120.25**	116.08
% Change from Previous Year (Gross)	**-1.02%**	**1.64%**	**-2.29%**	**-4.16%**	**6.51%**	**0.83%**	**-1.34%**	**-8.42%**	**7.30%**	-3.21%
% Change from 2013 (Gross)	**--**	**1.64%**	**-0.69%**	**-4.82%**	**1.37%**	**2.22%**	**0.85%**	**-7.64%**	**-0.90%**	-4.07%

Appendix B – Iowa GHG Emissions 2013 - 2022 by Pollutant[32]

Emissions ($MMtCO_2e$)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Gross CO_2	87.53	88.02	83.31	77.52	83.48	87.47	86.34	77.36	**83.11**	78.63
Net CO_2	**78.58**	**81.43**	**75.97**	**69.12**	**74.96**	**79.61**	**78.32**	**68.67**	**74.54**	70.02
Stationary Fossil Fuel Combustion	65.47	65.85	60.64	54.51	58.35	62.58	61.31	53.56	**57.87**	54.12
Transportation	19.21	19.32	19.81	19.93	20.25	19.74	20.09	18.56	**20.47**	19.42
Industrial Processes	2.83	2.83	2.84	3.07	4.87	5.14	4.93	5.22	**4.83**	5.08
Solid Waste	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
LULUCF[33]	**-8.95**	**-6.59**	**-7.34**	**-8.40**	**-8.52**	**-7.86**	**-8.02**	**-8.68**	**-8.57**	-8.61
CH_4	**21.45**	**20.88**	**21.82**	**21.74**	**22.40**	**19.30**	**19.67**	**19.41**	**18.72**	18.80
Stationary Fossil Fuel Combustion	0.17	0.17	0.14	0.09	0.13	0.15	0.14	0.13	0.14	0.13
Transportation	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Natural Gas and Oil Transmission and Distribution	1.40	1.40	1.40	1.41	1.27	1.41	1.42	1.42	1.47	1.48
Enteric Fermentation	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	**8.09**	8.22
Manure Management	9.67	9.31	9.91	9.79	10.58	7.02	7.43	7.40	**7.14**	7.06
Solid Waste	1.48	1.46	1.68	1.70	1.66	1.66	1.67	1.58	1.56	1.59
Wastewater	**0.33**	**0.31**	**0.30**	**0.30**	**0.33**	**0.34**	**0.33**	**0.32**	**0.30**	0.30
N_2O	19.65	21.20	22.46	22.98	24.39	24.53	23.40	21.47	**25.40**	25.66
Stationary Fossil Fuel Combustion	0.24	0.24	0.21	0.19	0.18	0.20	0.18	0.15	0.18	0.16
Transportation	0.21	0.19	0.18	0.16	0.14	0.14	0.09	0.23	0.24	0.25
Industrial Processes	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.66	0.81	0.92
Manure Management	1.18	1.75	1.16	1.17	1.17	1.18	1.19	1.16	**2.00**	2.08
Agricultural Soil Management	16.55	18.14	19.58	20.09	21.56	21.70	20.57	18.91	**21.62**	21.72
N_2O from Settlement Soils	0.57	0.52	0.49	0.51	0.53	0.48	0.50	0.31	**0.49**	0.47
Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.06	0.07	0.07
HFC, PFC, and SF_6	1.44	1.47	1.50	1.53	1.53	1.53	1.67	1.67	**1.59**	1.59
Industrial Processes	1.44	1.47	1.50	1.53	1.53	1.53	1.67	1.67	**1.59**	1.59
Gross Emissions	**130.07**	**132.14**	**129.09**	**123.76**	**131.80**	**132.84**	**131.08**	**119.92**	**128.82**	124.68
Sinks	**-8.95**	**-6.59**	**-7.34**	**-8.40**	**-8.52**	**-7.86**	**-8.02**	**-8.68**	**-8.57**	-8.61
Net Emissions (Sources and Sinks)	**121.12**	**125.55**	**121.75**	**115.36**	**123.28**	**124.98**	**123.06**	**111.23**	**120.25**	116.08

[32] 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.

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