



IOWA DEPARTMENT OF  
NATURAL RESOURCES

2021 Iowa Statewide  
Greenhouse Gas Emissions  
Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

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## Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	basic oxygen furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CEMS	continuous emission monitoring system
CH <sub>4</sub>	methane
CO <sub>2</sub>	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 <sub>2</sub> e	million metric tons carbon dioxide equivalent
MISO	Midcontinent Independent System Operator

## Acronyms and Key Terms (Continued)

MSW	municipal solid waste
N	nitrogen
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NO <sub>3</sub> <sup>-</sup>	nitrates
NO <sub>2</sub> <sup>-</sup>	nitrites
NO <sub>x</sub>	nitrogen oxides
N <sub>2</sub> O	nitrous oxide
NRCS	Natural Resources and Conservation Service
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
RCI	residential, commercial, and industrial
SEDS	EIA's State Energy Data System
SF <sub>6</sub>	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 [2021 Iowa Statewide Greenhouse Gas Emissions Inventory Report](#). Total Iowa GHG emissions from 2012 – 2021 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)<sup>1</sup> 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 – 2019, but allow the user to enter better state-specific activity data when it is available. Detailed information on the activity data used is provided in the corresponding chapter for each sector, under the “Method” heading. The individual modules then calculate the resulting GHG emissions from each sector. The results from each module were then tabulated in an Excel spreadsheet. The SIT Projection Tool was then used to forecast emissions to 2040. The SIT modules and their corresponding chapters in this TSD are listed in Table 1. The coal module was not used, as there are no coal mines currently operating in Iowa.

**Table 1: TSD Chapters and Corresponding SIT Modules**

TSD Chapter	SIT Module	Release Date	Pollutants Addressed
Agriculture	Ag	1/31/22	CH <sub>4</sub> , N <sub>2</sub> O
Energy	CO <sub>2</sub> FFC	1/31/22	CO <sub>2</sub>
	Stationary Combustion	1/31/22	CH <sub>4</sub> , N <sub>2</sub> O
Industrial Processes	IP	1/31/22	CO <sub>2</sub> , N <sub>2</sub> O, HFC, PFC, SF <sub>6</sub>
Natural Gas Transmission & Distribution	Natural Gas and Oil	1/31/22	CH <sub>4</sub>
Transportation	Mobile Combustion	1/31/22	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Waste	Solid Waste	1/31/22	CO <sub>2</sub> , CH <sub>4</sub>
	Wastewater	1/31/22	CH <sub>4</sub> , N <sub>2</sub> O
Land Use, Land Use Change, and Forestry	LULUCF	1/31/22	CO <sub>2</sub> , N <sub>2</sub> O
Indirect Emissions from Electricity Consumption	Electricity Consumption	1/31/22	CO <sub>2</sub>
Future Emissions	Projection Tool	1/31/22	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, HFC, PFC, SF <sub>6</sub>

<sup>1</sup> 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<sub>2</sub>e) that allows for better comparison of the impact of the different greenhouse gases. CO<sub>2</sub>e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting values. CO<sub>2</sub>e was calculated using Equation 1.

**Equation 1:**

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

Where:

*GHG<sub>i</sub>* = Mass emissions of each greenhouse gas

*GWP<sub>i</sub>* = 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**

<b>Pollutant</b>	<b>GWP used by DNR (IPCC AR4 2007)</b>
Carbon Dioxide (CO <sub>2</sub> )	1
Methane (CH <sub>4</sub> )	25
Nitrous Oxide (N <sub>2</sub> O)	298
Sulfur Hexafluoride (SF <sub>6</sub> )	22,600
Hydrofluorocarbons (HFC)	Vary by pollutant – For a complete list, refer to DNR's <a href="#">Greenhouse Gas Emissions Estimation Guidance</a> .
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<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). Table 3 summarizes the source of GHG emissions in each sector. N<sub>2</sub>O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2021).

**Table 3: Sources of Agricultural GHG Emissions in Iowa**

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

### **Method**

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency’s (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated January 31, 2022 (ICF 2022a and 2022b).

#### *Enteric Fermentation*

The SIT calculates CH<sub>4</sub> emissions from enteric fermentation by multiplying various livestock populations by an annual CH<sub>4</sub> emission factor (kilograms CH<sub>4</sub> 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<sub>4</sub> and N<sub>2</sub>O emissions from manure when it is being stored and treated in a manure management system. In general, CH<sub>4</sub> emissions increase in more anaerobic (lacking oxygen) conditions while N<sub>2</sub>O 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	2021	2021 Iowa Agricultural Statistics Bulletin (USDA 2021)
Beef cattle		
Goats		
Sheep		
Breeding swine		
Market swine under 60 lbs. <sup>2</sup>		
Market swine 60 – 119 lbs. <sup>3</sup>		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Broilers	2017 census value used as proxy for 2018-2021	USDA-NASS Quick Stats (USDA 2022)
Horses		
Turkeys		
Chickens	2020 census value used as proxy for 2021	2021 Iowa Agricultural Statistics Bulletin (USDA 2021)
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<sub>2</sub>O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2022). N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O (EPA 2022).

#### Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2022) were used to calculate N<sub>2</sub>O 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<sub>2</sub>O)

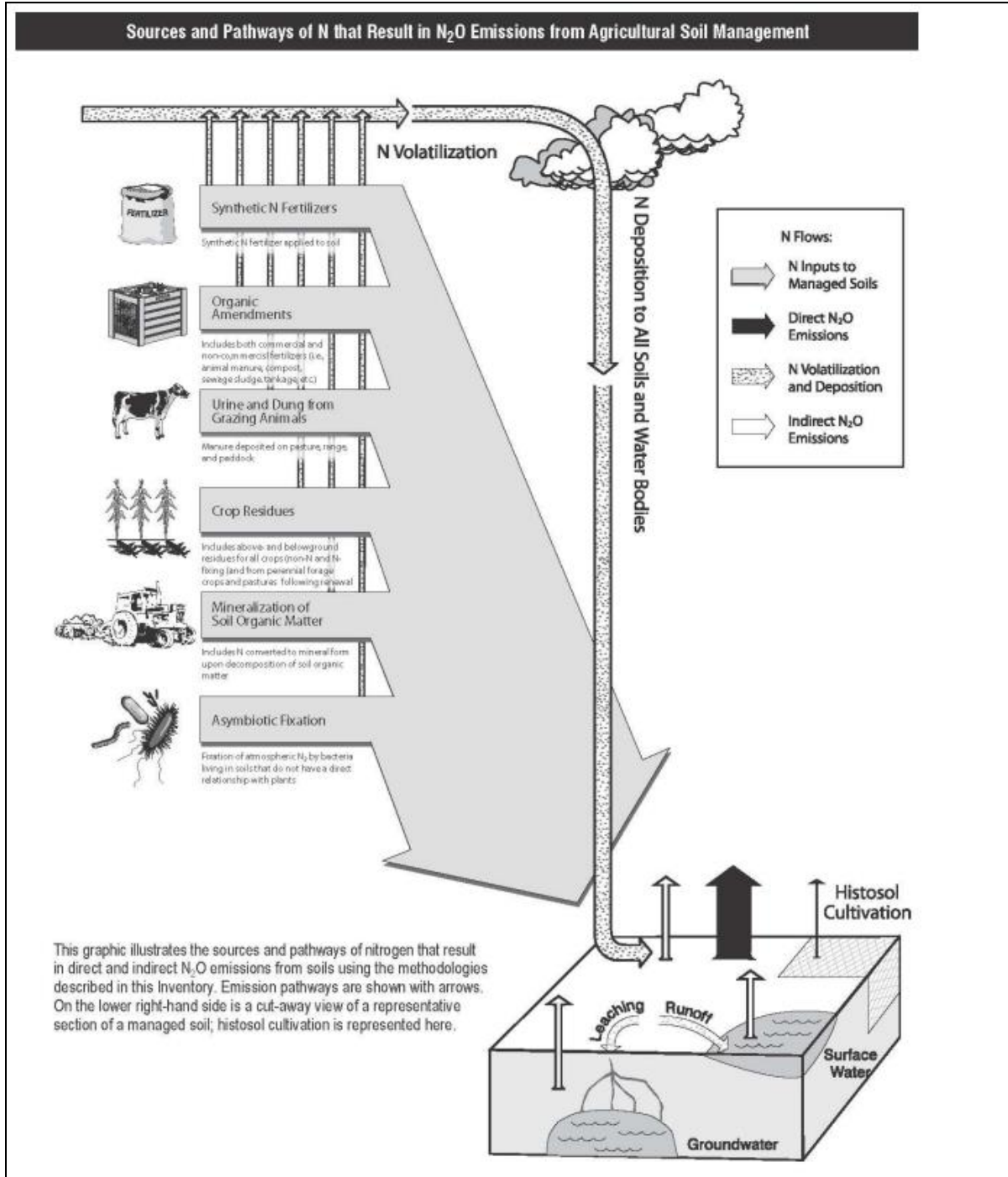
N<sub>2</sub>O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently available (Bedmarek 2012), so the DNR estimated the number of cultivated histosols acres by

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

<sup>3</sup> 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 2022) 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<sub>2</sub>O Emissions in Ag Soils (EPA 2022)**



### Fertilizer Utilization

The DNR calculated fertilizer emissions for 2021 using fertilizer tonnages from the *Fertilizer Tonnage Distribution in Iowa 2021 Crop Year* (IDALS 2021). The IDALS fertilizer data is provided per the 2021 growing season, which is from July 2020 – June 2021.

### *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 2022). 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 2022c). 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 2020 GHG Inventory Report was published in December 2021, the 2020 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:

- 2020 populations of bulls, steer stockers, heifer stockers, market swine and breeding swine were updated to match revised values in the 2021 Iowa Annual Statistics Bulletin (USDA 2021).
- Previously, Iowa DNR used 2019 fertilizer tonnage as a proxy for 2020. The 2020 values have been updated (IDALS 2020).
- Tons of soybeans produced, acres of soybeans harvested, and acres of corn harvested in 2020 were updated to match revised values in the USDA’s Quick Stats database (USDA 2022).

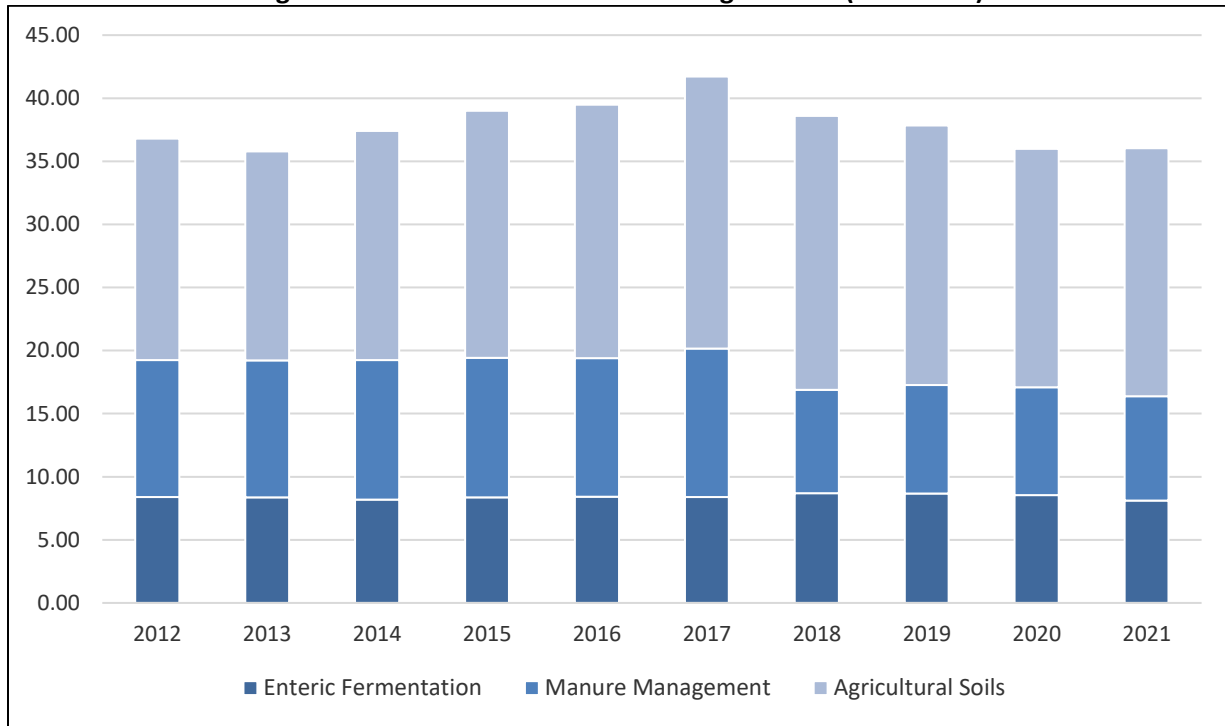
**Table 5: Recalculated Agricultural Emissions (MMtCO<sub>2</sub>e)**

<b>Category</b>	<b>2020 Value (Published Dec. 2021)</b>	<b>2020 Updated Value</b>
Enteric Fermentation	8.54	8.54
Manure Management	8.57	8.55
Agricultural Soils	20.54	18.91
<b>Total</b>	<b>37.65</b>	<b>36.00</b>

### Results

GHG emissions from agriculture increased 0.08% from 2020 – 2021 and decreased 2.06% from 2012 – 2021. Gross GHG emissions from agriculture were 36.03 MMtCO<sub>2</sub>e in 2021, or 28.56% of Iowa’s total gross 2021 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 (54.52%) are from soils as shown in Figure 2 and Table 6.

**Figure 2: Gross GHG Emissions from Agriculture (MMtCO<sub>2</sub>e)**



**Table 6: Gross GHG Emissions from Agriculture (MMtCO<sub>2</sub>e)<sup>4</sup>**

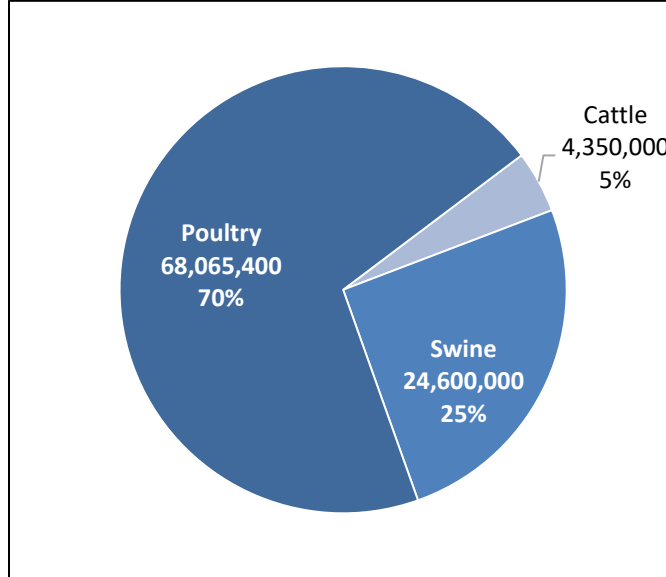
Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Enteric Fermentation	8.40	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	8.11
Manure Management	10.86	10.85	11.06	11.07	10.96	11.75	8.20	8.62	8.55	8.28
Agricultural Soils	17.53	16.55	18.14	19.58	20.09	21.56	21.70	20.57	18.91	19.64
<b>Total</b>	<b>36.78</b>	<b>35.77</b>	<b>37.39</b>	<b>39.00</b>	<b>39.49</b>	<b>41.71</b>	<b>38.60</b>	<b>37.85</b>	<b>36.00</b>	<b>36.03</b>

*Enteric Fermentation*

CH<sub>4</sub> emissions from enteric fermentation were 8.11 MMtCO<sub>2</sub>e in 2021, decreasing 5.05% from 2020. This can be attributed to a 6.85% decrease in the total cattle population. While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 3, enteric fermentation emissions are primarily driven by cattle. This is because cattle emit more CH<sub>4</sub> 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.

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

**Figure 3: 2021 Iowa Animal Populations (USDA 2022)<sup>5</sup>**



**Table 7: Methane Emitted per Animal**

Animal Type	kg/head CH <sub>4</sub> Emitted (ICF 2022a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.2 – 142.4
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

*Manure Management*

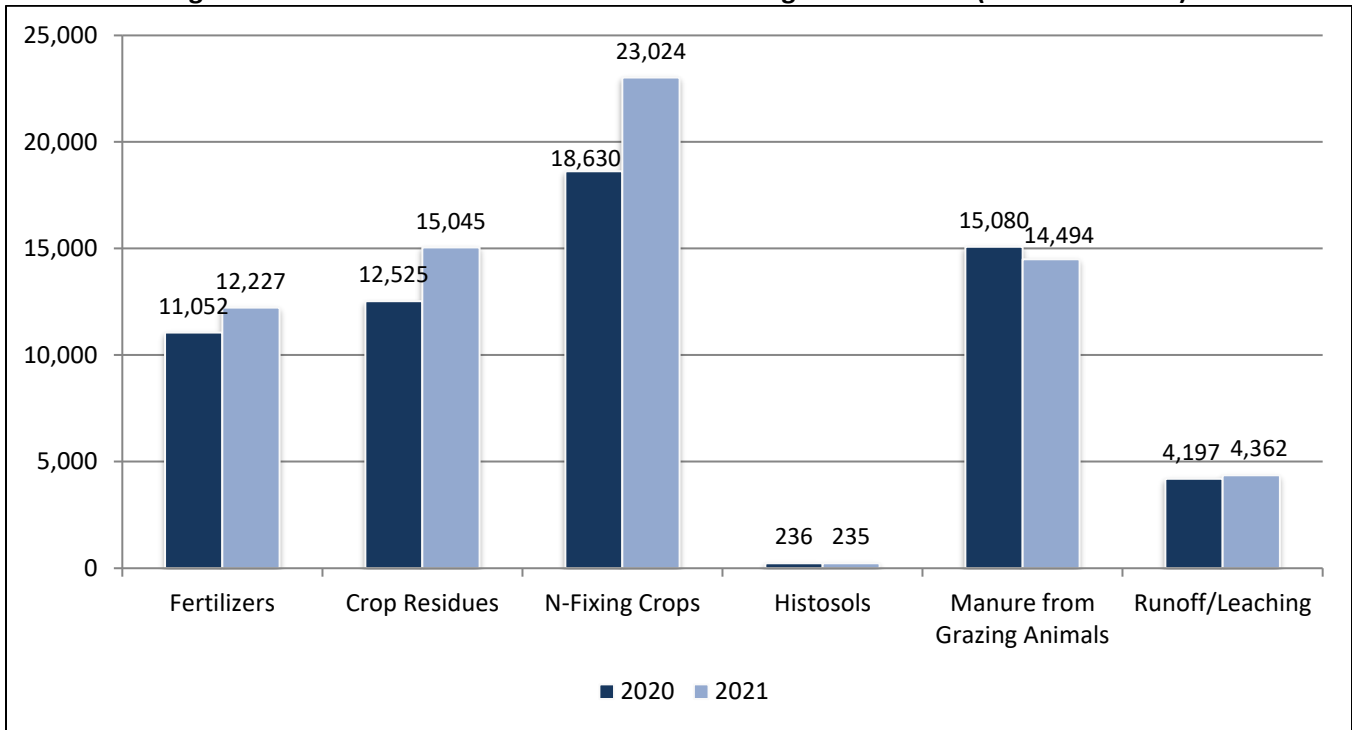
Factors influencing CH<sub>4</sub> and N<sub>2</sub>O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management decreased 3.17% from 2020 and accounted for 22.98% of agricultural GHG emissions in 2021.

*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 increased in 2021 while there was a smaller increase in production of corn, as shown in Table 8. Production of alfalfa also increased while oats decreased and updated data was not available for wheat, rye, pea, and sorghum production. This led to an overall increase in N<sub>2</sub>O emissions from agricultural soils of 3.87% from the previous year. N<sub>2</sub>O emissions from agricultural soils accounted for 54.52% of all agricultural GHG emissions and 15.52% of total gross statewide GHG emissions in 2021.

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

**Figure 4: 2020 - 2021 Gross GHG Emissions from Agricultural Soils (metric tons N<sub>2</sub>O)**



**Table 8: Iowa Crop Production 2020 – 2021 (USDA 2022)**

Crop	2020 (1000 Bushels)	2021 (1000 Bushels)
Barley	54	54
Corn for Grain	2,283,300	2,539,800
Oats	5,694	4,004
Rye	247	247
Sorghum for Grain	25	25
Soybeans	505,980	631,890
Wheat	348	348
<b>Total</b>	<b>2,795,648</b>	<b>3,176,368</b>
Crop	2020 (1000 tons)	2021 (1000 tons)
Alfalfa	3,083	3,185
Crop	2020 (1000 CWT)	2021 (1000 CWT)
Peas, Dry Edible	11	11

**Uncertainty<sup>6</sup>**

*Enteric Fermentation*

The quantity of methane (CH<sub>4</sub>) 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

<sup>6</sup> This information is largely excerpted from the *SIT Agriculture Module* (ICF 2022a).

type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2022a).

#### *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<sub>4</sub> and N<sub>2</sub>O emission factors used for these systems. In addition, there is uncertainty in the maximum CH<sub>4</sub> producing potential (B<sub>0</sub>) 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<sub>0</sub> 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<sub>0</sub> for all animal types and feeding circumstances (ICF 2004).

#### *Agricultural Soils*

The N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>FFC module for carbon dioxide (CO<sub>2</sub>) emissions and the Stationary Combustion module for CH<sub>4</sub> and N<sub>2</sub>O emissions (ICF 2022a-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 – 2019 from U.S. Energy Information Administration (EIA) State Energy Data System (SEDS) (EIA 2022b). Because Iowa-specific 2021 energy consumption data will not be published by the EIA until June 2023, the DNR projected 2021 energy consumption using projections provided by EPA in the SIT Projection Tool (ICF 2022a). 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 2022) or EPA’s federal GHG Reporting Program (EPA 2022) were used as follows:

#### *2005 – 2009*

CO<sub>2</sub> 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<sub>2</sub> emissions reported by facilities to CAMD are actual measured emissions values from continuous emission monitoring systems (CEMS) located on electric generating units.

#### *2010 - 2021*

Power plants became subject to the federal GHG reporting program starting with calendar year 2010. Facilities are required to report CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions. This CO<sub>2</sub> data is also from CEMS and is more accurate than EIA data. In addition, the CH<sub>4</sub> and N<sub>2</sub>O emissions are calculated using facility-specific fuel heating values. The CO<sub>2</sub> data reported to the federal GHG reporting program is consistent with the CO<sub>2</sub> emissions reported by the same facilities to CAMD.

### **Adjustments**

The DNR previously forecasted 2020 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2020 energy data was released by EIA in June 2022 (EIA 2022b), so the DNR used the data to recalculate 2020 emissions as shown in Table 10.

**Table 10: Recalculated RCI Emissions (MMtCO<sub>2</sub>e)**

<b>Category</b>	<b>2020 Value (Published Dec. 2021)</b>	<b>2020 Updated Value</b>
Residential	5.23	5.22
Commercial	4.06	4.05
Industrial	27.45	27.49
<b>Total</b>	<b>36.74</b>	<b>36.76</b>

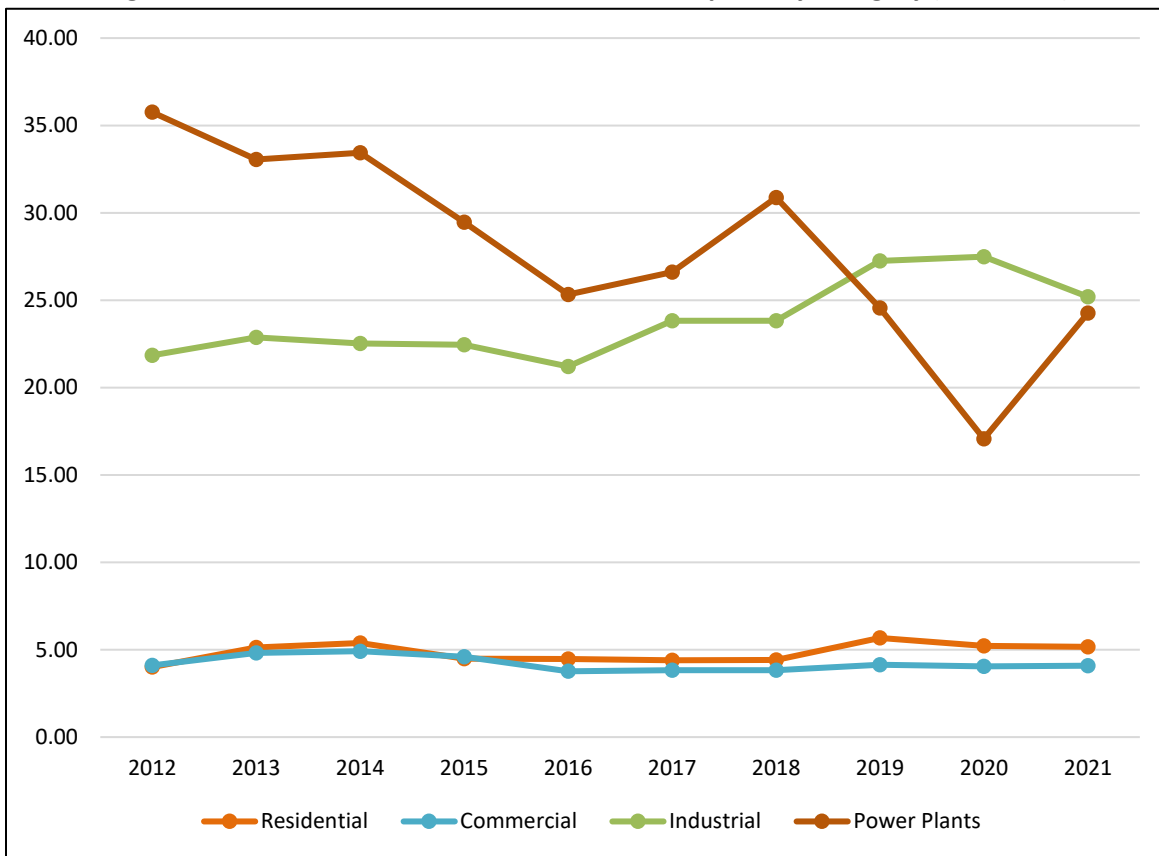
### **Results**

Total GHG emissions from fossil fuel consumption in 2021 were 58.72 MMtCO<sub>2</sub>e, an increase of 9.07% from 2020 and a decrease of 10.66% from 2012 levels as shown in Table 11 and Figure 5. Emissions from commercial fuel use increased 0.81% from the previous year, while emissions from residential and industrial fuel use decreased. Markedly, emissions from power plants increased by 42.16% from 2020 to 2021. However, it should be noted that 2021 emissions from power plants were still slightly lower than 2019. With the exception of 2020, the 2021 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<sub>2</sub>e)<sup>7</sup>**

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Residential	4.01	5.12	5.38	4.49	4.48	4.41	4.42	5.67	5.22	5.16
Commercial	4.11	4.83	4.92	4.60	3.77	3.82	3.83	4.14	4.05	4.09
Industrial	21.84	22.87	22.52	22.44	21.21	23.82	23.83	27.26	27.49	25.20
Power Plants	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57	17.07	24.27
<b>Total</b>	<b>65.72</b>	<b>65.89</b>	<b>66.26</b>	<b>61.00</b>	<b>54.78</b>	<b>58.97</b>	<b>62.93</b>	<b>61.64</b>	<b>53.83</b>	<b>58.72</b>

**Figure 5: GHG Emissions from Fossil Fuel Consumption by Category (MMtCO<sub>2</sub>e)**



As noted above, emissions from fossil-fuel fired power plants in 2021 increased from 2020 but were the second lowest within the 2012-2021 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.

<sup>7</sup> 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<sub>2</sub> Uncertainty**<sup>8</sup>

The amount of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions to a small extent.

### **CH<sub>4</sub> and N<sub>2</sub>O Uncertainty**<sup>9</sup>

The amount of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub>, 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.

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<sup>8</sup> This information is largely excerpted from the *SIT CO<sub>2</sub>FFC Module* (ICF 2022a).

<sup>9</sup> This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2022b).

## 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 <sub>2</sub>
Cement Production	CO <sub>2</sub>
Electric Power Transmission & Distribution	SF <sub>6</sub>
Iron and Steel Production	CO <sub>2</sub>
Lime Manufacture	CO <sub>2</sub>
Limestone and Dolomite Use	CO <sub>2</sub>
Nitric Acid Production	N <sub>2</sub> O
Ozone Depleting Substances (ODS) Substitutes	HFCs, PFCs, and SF <sub>6</sub>
Semiconductor Manufacturing	HFCs, PFCs, and SF <sub>6</sub>
Soda Ash Use	CO <sub>2</sub>

CO<sub>2</sub> is released during the manufacture of ammonia. The chemical equations to calculate the release of CO<sub>2</sub> 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<sub>2</sub> emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO<sub>2</sub>. Other emissions of CO<sub>2</sub> can occur during condensate stripping or regeneration of the scrubbing solution. CO<sub>2</sub> 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<sub>2</sub>) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO<sub>2</sub>. The CO<sub>2</sub> 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<sub>6</sub>) is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2022b).

### *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 2022b). 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<sub>2</sub> emissions result primarily from the consumption of carbon electrodes and from the consumption of supplemental materials used to augment the melting process (EPA 2022b).

#### *Lime Manufacture*

Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO<sub>2</sub>. The CO<sub>2</sub> 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<sub>2</sub>O) 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<sub>6</sub> may also be used (ICF 2022b).

#### *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 2022b). In Iowa, it is commonly used by corn wet milling facilities for pH control, in ion exchange regeneration, and in other operations (DNR 2010).

#### *Other Industry Types*

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

### **Method**

The 2021 emissions from industrial processes were calculated using either the SIT (ICF 2022a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2022a) as shown in Table 13.

**Table 13: Industrial Processes Calculation Methods and Activity Data**

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2021	40 CFR 98 Subpart G	GHGRP (EPA 2022a)
Cement Production	2021	40 CFR 98 Subpart H	GHGRP (EPA 2022a)
Electric Power Transmission & Distribution	2020 as proxy for 2021	SIT	National GHG Inventory (EPA 2022b)
Iron and Steel Production	2021	40 CFR 98 Subpart Q	GHGRP (EPA 2022a)
Lime Manufacture	2021	40 CFR 98 Subpart S	GHGRP (EPA 2022a)
Limestone and Dolomite Use	2015 as proxy for 2016 - 2021	SIT	(USGS 2017)
Nitric Acid Production	2021	40 CFR 98 Subpart V	GHGRP (EPA 2022a)
ODS Substitutes	2019 as proxy for 2020-2021	SIT	National GHG Inventory (EPA 2022b)
Semiconductor Manufacturing	2019 as a proxy for 2020-2021	SIT	SIT defaults
Soda Ash Use	2019 as a proxy for 2020-2021	SIT	(USGS 2021)

*Categories Calculated using the SIT*

Because current emissions data was not available for electric power transmission and distribution, the 2020 national emissions were used as a proxy for 2021. The 2020 value was calculated by determining the ratio between 2020 Iowa retail sales to 2020 national retail sales (EIA 2022), and applying that ratio to 2020 national emissions of SF<sub>6</sub>. The 2021 retail sales ratio was used for 2021.

Emissions in 2015 from the use of limestone and dolomite in industrial processes were used as a proxy for 2016 – 2021 emissions. The 2015 value was calculated by multiplying Iowa’s 2015 consumption by the ratio of national consumption for industrial uses to total national consumption.

Emissions in 2019 from ODS substitutes were used as proxy for 2020 and 2021. The 2019 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 2022).

Emissions in 2021 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 2022).

Emissions in 2021 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 2022).

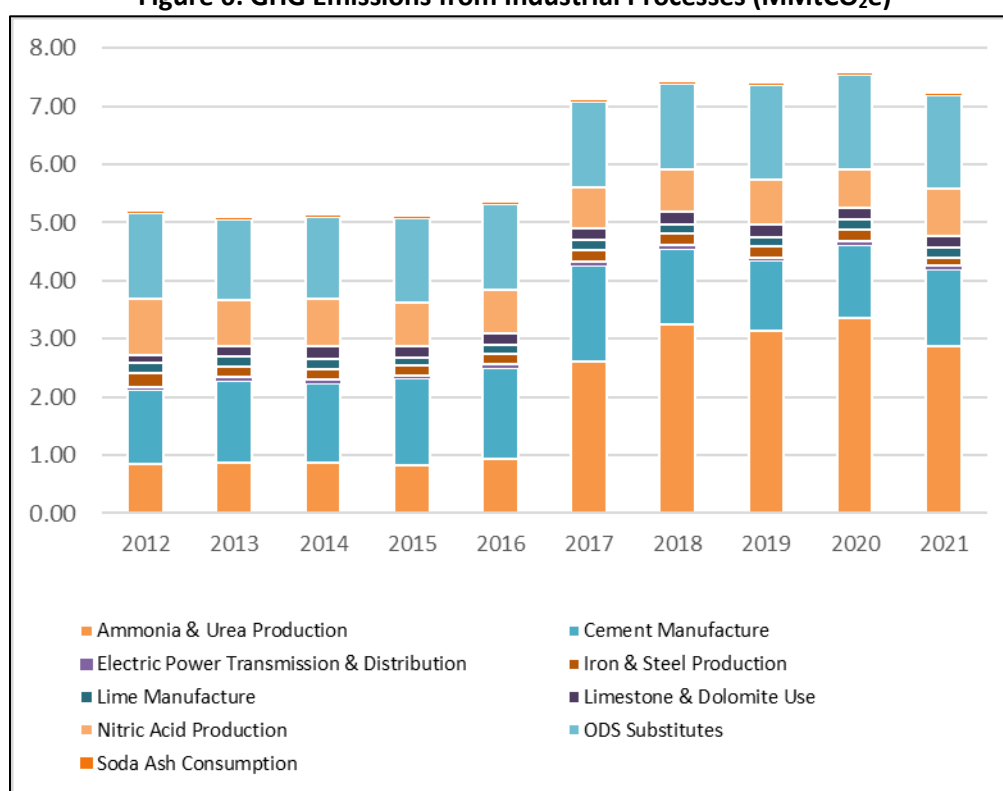
**Results**

GHG emissions from industrial processes in 2021 were 7.21 MMtCO<sub>2</sub>e, or 5.72% of total statewide GHG emissions. Emissions from this sector decreased 4.50% from 2020 as shown in Table 14 and Figure 6, primarily due to decreases of emissions from ammonia and urea production (-0.48 MMtCO<sub>2</sub>e) as well as small decreases in iron and steel production and lime manufacture. The decrease was offset by increases in emissions in nitric acid production (0.15 MMtCO<sub>2</sub>e) and cement manufacture (0.06 MMtCO<sub>2</sub>e).

**Table 14: GHG Emissions from Industrial Processes (MMtCO<sub>2</sub>e)<sup>10</sup>**

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020
Ammonia & Urea	0.85	0.88	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88
Cement Manufacture	1.27	1.41	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31
Electric Power T&D	0.06	0.06	0.06	0.04	0.05	0.05	0.05	0.05	0.06	0.06
Iron & Steel Production	0.23	0.19	0.18	0.16	0.19	0.20	0.19	0.18	0.14	0.14
Lime Manufacture	0.18	0.16	0.17	0.13	0.15	0.18	0.16	0.17	0.16	0.16
Limestone & Dolomite Use	0.15	0.18	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.81	0.81
ODS Substitutes	1.47	1.39	1.42	1.45	1.47	1.47	1.47	1.61	1.62	1.62
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
<b>Total</b>	<b>5.18</b>	<b>5.07</b>	<b>5.12</b>	<b>5.09</b>	<b>5.34</b>	<b>7.10</b>	<b>7.40</b>	<b>7.37</b>	<b>7.55</b>	<b>7.21</b>

**Figure 6: GHG Emissions from Industrial Processes (MMtCO<sub>2</sub>e)**



### **Uncertainty**

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.

<sup>10</sup> Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2012– 2021 rounded to 0.001 MMtCO<sub>2</sub>e or less.

Other major sources of uncertainty associated with calculating emissions from industrial processes are listed below:<sup>11</sup>

- 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.

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<sup>11</sup> This information is largely excerpted from the *SIT Industrial Processes Module* (ICF 2022a).



## 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<sub>4</sub>) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO<sub>2</sub>) 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<sub>4</sub> is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2022b).

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 2022). 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 2022).

#### *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<sub>4</sub> is emitted from leaks, meters, regulators, and accidents (ICF 2022b). Activity data from the DOT PHMSA's Office of Pipeline Safety was used for calculating emissions (DOT 2022). 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 1.4730 MMtCO<sub>2</sub>e<sup>12</sup> in 2021, an increase of 3.67% from 2020 and an increase of 5.06% from 2012 as shown in Table 15 and Figure 7. GHG emissions from this sector account for 1.17% of 2021 statewide GHG emissions.

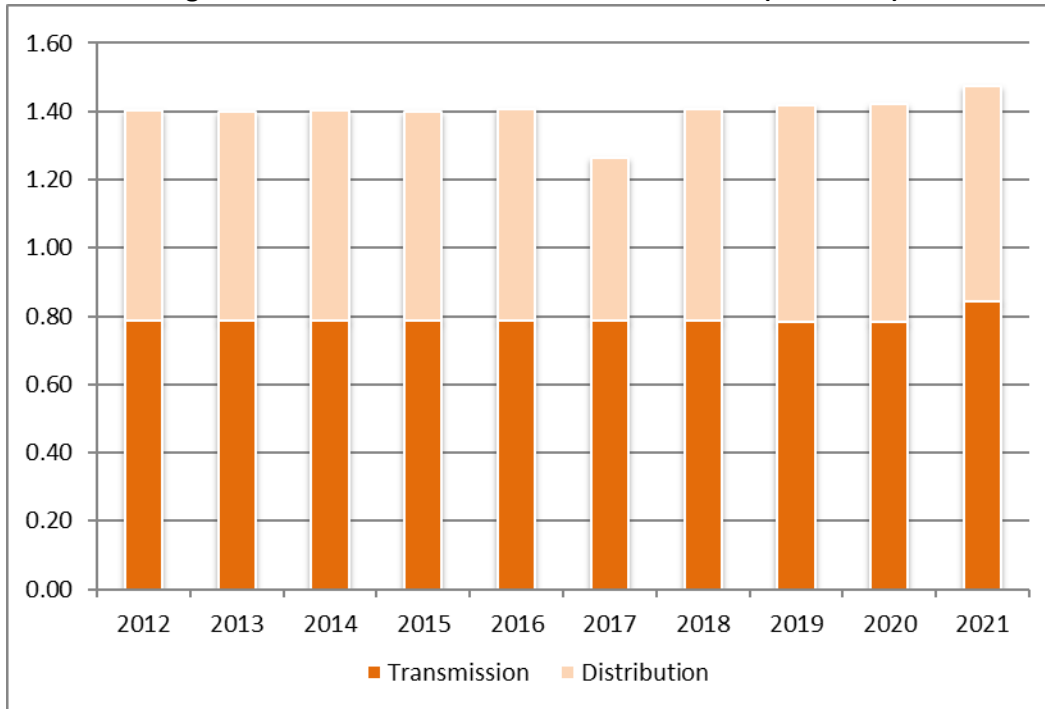
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<sup>12</sup> DNR generally uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

**Table 15: GHG Emissions from Natural Gas T & D (MMtCO<sub>2</sub>e)**

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Transmission	0.7862	0.7865	0.7864	0.7868	0.7867	0.7868	0.7864	0.7842	0.7845	0.8438
Distribution	0.6158	0.6135	0.6168	0.6118	0.6205	0.4789	0.6209	0.6321	0.6363	0.6292
<b>Total</b>	<b>1.4020</b>	<b>1.4000</b>	<b>1.4031</b>	<b>1.3986</b>	<b>1.4073</b>	<b>1.2657</b>	<b>1.4073</b>	<b>1.4163</b>	<b>1.4208</b>	<b>1.4730</b>

**Figure 7: GHG Emissions from Natural Gas T & D (MMtCO<sub>2</sub>e)**



### **Uncertainty**<sup>13</sup>

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 2022a).

<sup>13</sup> 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 2022a), which was updated by EPA in 2022 to calculate CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O 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<sub>2</sub>O emissions factors in the 2021 SIT Mobile Combustion module, which are significantly higher than the factors used in the past.

### Highway Vehicles (CH<sub>4</sub> and N<sub>2</sub>O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH<sub>4</sub> and N<sub>2</sub>O 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 2021 annual VMT of 33,219 million miles from the Iowa Department of Transportation (IDOT 2022). 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-76 and A-77 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* (EPA 2022). The classes and the national distribution percentages are shown in Table 16.

**Table 16: VMT Vehicle/Fuel Classes and Distribution**

Vehicle Class	Acronym	2020 (EPA 2022)	2021 Iowa VMT (10 <sup>6</sup> miles)
Heavy duty diesel vehicle	HDDV	9.02%	2,995
Heavy duty gas vehicle	HDGV	1.20%	397
Light duty diesel truck	LDDT	0.83%	275
Light duty diesel vehicle	LDDV	0.32%	106
Light duty gasoline truck	LDGT	22.48%	7,467
Light duty gasoline vehicle	LDGV	65.55%	21,775
Motorcycle	MC	0.62%	207
<b>Total</b>		<b>100.00%</b>	<b>33,219</b>

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 2022).
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 2022).

*Non-highway Vehicles (CH<sub>4</sub> and N<sub>2</sub>O)*

Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH<sub>4</sub> and N<sub>2</sub>O emissions from non-highway vehicles were calculated using data from either the Energy Information Administration (EIA) or Federal Highway Administration as shown in Table 17.

**Table 17: Iowa-specific Non-Highway Activity Data Used**

Vehicle Type	Fuel Type	Year	Data Source
Aviation	Gasoline	2020 used as proxy for 2021	EIA SEDS (EIA 2022b)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2020 used as proxy for 2021	FHWA 2022
Heavy Duty Utility			
Tractors			
Construction			
Construction	Distillate Fuel	2020 used as proxy for 2021	EIA Adjusted Sales (EIA 2022a)
Locomotives			
Tractors			
Heavy Duty	Distillate Fuel	2018 used as proxy for 2019-2021	SIT default value
Small Utility	Gasoline		
Alternative Fuel Vehicles	Gasoline		

**Adjustments**

Emissions from non-highway vehicles were recalculated for 2020 as shown in Table 18 by using updated fuel activity data from EIA and the FHWA.

**Table 18: Recalculated Emissions from Transportation (MMtCO<sub>2</sub>e)<sup>14</sup>**

Pollutant	2020 Value (Published Dec. 2021)	2020 Updated Value
CO <sub>2</sub>	18.18	18.56
CH <sub>4</sub>	0.03	0.03
N <sub>2</sub> O	0.08	0.23
<b>Total</b>	<b>18.25</b>	<b>18.81</b>

**Results**

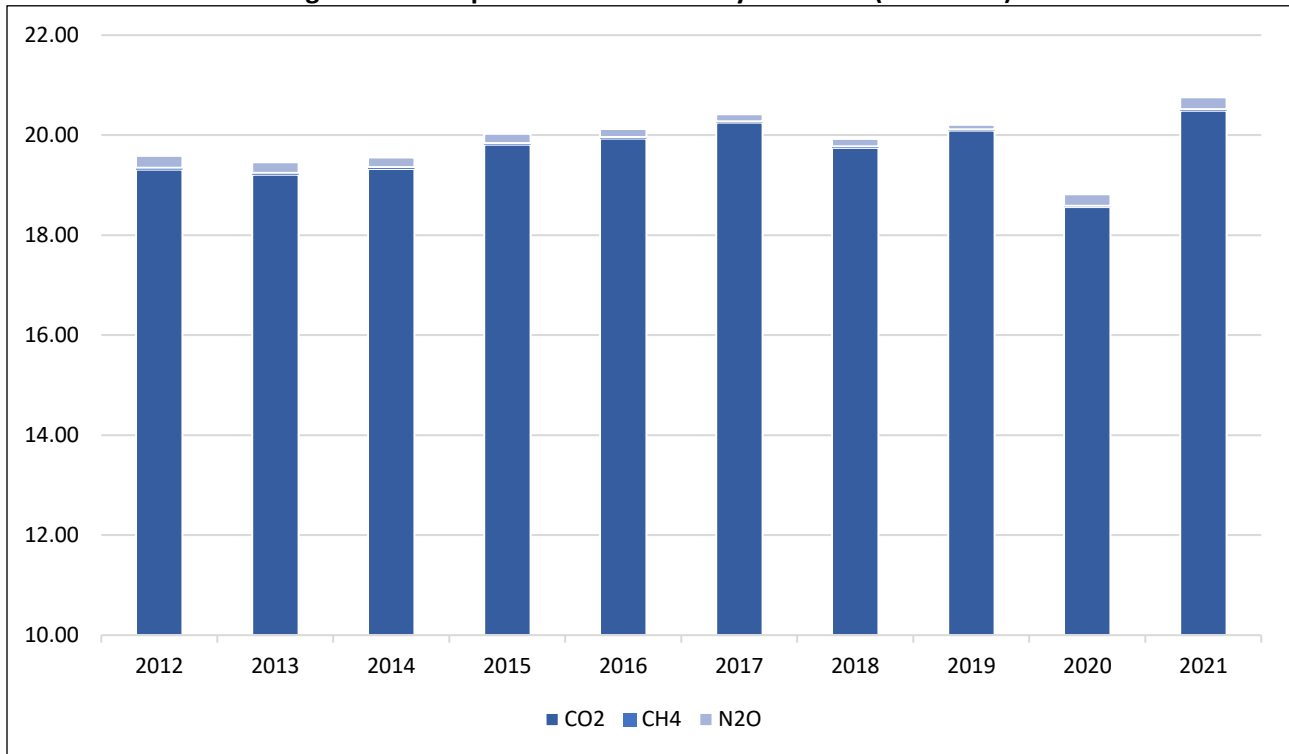
Total GHG emissions from transportation were 20.76 MMtCO<sub>2</sub>e in 2021 as shown in Table 19. This is an increase of 10.32% from 2020 primarily due to a 11.17% increase in VMT from 2020 - 2021, which reflects travel returning to pre-pandemic levels. CO<sub>2</sub> accounts for nearly all the Iowa transportation GHG emissions (98.70%) as shown in Figure 8. The majority of the transportation emissions (54.43%) are from gasoline highway vehicles as shown in Figure 9.

<sup>14</sup> Totals may not equal the sum of subtotals shown in this table due to independent rounding.

**Table 19: GHG Emissions from Transportation (MMtCO<sub>2</sub>e)<sup>15</sup>**

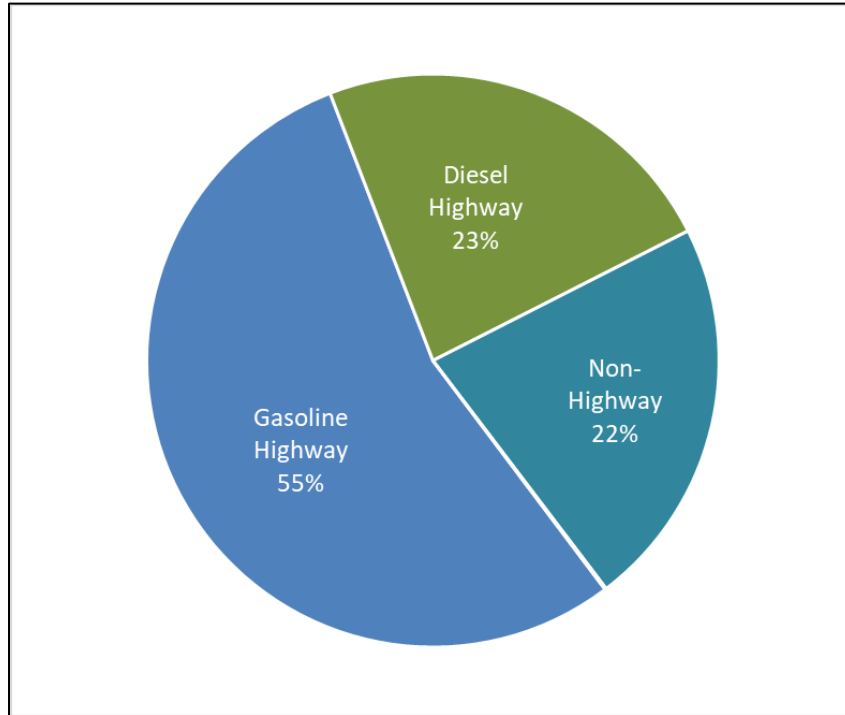
Pollutant	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO <sub>2</sub>	19.31	19.21	19.32	19.81	19.93	20.25	19.74	20.09	18.56	20.49
CH <sub>4</sub>	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N <sub>2</sub> O	0.24	0.21	0.19	0.18	0.16	0.14	0.14	0.09	0.23	0.24
<b>Total</b>	<b>19.59</b>	<b>19.46</b>	<b>19.55</b>	<b>20.02</b>	<b>20.12</b>	<b>20.42</b>	<b>19.92</b>	<b>20.20</b>	<b>18.81</b>	<b>20.76</b>

**Figure 8: Transportation Emissions by Pollutant (MMtCO<sub>2</sub>e)**



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

**Figure 9: 2021 GHG Emissions by Fuel/Vehicle Type<sup>16</sup>**



**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 2022). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable to locate Iowa-specific VMT data. Uncertainty may be introduced if the fuel consumption data or emission factors used do not reflect Iowa scenarios, such as using default national emission factors. In addition, it is assumed that all fuel purchased is consumed in the same year (ICF 2022b).

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<sup>16</sup> Emissions from alternative vehicles round to 0%.

## Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH<sub>4</sub>) emissions from municipal solid waste landfills and carbon dioxide (CO<sub>2</sub>) and nitrous oxide (N<sub>2</sub>O) emitted from the combustion of municipal solid waste to produce electricity. CH<sub>4</sub> 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<sub>4</sub> that is recovered and flared, and
- The quantity of CH<sub>4</sub> oxidized in landfills instead of being released into the atmosphere.

Fluctuations in CH<sub>4</sub> emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, the frequency of composting, and the rate of recovery of degradable materials such as paper and paperboard (EPA 2022b).

### **Method**

#### *Municipal Solid Waste (MSW) Landfills*

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2022a), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO<sub>2</sub>e or more to report their emissions. This included twenty-four Iowa landfills in 2020. An additional twenty-two 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<sub>4</sub> emitted from 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 3,094 tons of refuse derived waste in 2021 (Feucht 2022). The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO<sub>2</sub> emissions from MSW combustion using SIT (ICF 2022a). 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 20.

**Table 20: Proportions of Discards used in the Solid Waste Module**

<b>Material</b>	<b>SIT Default Value</b>	<b>2011 Iowa Study</b>	<b>2017 Iowa Study</b>	<b>2022 Iowa Study</b>
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.

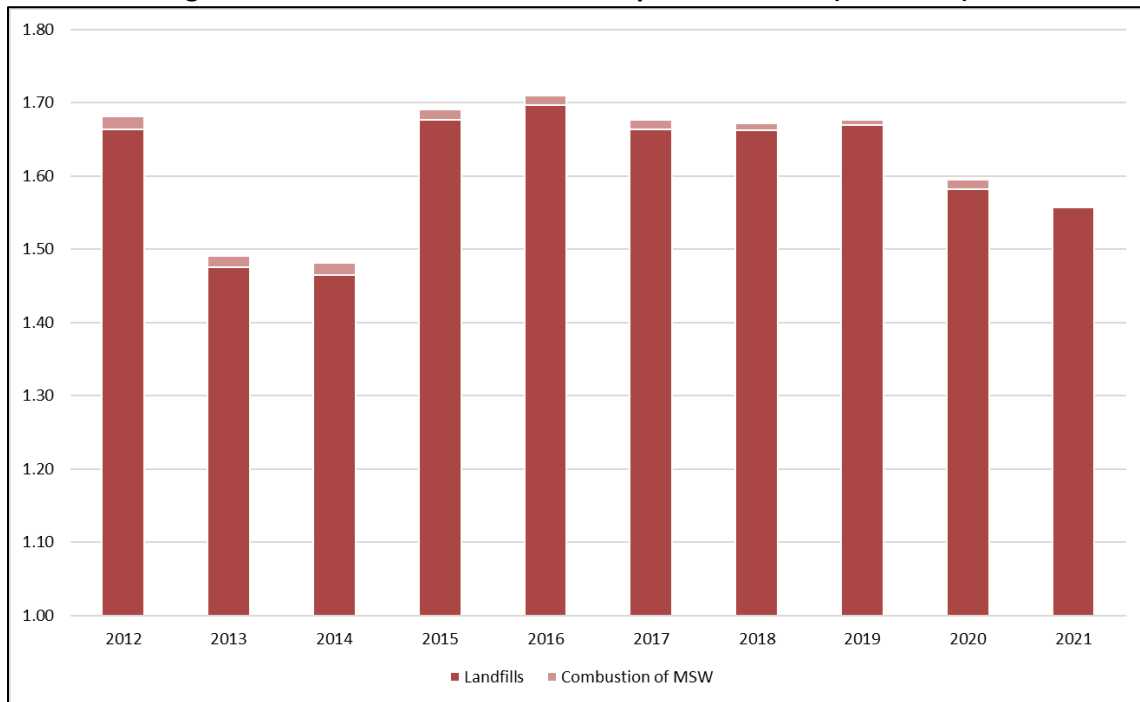
**Results**

Total GHG emissions from the solid waste category were 1.558 MMtCO<sub>2</sub>e in 2021, a decrease of 2.31% from 2020 as shown in Table 21 and Figure 10. Solid waste emissions account for 1.23% of total statewide GHG emissions. Emissions from waste disposed in landfills, the largest category of emissions, decreased by 6.42%. Additionally, emissions from combustion of MSW decreased 88.35%. 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<sub>4</sub> that is recovered and flared, and varying oxidation rates.

**Table 21: GHG Emissions from Municipal Solid Waste (MMtCO<sub>2</sub>e)<sup>17, 18</sup>**

Sector	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW Landfills	1.66	1.48	1.46	1.68	1.70	1.664	1.662	1.669	1.581	1.557
MSW Combustion	0.02	0.02	0.02	0.01	0.01	0.013	0.009	0.008	0.014	0.002
<b>Total</b>	<b>1.68</b>	<b>1.49</b>	<b>1.48</b>	<b>1.69</b>	<b>1.71</b>	<b>1.676</b>	<b>1.671</b>	<b>1.677</b>	<b>1.595</b>	<b>1.558</b>

**Figure 10: GHG Emissions from Municipal Solid Waste (MMtCO<sub>2</sub>e)<sup>19</sup>**



<sup>17</sup> Totals may not equal the sum of subtotals shown in this table due to independent rounding.

<sup>18</sup> 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 2020 to 2021.

<sup>19</sup> Combustion of MSW emissions in 2021 were 0.002 MMtCO<sub>2</sub>e and are too small to appear on the chart due to scale differences.



## Uncertainty<sup>20</sup>

### *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<sub>2</sub> 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<sub>2</sub> emissions being slightly over-estimated (ICF 2022b).

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<sup>20</sup> This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2022b).

## 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<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). CH<sub>4</sub> is emitted from the treatment of wastewater, both industrial and municipal. CH<sub>4</sub> is produced when organic material is treated in an anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N<sub>2</sub>O 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<sub>2</sub>O is a complex function of biological, chemical, and physical factors, and emission rates depend on the specific conditions of the wastewater and the wastewater collection and treatment system. Human sewage makes up a significant portion of the raw material leading to N<sub>2</sub>O emissions (ICF 2022b).

### **Method**

#### *Municipal Wastewater*

GHG emissions from municipal wastewater are calculated in the SIT by multiplying a series of emission factors by the annual Iowa population, which was updated for 2021 (U.S. Census 2022). For example, to calculate CH<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> and N<sub>2</sub>O emissions, except that N<sub>2</sub>O was calculated using the most recent protein (kg/person-year) value (44.4) from Table 7-16 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* (EPA 2022b). Because the 2021 protein value was not available at the time of publication, the 2020 value was used as a surrogate for 2021.

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 2021, 40,002.91 metric tons of municipal wastewater sludge was applied to land to condition soil (DNR 2022). 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<sub>2</sub>O emissions. This value taken from the *1990 Census of Housing* and is lower than the SIT default value of 79%. The *2000 Census of Housing* and *2010 Census of Housing* do not include the Iowa fraction of 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<sub>2</sub>e 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<sub>2</sub>e or more (EPA 2022a). The number of ethanol facilities decreased from 2020 and the number of food processors did not change.

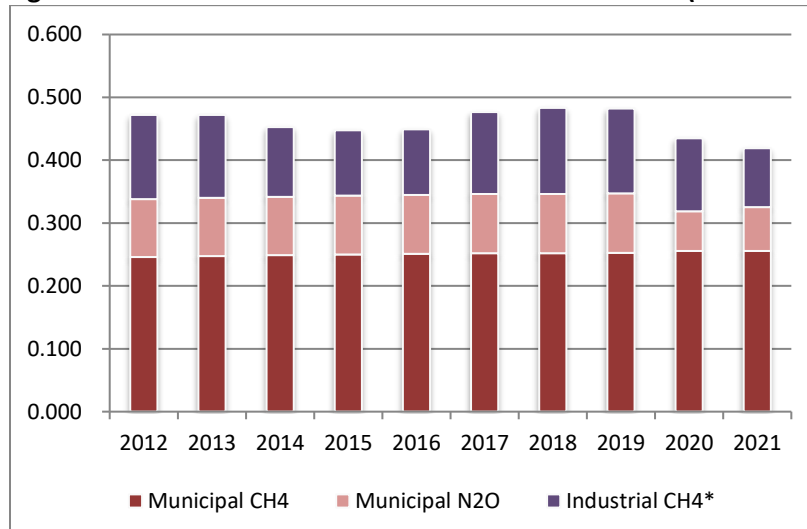
**Results**

Wastewater emissions account for 0.33% of the total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.419 MMtCO<sub>2</sub>e in 2021, a 3.56% decrease from 2020 and a 11.13% decrease from 2012 as shown in Table 22. 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<sub>4</sub> and N<sub>2</sub>O from municipal wastewater treatment accounted for 77.55% of total wastewater treatment GHG emissions as shown in Figure 11.

**Table 22: GHG Emissions from Wastewater (MMtCO<sub>2</sub>e)<sup>21</sup>**

Sector	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Municipal CH <sub>4</sub>	0.246	0.247	0.249	0.250	0.251	0.252	0.252	0.253	0.255	0.256
Municipal N <sub>2</sub> O	0.092	0.093	0.093	0.094	0.094	0.094	0.094	0.094	0.063	0.069
Industrial CH <sub>4</sub>	0.134	0.132	0.111	0.104	0.104	0.131	0.137	0.135	0.116	0.094
<b>Total</b>	<b>0.472</b>	<b>0.472</b>	<b>0.453</b>	<b>0.447</b>	<b>0.449</b>	<b>0.477</b>	<b>0.483</b>	<b>0.482</b>	<b>0.435</b>	<b>0.419</b>

**Figure 11: GHG Emissions from Wastewater Treatment (MMtCO<sub>2</sub>e)**



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

<sup>21</sup> 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.

## **Uncertainty**<sup>22</sup>

### *Municipal Wastewater*

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH<sub>4</sub> 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 lowa-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 2022a).

N<sub>2</sub>O 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 2022a).

### *Industrial Wastewater*

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 mtCO<sub>2</sub>e 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.

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<sup>22</sup> This information is largely excerpted from the *SIT Wastewater Module* (ICF 2022a).

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

This chapter addresses carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) emissions from liming of agricultural soils and fertilization of settlement soils,<sup>23</sup> 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<sub>2</sub> is also emitted from applying lime to agricultural soils and applying urea as a fertilizer. N<sub>2</sub>O is emitted when fertilizers are applied to settled soils such as landscaping, lawns, and golf courses. CH<sub>4</sub> and N<sub>2</sub>O are also emitted from forest fires (ICF 2022b).

### **Method**

#### *Forest Carbon Flux*

CO<sub>2</sub> 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 2022b). The new methodologies are consistent with those used by EPA in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2020* (EPA 2022) and produced substantially different results than the former method used prior to 2019. Because 2020 or 2021 forest carbon flux data is not available, 2019 was used as a proxy for 2021.

#### *Liming of Agricultural Soils*

CO<sub>2</sub> 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 (Hall 2022). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (IDOT) tracks general information for

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<sup>23</sup> Settled soils such as landscaping, lawns, and golf courses (ICF 2022b).

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*

2021 urea emissions were calculated using the amount of urea applied annually (IDALS 2021). 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 2022). The SIT extrapolates the 2011 – 2018 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 19% 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 2022b). N<sub>2</sub>O 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 2021 values were derived, please see *Chapter 2-Agriculture* of this report.

#### *Non-CO<sub>2</sub> Emissions from Forest Fires*

CH<sub>4</sub> and N<sub>2</sub>O 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 2021 (DNR 2022). 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 second 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 2022). 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 2022b). 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 -2020* (EPA 2022).

**Adjustments**

2020 emissions from urea fertilization were recalculated using fertilizer data from the 2021 Iowa Agricultural Statistics Bulletin (USDA 2021) as shown in Table 23. Previously 2019 fertilizer usage was used as a proxy for 2020.

**Table 23: Recalculated Emissions from Urea Fertilization (MMtCO<sub>2</sub>e)**

Pollutant	2020 Value (Published Dec. 2021)	2020 Updated Value
CO <sub>2</sub>	+0.08	+0.12

**Results**

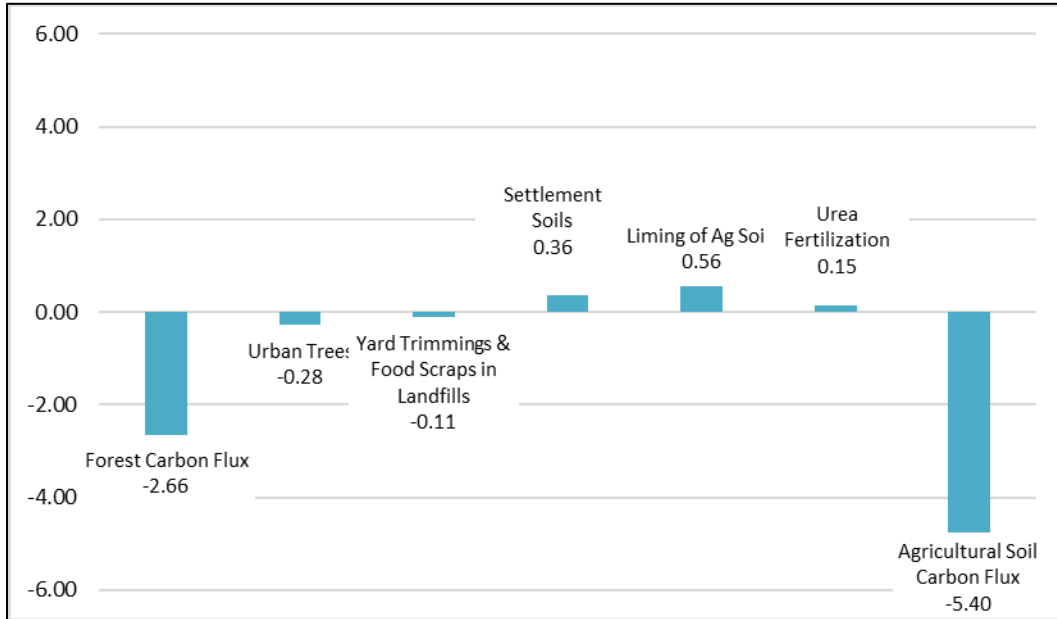
Overall, sources in the LULUCF sector stored slightly less carbon in 2021 than they stored in 2020, storing 7.39 MMtCO<sub>2</sub>e as shown in Table 24 and Figure 12. This is a decrease of 1.93% from 2020 and decrease of 42% from 2012. Emissions of CO<sub>2</sub> are shown above the x-axis in Figure 12 and carbon sinks are shown below the x-axis.

**Table 24: GHG Emissions and Sinks from LULUCF (MMtCO<sub>2</sub>e)<sup>24</sup>**

Sector	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Forest Carbon Flux	-2.58	-2.57	-2.56	-2.59	-2.61	-2.63	-2.66	-2.66	-2.66	-2.66
Liming of Ag Soils	+0.65	+0.47	+0.41	+0.34	+0.46	+0.45	+0.40	+0.28	+0.54	+0.56
Urea Fertilization	+0.13	+0.11	+0.15	+0.15	+0.19	+0.18	+0.13	+0.13	+0.12	+0.15
Urban Trees	-0.31	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34	-0.34	-0.34	-0.28
Yard Trimmings & Food Scraps Stored in Landfills	-0.12	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08	-0.10	-0.11
N <sub>2</sub> O from Settlement Soils	+0.57	+0.57	+0.52	+0.49	+0.51	+0.53	+0.48	+0.50	+0.31	+0.36
Agricultural Soil Carbon Flux	-10.98	-6.62	-4.53	-5.21	-7.88	-7.59	-6.65	-6.65	-5.40	-5.40
<b>Total</b>	<b>-12.64</b>	<b>-8.46</b>	<b>-6.44</b>	<b>-7.26</b>	<b>-9.77</b>	<b>-9.49</b>	<b>-8.72</b>	<b>-8.88</b>	<b>-7.54</b>	<b>-7.39</b>

<sup>24</sup> Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

**Figure 12: 2021 GHG Emissions and Sinks from LULUCF (MMtCO<sub>2</sub>e)**



### **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.



## Chapter 10 – Electricity Consumption

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

Electricity consumed by lowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2022b). 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 2022a).

#### *Residential, Commercial, and Industrial*

2021 emissions were calculated from the electricity consumption values reported by the EIA as “Annual sales to ultimate customers by state and sector” (EIA 2022a).

#### *Transportation*

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the Iowa Department of Transportation (IDOT 2022), 5,627 electric vehicles were registered in Iowa as of March 31, 2021. This is an increase of 9.26% from March 31, 2020, but is 0.12% of the total 4.59 million vehicles registered in the state in 2021 (IDOT 2022). 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**

2020 emissions have been recalculated since the DNR’s 2020 GHG Inventory Report was published in December 2021. The DNR previously forecasted 2020 emissions due to a lack of Iowa-specific energy consumption data. However, the 2020 energy data was released by EIA in June 2021 (EIA 2022b), so the DNR used the data to recalculate 2020 emissions as shown in Table 25 and Table 26.

**Table 25: Updated 2020 Activity Data**

<b>Category</b>	<b>2020 Value Published Dec. 2021</b>	<b>2020 Updated Value</b>
Electricity Consumption (kWh)		
Residential	13,874,569,244	14,567,483,000
Commercial	12,185,823,124	11,605,738,000
Industrial	22,810,023,265	24,466,641,000
<b>Total</b>	<b>48,892,303,133</b>	<b>50,661,749,500</b>

**Table 26: Recalculated Electricity Emissions (MMtCO<sub>2</sub>e)**

Category	2020 Value Published Dec. 2021	2020 Updated Value
Residential	7.08	6.00
Commercial	6.22	4.78
Industrial	11.64	10.07
Transportation	0.01	0.01
<b>Total</b>	<b>24.95</b>	<b>20.86</b>

**Results**

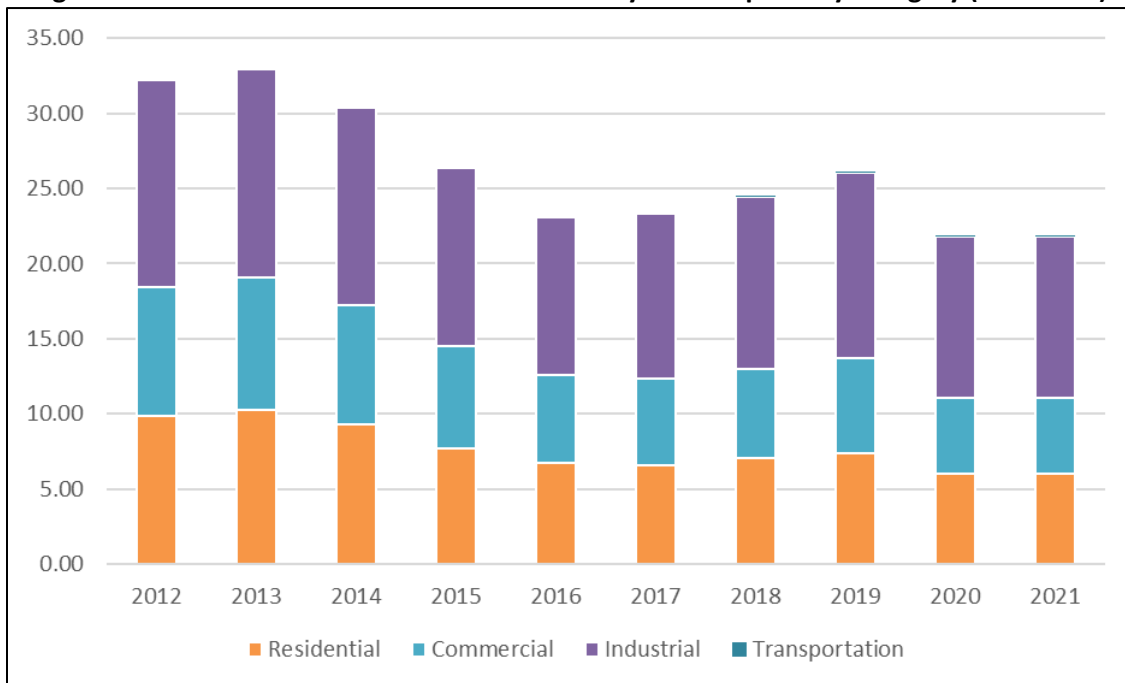
Indirect GHG emissions from electricity consumption were 21.79 MMtCO<sub>2</sub>e in 2021, increasing 4.45% since 2020, due to projected increases in electricity consumption in all categories (EIA 2021a) except transportation, as shown in Table 27 and Figure 13. Industrial users consumed the largest percentage of electricity, 49.33%, as shown in Figure 14.

**Table 27: GHG Emissions from Electricity Consumption (MMtCO<sub>2</sub>e)<sup>25</sup>**

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Residential	9.85	10.30	9.29	7.72	6.72	6.54	7.08	7.40	6.00	6.03
Commercial	8.60	8.77	7.64	6.76	5.86	5.79	5.92	6.28	4.78	5.00
Industrial	13.74	13.83	13.16	11.92	10.51	11.00	11.42	12.37	10.07	10.75
Transportation	* not calculated			0.00	0.00	0.00	0.01	0.01	0.01	0.01
<b>Total</b>	<b>32.19</b>	<b>32.90</b>	<b>30.39</b>	<b>26.41</b>	<b>23.09</b>	<b>23.32</b>	<b>24.43</b>	<b>26.05</b>	<b>20.86</b>	<b>21.79</b>

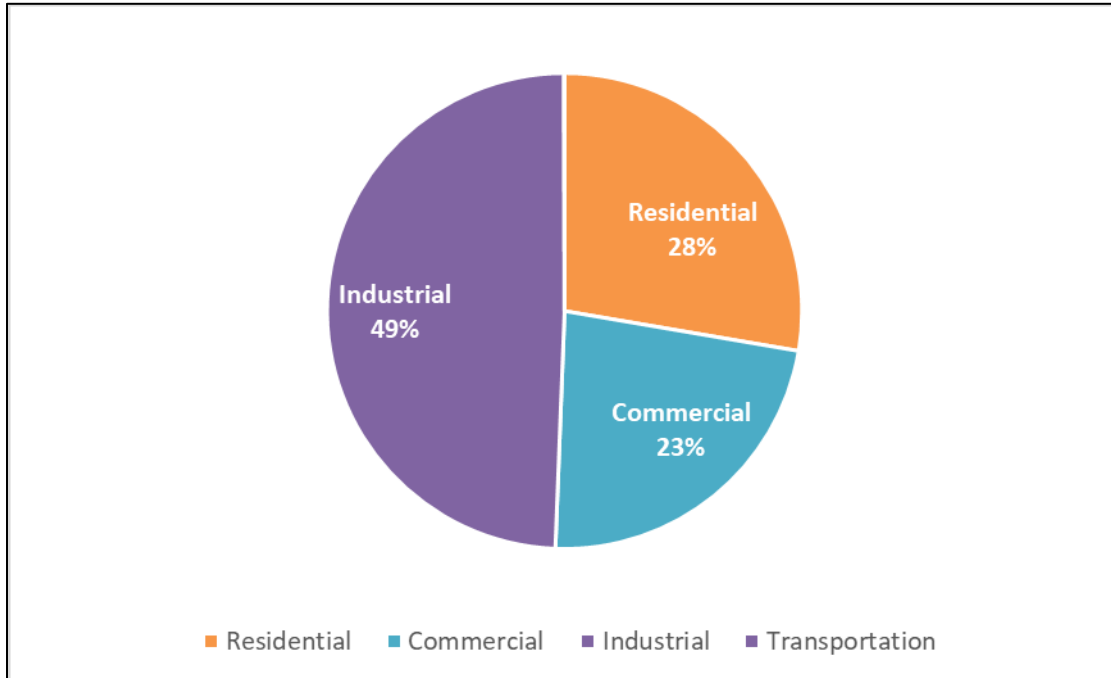
\* 2015 was the first time that DNR calculated indirect emissions from electricity consumption.

**Figure 13: Indirect GHG Emissions from Electricity Consumption by Category (MMtCO<sub>2</sub>e)**



<sup>25</sup> Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 14: Electricity Consumption by Category<sup>26</sup>



<sup>26</sup> 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). 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 -2021 (U.S. Census 2022) and the 2025, 2030, 2035, and 2040 projections from Woods & Poole Economics (Woods & Poole, 2009).

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 2021 to be consistent with the DNR's 2021 calculated GHG inventory, but this discrepancy is unavoidable. It would be preferable to forecast emissions using the DNR's 2021 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 2021 GHG inventory and projected emissions from the SIT Projection Tool for 2021, 2025, 2030, 2035, and 2040 for each category are shown in Table 28 (intervening year forecasts are available from the DNR upon request). The 2021 "forecast" was produced to help gauge the reasonableness of the projections. While the total projected emissions were within 2 MMtCO<sub>2</sub>e of the calculated value, actual calculated emissions in individual sectors such as agriculture, powerplants, and residential, commercial and industrial fuel use were more than 10% above or below the projected emissions.

**Table 28: Projected Gross GHG Emissions 2021 – 2040 (MMtCO<sub>2</sub>e)**

Sector	Calculated	Projected				
	2021	2021	2025	2030	2035	2040
Agriculture	36.03	44.66	50.16	55.84	61.50	65.74
Power Plants	24.27	21.21	18.10	18.63	18.13	18.37
RCI Fossil Fuel Use	34.45	30.43	31.12	31.56	31.85	32.64
Industrial Processes	7.21	7.17	8.30	9.56	10.49	11.42
Natural Gas T & D	1.47	1.54	1.59	1.59	1.59	1.59
Transportation	20.76	20.13	20.05	19.32	18.93	18.88
Waste	1.98	3.17	3.30	3.45	3.60	3.71
<b>Total</b>	<b>126.16</b>	<b>128.31</b>	<b>131.55</b>	<b>138.74</b>	<b>144.77</b>	<b>152.63</b>

### 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 three factors that may affect future GHG emissions:

#### 1. Macroeconomic Conditions

The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* (STEO) on November 8, 2022, predicting that "Uncertainty in macroeconomic conditions could significantly affect energy markets in the forecast period. Based on the S&P Global macroeconomic model, we now expect U.S. GDP will fall slightly in 2023, which we forecast will contribute to a drop in total U.S. energy

consumption next year.” (EIA 2022). It should be noted that the STEO addresses national emissions, not Iowa-specific emissions.

## 2. *Emissions from Power Plants*

Emissions from power plants may also be affected by the economy, weather, future environmental regulations, demand by customers, how electricity generation is dispatched by the grid operator electricity, and other market forces. Iowa power plants continue to shift away from burning coal to burning natural gas and installing renewable generation. Two Iowa electric utilities have publicly announced plans to retire their coal-fired electric generating units.

- Alliant Energy plans to eliminate all coal from its power generating system by 2040. Their sustainability plan includes goals to reduce CO<sub>2</sub> emissions by 50% in the next 10 years and reach net-zero CO<sub>2</sub> emissions by 2050. In 2022, Alliant Energy stopped burning coal in its Burlington Generating Station, switching to 100% natural gas (Niehaus 2022). It also plans to close its Lansing coal-fired power plant at the end of 2022 (Miller 2022).
- Muscatine Power and Water (MP&W) is planning to retire three coal-fired electric generating units and replace them with a natural-gas fired plant. Unit 7 (25.0 megawatts) and Unit 8A (75 megawatts) will retire before December 31, 2028 (Brewster 2022). The new natural-gas fired plant will start operating in 2028. MP&W will also install 30 megawatts of photovoltaic solar generation in 2023 (Kluver 2021).

### **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 or 2021 data.

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

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## Appendix A – Iowa GHG Emissions 2012 - 2021 by Sector<sup>27</sup>

Emissions (MMtCO <sub>2</sub> e)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Agriculture	36.78	35.77	36.39	39.00	39.49	41.71	38.60	37.85	<b>36.00</b>	36.03
Enteric Fermentation	8.40	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	8.11
Manure Management	10.86	10.85	11.06	11.07	10.96	11.75	8.20	8.62	<b>8.55</b>	8.28
Agricultural Soil Management	17.53	16.55	18.14	19.58	20.09	21.56	21.70	20.57	<b>18.91</b>	19.64
Fossil Fuel Combustion	65.72	65.88	66.26	61.00	54.78	58.67	62.94	61.64	<b>53.83</b>	58.72
Electric Generating Facilities	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57	17.07	24.27
Residential, Commercial, Industrial	29.96	32.82	32.82	31.54	29.45	32.05	32.07	37.07	<b>36.76</b>	34.45
Industrial Processes	5.18	5.07	5.12	5.09	5.34	7.10	7.40	7.38	7.55	7.21
Ammonia & Urea Production	0.85	0.88	0.86	0.81	0.92	2.60	3.26	3.14	3.37	2.88
Cement Manufacture	1.27	1.41	1.38	1.50	1.58	1.66	1.30	1.21	1.25	1.31
Electric Power Transmission and Distribution Systems	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.06	0.06
Iron and Steel Production	0.23	0.19	0.18	0.16	0.19	0.20	0.19	0.18	0.20	0.14
Lime Manufacture	0.18	0.16	0.17	0.13	0.15	0.18	0.16	0.17	0.18	0.16
Limestone and Dolomite Use	0.15	0.18	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.66	0.81
ODS Substitutes	1.47	1.39	1.42	1.45	1.47	1.47	1.47	1.61	1.62	1.62
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.02
LULUCF <sup>28</sup>	-12.64	-8.46	-6.44	-7.26	-9.77	-9.49	-8.72	-8.88	<b>-7.53</b>	-7.37
Forest Carbon Flux	-2.58	-2.57	-2.56	-2.59	-2.61	-2.63	-2.66	-2.66	-2.66	-2.66
Liming of Agricultural Soils	0.65	0.47	0.41	0.34	0.46	0.45	0.40	0.28	0.54	0.56
Urea Fertilization	0.13	0.11	0.15	0.15	0.19	0.18	0.13	0.08	<b>0.12</b>	0.15
Urban Trees	-0.31	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34	-0.34	-0.34	-0.28
Yard Trimmings and Food Scraps Stored in Landfills	-0.12	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08	<b>-0.10</b>	-0.09
Fertilization of Settlement Soils	0.57	0.57	0.52	0.49	0.51	0.53	0.48	0.50	<b>0.31</b>	0.36
Agriculture Soil Carbon Flux	-10.98	-6.62	-4.53	-5.21	-7.88	-7.59	-6.65	-6.65	<b>-5.40</b>	-5.40

<sup>27</sup> 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.

<sup>28</sup> Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

<b>Emissions (MMtCO<sub>2</sub>e)</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>
Natural Gas Transmission & Distribution	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42	1.42	1.47
Transmission	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.84
Distribution	0.62	0.61	0.62	0.61	0.62	0.48	0.62	0.63	0.64	0.63
Transportation	19.59	19.46	19.55	20.02	20.12	20.42	19.92	20.20	<b>18.81</b>	20.76
Waste	2.15	1.96	1.93	2.14	2.16	2.15	2.15	2.16	2.03	1.98
Solid Waste	1.68	1.49	1.48	1.69	1.71	1.68	1.67	1.68	1.60	1.56
Wastewater	0.47	0.47	0.45	0.45	0.45	0.48	0.48	0.48	0.44	0.42
Gross Emissions	130.82	129.55	131.67	128.65	123.30	131.32	132.42	130.64	<b>119.65</b>	126.16
Sinks	-12.64	-8.46	-6.44	-7.26	-9.77	-9.49	-8.72	-8.88	<b>-7.53</b>	-7.37
Net Emissions	118.18	121.09	125.23	121.39	113.53	121.83	123.70	121.76	<b>112.12</b>	118.80
% Change from Previous Year (Gross)		-0.98%	1.64%	-2.29%	-4.16%	6.51%	0.83%	-1.34%	<b>-8.41%</b>	5.44%
% Change from 2012 (Gross)		-0.98%	0.65%	-1.66%	-5.75%	0.38%	1.22%	-0.14%	<b>-8.54%</b>	-3.56%

## Appendix B – Iowa GHG Emissions 2012 - 2021 by Pollutant<sup>29</sup>

Emissions (MMtCO <sub>2</sub> e)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gross CO <sub>2</sub>	87.32	87.53	88.02	83.31	77.52	83.48	87.47	86.34	<b>77.36</b>	83.61
Net CO <sub>2</sub>	74.10	78.49	81.05	75.55	67.24	73.46	78.28	76.97	<b>69.52</b>	75.89
Stationary Fossil Fuel Combustion	65.30	65.47	65.85	60.64	54.51	58.35	62.58	61.31	53.56	58.39
Transportation	19.31	19.21	19.32	19.81	19.93	20.25	19.74	20.09	<b>18.56</b>	20.49
Industrial Processes	2.69	2.83	2.83	2.84	3.07	4.87	5.14	4.93	5.22	4.73
Solid Waste	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00
LULUCF <sup>30</sup>	-13.22	-9.03	-6.96	-7.76	-10.28	-10.02	-9.20	-9.37	<b>-7.84</b>	-7.73
CH <sub>4</sub>	21.72	21.50	20.93	21.88	21.80	22.45	19.36	19.73	<b>19.46</b>	18.84
Stationary Fossil Fuel Combustion	0.17	0.17	0.17	0.14	0.09	0.13	0.15	0.14	<b>0.13</b>	0.14
Transportation	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	<b>0.03</b>	0.03
Natural Gas and Oil Transmission and Distribution	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42	1.42	1.47
Enteric Fermentation	8.40	8.38	8.19	8.36	8.43	8.40	8.69	8.66	8.54	8.11
Manure Management	9.67	9.67	9.31	9.91	9.79	10.58	7.02	7.43	<b>7.40</b>	7.18
Solid Waste	1.66	1.48	1.46	1.68	1.70	1.66	1.66	1.67	1.58	1.56
Wastewater	0.38	0.38	0.36	0.35	0.36	0.38	0.39	0.39	0.37	0.35
N <sub>2</sub> O	20.83	19.65	21.20	22.46	22.98	24.39	24.53	23.40	<b>21.47</b>	22.40
Stationary Fossil Fuel Combustion	0.25	0.24	0.24	0.21	0.19	0.18	0.20	0.18	0.15	0.18
Transportation	0.24	0.21	0.19	0.18	0.16	0.14	0.14	0.09	<b>0.23</b>	0.24
Industrial Processes	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78	0.66	0.81
Manure Management	1.19	1.18	1.75	1.16	1.17	1.17	1.18	1.19	<b>1.16</b>	1.10
Agricultural Soil Management	17.53	16.55	18.14	19.58	20.09	21.56	21.70	20.57	<b>18.91</b>	19.64
N <sub>2</sub> O from Settlement Soils	0.57	0.57	0.52	0.49	0.51	0.53	0.48	0.50	<b>0.31</b>	0.36
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	0.09	0.06	0.07
HFC, PFC, and SF <sub>6</sub>	1.53	1.44	1.47	1.50	1.53	1.53	1.53	1.67	1.67	1.67
Industrial Processes	1.53	1.44	1.47	1.50	1.53	1.53	1.53	1.67	1.67	1.67
Gross Emissions	131.40	130.12	132.19	129.15	123.81	131.85	132.90	131.14	<b>119.96</b>	126.52
Sinks	-13.22	-9.03	-6.96	-7.76	-10.28	-10.02	-9.20	-9.37	<b>-7.84</b>	-7.73
Net Emissions (Sources and Sinks)	118.18	121.09	125.23	121.39	113.53	121.83	123.70	121.76	<b>112.12</b>	118.80

<sup>29</sup> 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.

<sup>30</sup> Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.