IOWA DEPARTMENT OF NATURAL RESOURCES

2017 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

December 27, 2018

Iowa Department of Natural Resources
502 E. 9th Street
Des Moines, IA 50319

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	basic oxygen furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CEMS	continuous emission monitoring system
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CPP	Clean Power Plan
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
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Agency
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
FTA	Federal Transit 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
LFGTE	landfill gas to energy
LULUCF	land use, land use change, and forestry

Acronyms and Key Terms (Continued)

MC	motorcycle
MMtC	million metric tons carbon
$MMtCO_2e$	million metric tons carbon dioxide equivalent
MISO	Midcontinent Independent System Operator
MSW	municipal solid waste
N	nitrogen
NAICS	North American Industry Classification System
NEI	National Emissions Inventory
NEMS	National Energy Modeling System
NMVOC	non-methane volatile organic compounds
NO_3-	nitrates
NO_2-	nitrites
NO_x	nitrogen oxides
N_2O	nitrous oxide
NRCS	Natural Resources and Conservation Service
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
RCI	residential, commercial, and industrial
SEDS	EIA's State Energy Data System
SF_6	sulfur hexafluoride
SIT	State Inventory Tool
T & D	transmission and distribution
TAR	Third Assessment Report
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 *2017 Iowa Statewide Greenhouse Gas Emissions Inventory Report*. Total Iowa GHG emissions from 2008 – 2017 are provided in Appendices A and B of this document. A state-specific inventory provides an in-depth analysis of emission trends and develops a baseline to track progress in reducing emissions.

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

Method

Emissions were calculated using the most recent version of the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT)[1] and using available Iowa-specific activity data. The energy and industrial processes sectors were also supplemented with GHG emissions data submitted by individual Iowa facilities to the federal GHG reporting program (40 CFR 98).

The calculation methods in the SIT are based on the August 2004 version of EPA's Emission Inventory Improvement Program (EIIP) guidance for greenhouse gases (ICF 2004). The individual modules for each sector are Excel workbooks populated with emission factors and default activity data for years 1990 – 2015, 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 auto-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 2030. 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	10/01/17	CH_4, N_2O
Energy	CO_2FFC	10/01/17	CO_2
	Stationary Combustion	10/01/17	CH_4, N_2O
Industrial Processes	IP	03/15/18	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission & Distribution	Natural Gas and Oil	10/01/17	CH_4
Transportation	Mobile Combustion	10/01/17	CO_2, CH_4, N_2O
Waste	Solid Waste	12/18/17	CO_2, CH_4
	Wastewater	10/01/17	CH_4, N_2O
Land Use, Land Use Change, and Forestry	LULUCF	10/01/17	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	03/08/18	CO_2
Future Emissions	Projection Tool	05/21/18	CO_2, CH_4, N_2O, HFC, PFC, SF_6

[1] The SIT may be requested at https://www.epa.gov/statelocalclimate/download-state-inventory-and-projection-tool.

Global Warming Potentials (GWP)

The potency of various greenhouse gases can vary, so greenhouse gas emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO_2e) that allows for better comparison of the impact of different greenhouse gases. CO_2e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting values. CO_2e was calculated using Equation 1.

Equation 1:

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

Where:

GHG_i = Mass emissions of each greenhouse gas

GWP_i = Global warming potential for each greenhouse gas

n = the number of greenhouse gases emitted

The DNR used the GWPs from the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) (IPCC 2007). The values used are shown in Table 2.

Table 2: Global Warming Potentials

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

Chapter 2 - Agriculture

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

GHG emissions are emitted from four agricultural sectors in Iowa – enteric fermentation, manure management, agricultural soils, and agricultural burning. The GHGs emitted are methane (CH_4) and nitrous oxide (N_2O). Table 3 summarizes the source of GHG emissions in each sector. N_2O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2018b).

Table 3: Sources of Agricultural GHG Emissions in Iowa

<table>
<tr><th colspan="2">Sector</th><th>GHGs Emitted</th><th>Source of Emissions</th></tr>
<tr><td colspan="2">Enteric Fermentation</td><td>CH_4</td><td>Microbial activity in the digestive systems of dairy cattle, beef cattle, sheep, goats, swine, and horses.</td></tr>
<tr><td colspan="2">Manure Management</td><td>CH_4, N_2O</td><td>Decomposition of manure during storage and treatment of livestock manure.</td></tr>
<tr><td rowspan="3">Agricultural Soils</td><td>Residues, legumes, and histosols</td><td>N_2O</td><td>Biological nitrogen fixation by crops, crop residues remaining on fields, and cultivation of high organic content soils (histosols).</td></tr>
<tr><td>Fertilizers</td><td>N_2O</td><td>Application of manure, fertilizers, etc. to soils and leaching/runoff of nitrogen into ground or surface water.</td></tr>
<tr><td>Animals</td><td>N_2O</td><td>Animal excretions directly on to soils such as pastures.</td></tr>
<tr><td colspan="2">Agricultural Burning</td><td>CH_4, N_2O</td><td>Burning of crop residues.</td></tr>
</table>

<u>Method</u>

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated October 1, 2017 (ICF 2017a and 2017b).

Enteric Fermentation

The SIT calculates CH_4 emissions from enteric fermentation by multiplying various livestock populations by an annual CH_4 emission factor (kilograms CH_4 per head). The data sources for the animal populations used are listed in Table 4. The number of "Feedlot Heifers" and "Feedlot Steers" was derived by applying a 35/65 heifer/steer ratio to the "Total Number on Feed."

Manure Management

This sector includes CH_4 and N_2O emissions from manure when it is being stored and treated in a manure management system. In general, CH_4 emissions increase in more anaerobic (lacking oxygen) conditions while N_2O emissions increase under aerobic conditions (Strait et al. 2008). The same dairy cattle, beef cattle, sheep, goat, horse, and swine populations were used as for the enteric fermentation sector for consistency. Several other animal types were added as shown in Table 4.

Table 4: Animal Population Data Sources

Animal Type	Year	Data Source
Dairy cattle	2017	2017 Iowa Agricultural Statistics Bulletin (USDA 2017)
Beef cattle		
Sheep		
Goats	2012 used as proxy for 2013 - 2017	USDA-NASS Quick Stats (USDA 2018b)
Horses		
Breeding swine	2017	2017 Iowa Agricultural Statistics Bulletin (USDA 2017)
Market swine under 60 lbs.[2]		
Market swine 60 – 119 lbs.[3]		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Chickens	2017	2017 Iowa Agricultural Statistics Bulletin (USDA 2017)
Hens		
Broilers	2012 used as proxy for 2013-2017	USDA-NASS Quick Stats (USDA 2018b)
Pullets		
Turkeys		

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 Residue Burning

Burning of cropland is not a typical agricultural practice in Iowa. According to Iowa State University Extension and Outreach,

> *"Burning corn and soybean fields is just NOT a practice that is used in Iowa or many other Midwest states as a way of preparing the fields for planting a subsequent crop. Yes, there are rare occasions were corn residue is burnt off a field but it would not even be 1% of the crop acres. An example would be if the residue washed and piled up in an area it may be burnt to allow tillage, planting and other practices to occur. Another rare occasion is when accidental field fires occur during harvesting of the corn crop. But again this would be less than 1% of the crop acres."* (Licht 2015).

The SIT over-estimates agricultural fires, as it assumes that 3% of Iowa corn, soybean, and wheat field residue is burned annually. The *Year 2000 Iowa Greenhouse Gas Emissions Inventory* notes that "According to expert opinion, even this lower estimate [3%] is thought to be too large in Iowa because burning is mostly a maintenance tool for conservation plantings, which are not extensive" (Wollin and Stigliani 2005). The DNR has been working with EPA emission inventory staff for several years to refine estimates for agricultural fires in the EPA's National Emissions Inventory (NEI) and the DNR's annual greenhouse gas inventories (DNR 2015, Pouliot 2015, and Stein 2015).

In 2015, DNR staff reviewed the details of 1,008 fires in 2014 that were reported to Iowa DNR by local fire departments (Kantak 2015) as shown in Table 5. Staff found that:

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

- 39 of the fires were truly agricultural fires, with 38 of 39 being fires being purposely set on grasslands enrolled in the Conservation Reserve Program, and one fire in a field of millet. No cornfield or soybean field fires were reported to DNR.
- 309 of the fires were identified as being prescribed fires (fires ignited by management actions to meet specific objectives): 166 on state land, 101 on private land, 37 on county land, and 5 on federal land.
- 660 of the fires were identified as being wildfires. Seven were accidental fires in cornfields that were started by overheated harvesting equipment. Several were wildfires that occurred when trash or brush burning spread out of control to a nearby field or ditch.

Table 5: Fires in 2014 Reported to Iowa DNR

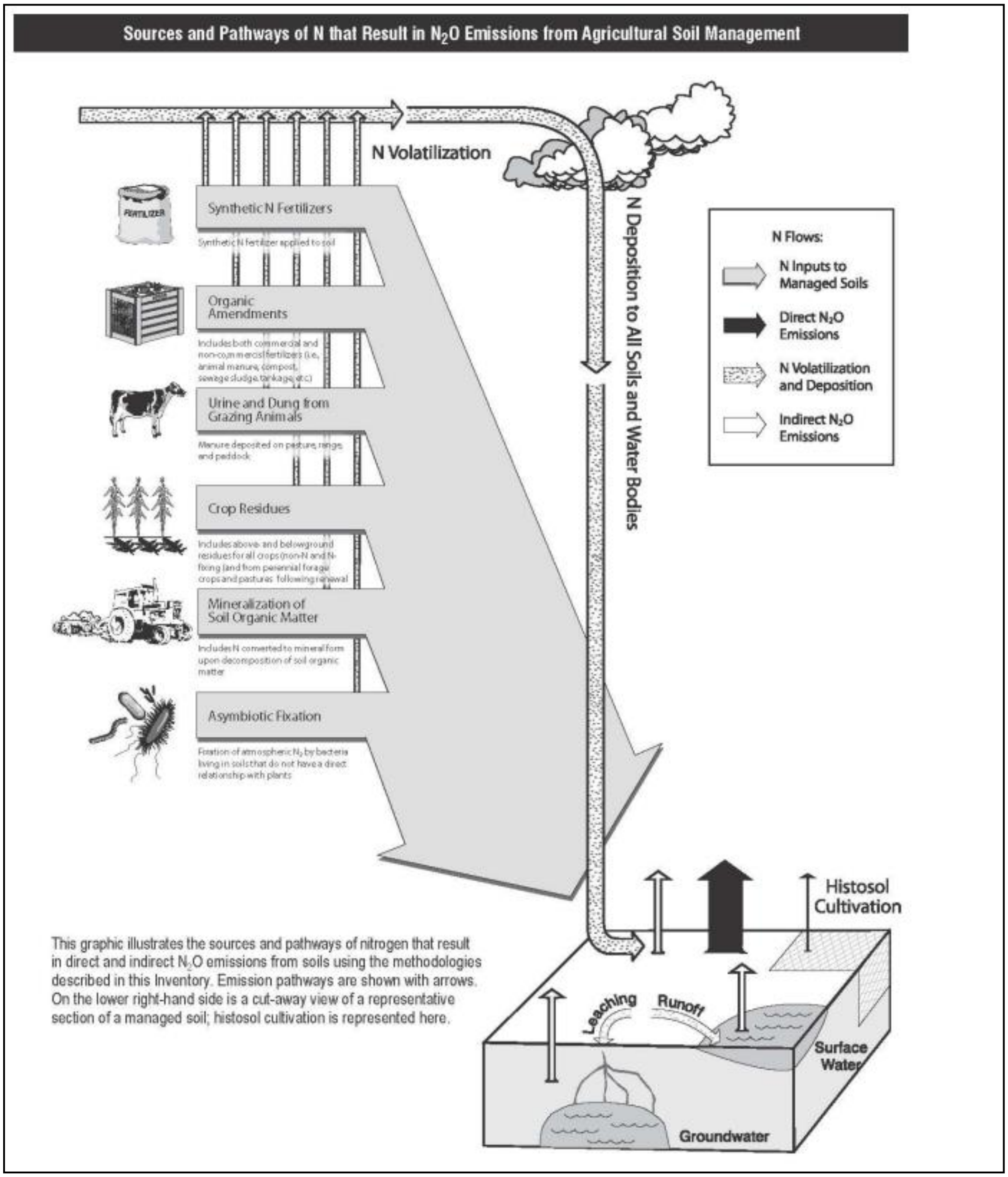
Type of Fire	No. of Fires in 2014 Reported to Iowa DNR	Total Acres Reported	Average Acres Burned
Agricultural Fires	39	1,981.4	50.8
Prescribed Fires	309	14,701.7	47.6
Wildfires	660	12,218.6	18.5
Total	**1,008**	**28,901.7**	**28.7**

There are several discrepancies between the pollutants EPA calculates for agricultural fires in the NEI (EPA 2015) and the SIT (ICF 2017a). EPA calculates carbon dioxide (CO_2) and methane (CH_4) emissions in the NEI, but calculates emissions from CH_4 and nitrous oxide (N_2O) in the SIT. In addition, the NEI calculates emissions from the burning of grasses and CRP lands, but the SIT only calculates emissions from crops. EPA calculates emissions from the burning of grass and pasture lands in the national GHG inventory, but not from crops (EPA 2016). Due to these discrepancies, emissions from agricultural residue burning were not included in this inventory. Resolving this discrepancy continues to be an area of future improvement in the inventory.

Agricultural Soils

N_2O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2016). N_2O is emitted when the natural processes of denitrification and nitrification interact with agricultural practices that add or release nitrogen (N) in the soil profile. Denitrification is the process of converting nitrate to nitrogen gas. It is carried out by microorganisms in an oxygen-lacking environment. Nitrification occurs when ammonia is converted to nitrites and nitrates by naturally occurring, specialized bacteria in the environment.

Figure 1: Sources and Pathways of N_2O Emissions in Ag Soils (EPA 2016)



Direct N_2O emissions occur at the site of application of both synthetic and organic fertilizers to the soil, production of N-fixing crops, and integration of crop residues into the soil by practices such as cultivation. Indirect emissions occur when N is made available or is transported to another location following volatilization, leaching or runoff, and is then converted to N_2O (EPA 2016).

Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2018b) were used to calculate N_2O from nitrogen-fixing crops, including alfalfa, soybeans, and rye. It was also used to calculate the quantity of nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans.

Soil Cultivation - Nitrous Oxide (N_2O)

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently available (Bedmarek 2012), so the DNR estimated the number of cultivated histosols acres by multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2018b) 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).

Soil Tillage Practices

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. This balance between emissions and sequestration is called the soil carbon flux. In the past, the SIT did not include the ability to calculate emissions from soil carbon flux from tillage practices. Although this feature was added in 2018, the DNR has not had sufficient time to evaluate its methods and use. If resources allow, it may be used in future GHG inventories.

Practicing no-till for many consecutive years produces the greatest carbon sequestration. When soil is tilled, the soil becomes oxygenated, increasing microbial activity and releasing stored carbon. However, the amount of carbon stored and released is uncertain. Scientific studies and literature reviews, such as those by Baker et al. (2007), Blanco-Canqui, and Lal (2008), have created uncertainty in this area, while other studies such as those by Franzluebbers (2009) and Boddey et al (2009) dispute them. According to the USDA's "*'No-Till" Farming is a Growing Practice",* there is much uncertainty in the interaction between tillage practices, carbon, and other greenhouse gases" (USDA 2010). A 2007 study by West and Six explains that, "*The extent to which soil C accumulation occurs after a reduction in tillage intensity is determined by the history of land management, soil attributes, regional climate, and current carbon stocks"* (West and Six 2007). The relationship between tillage and nitrogen oxides (N_2O) is also not completely certain. Several studies have observed increases, decreases, and no change in N_2O when soil is tilled (USDA 2010).

The complexity of calculating soil carbon flux is described in USDA's *Science-Based Methods for Entity-Scale Quantification of Greenhouse Gas Sources and Sinks from Agriculture and Forestry Practices*. This 605-page document was developed to create "a standard set of GHG estimation methods for use by USDA, landowners, and other stakeholders to assist them in evaluating the GHG impacts of their management decisions" (Eve 2014). It recommends that soil organic carbon stocks be calculated by modeling with the DAYCENT model. At this time, the DNR does not have the required data inputs or the capability to run the DAYCENT model.

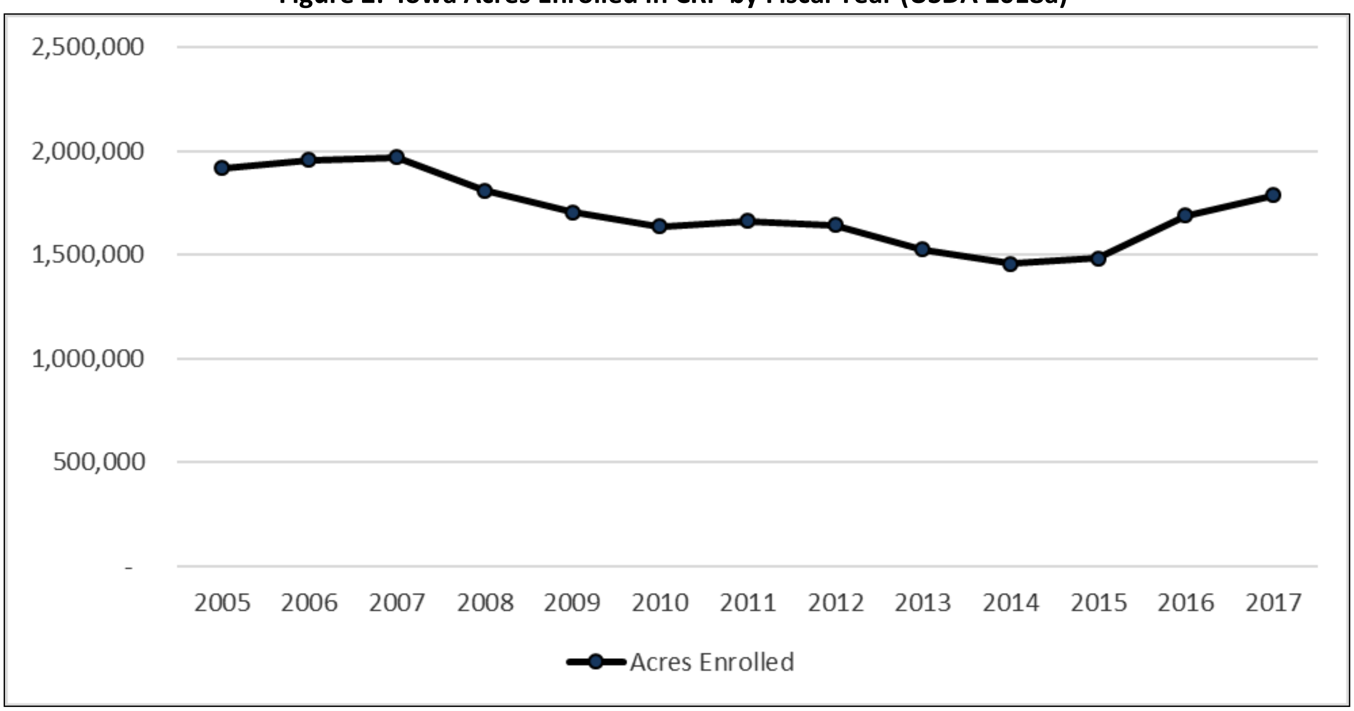
The USDA has also established seven regional climate change offices, offering climate hazard and adaptation data and services to farmers, ranchers, and forest landowners. The NRCS, a department within the USDA, has also launched a program called Carbon Management and Evaluation Online Tool (COMET-FARM) that allows users to calculate how much carbon is removed from the atmosphere from certain conservation efforts. The COMET-FARM website explains that:

> *The tool guides you through describing your farm and ranch management practices including alternative future management scenarios. Once complete, a report is generated comparing the carbon changes and greenhouse gas emissions between your current management practices and future scenarios (NRCS 2015).*

COMENT-FARM is not designed to calculate statewide greenhouse gas emissions from farming and ranching. It requires specific data inputs for each individual farm. However, if NRCS should publish results from the tool in the future, the DNR may include them in future inventory reports.

While the DNR is unable to quantify the statewide total agricultural soil carbon flux at this time, it may correlate with the cumulative Iowa acres enrolled in the CRP program shown in Figure 2. However, effects from cover crops may alter the relationship, but were not considered. This may be a future inventory improvement project.

Figure 2: Iowa Acres Enrolled in CRP by Fiscal Year (USDA 2018a)



<u>Fertilizer Utilization</u>

The DNR calculated fertilizer emissions for 2017 using fertilizer tonnages from the Iowa Department of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* report (IDALS 2017). The IDALS fertilizer data is provided per the 2017 growing season, which is from July 2016 – June 2017. The 2017 growing season was then used as a proxy for the 2018 growing season (July 2017 – June 2018) and first half of the 2019 growing season (July 2018 – December 2018).

Adjustments
Since the DNR's 2016 GHG Inventory Report was published in December 2017, the 2012 - 2016 emissions from enteric fermentation, manure management, and agricultural soils have been updated using revised activity data (such as animal populations or fertilizer application) from USDA or IDALS and revised emission factors from EPA (ICF 2017a). Specifically, annual chicken and hen populations (USDA 2017) were used instead of using the 2012 Census of Agriculture populations as a proxy for the 2012 – 2016 populations. The amount of synthetic fertilizers used to calculate agricultural soil emissions was reduced by 10% for 2012 – 2016 because it is assumed that 10% of the synthetic fertilizers are applied to settlement soils (landscaping, lawns, golf courses etc.). In previous inventories, the settlement emissions were double-counted. Refer to *Chapter 2 – Land Use, Land Use Change, and Forestry (LULUCF)* for more information on settlement soils.

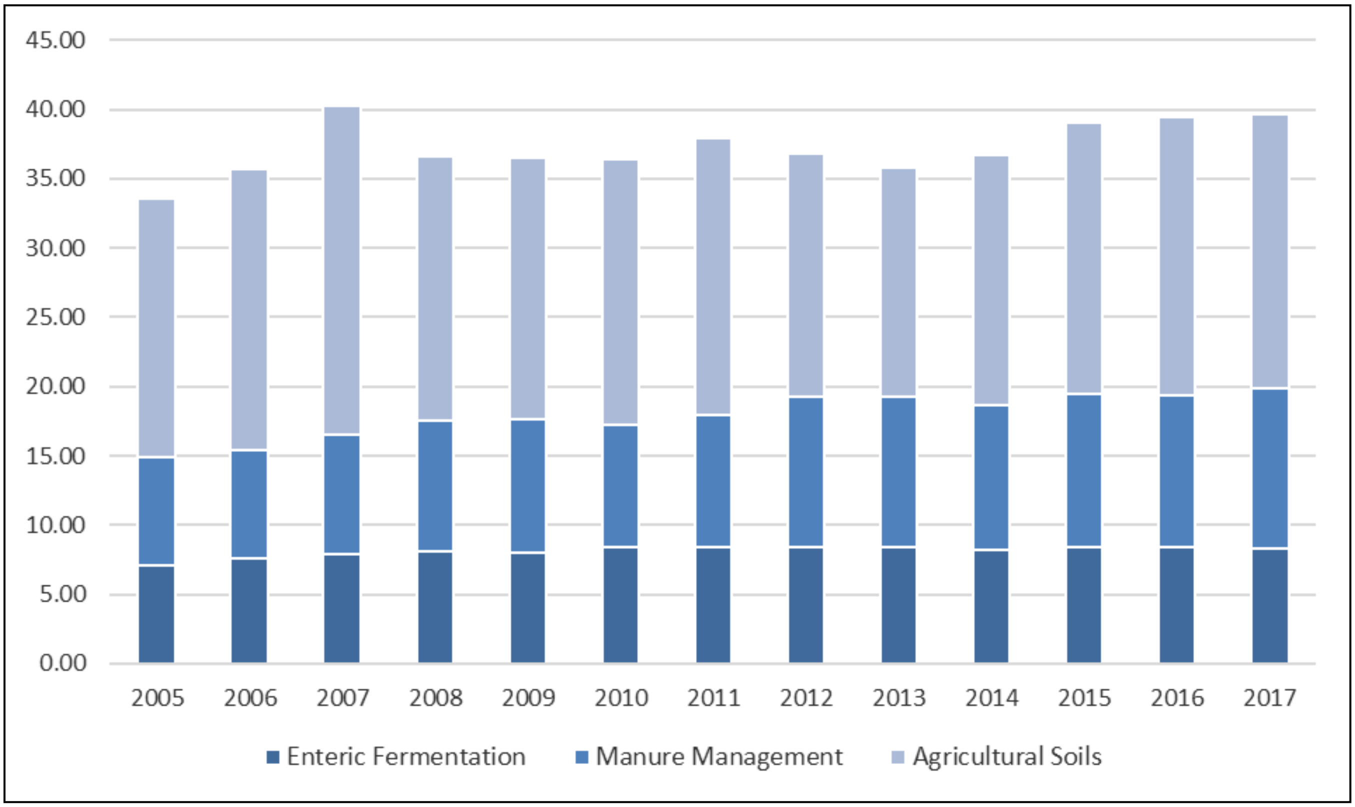
Results
GHG emissions from agriculture increased 0.32% from 2016 – 2017 and 8.08% from 2008 – 2017. Gross GHG emissions from agriculture were 39.71 MMtCO_2e in 2017, or 30.23% of Iowa's total gross GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. Nearly half of the agricultural emissions (49.74%) are from soils as shown in Table 6 and Figure 3.

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

Category	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Enteric Fermentation	8.05	8.02	8.39	8.41	8.40	8.38	8.19	8.36	8.43	8.33
Manure Management	9.52	9.59	8.83	9.53	10.86	10.85	10.42	11.07	10.96	11.58
Agricultural Soils	19.07	18.87	19.16	19.98	17.53	16.55	18.14	19.58	20.09	19.71
Total	**36.65**	**36.48**	**36.38**	**37.91**	**36.78**	**35.77**	**36.75**	**39.00**	**39.49**	**39.61**

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

Figure 3: Gross GHG Emissions from Agriculture ($MMtCO_2e$)



Enteric Fermentation

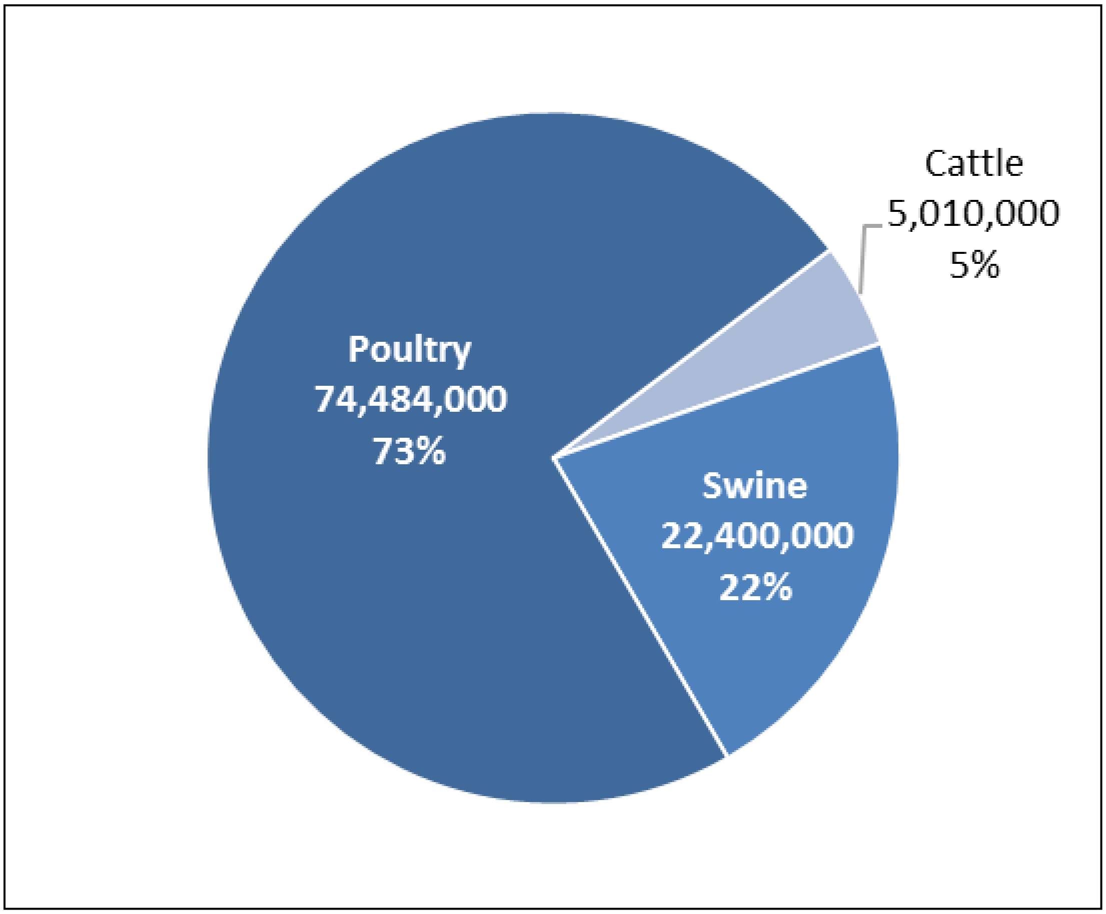
CH_4 emissions from enteric fermentation were 8.33 $MMtCO_2e$ in 2017, decreasing 1.22% from 2016. This can be attributed to a 3.28% decrease in the total cattle population even though the total swine population increased 7.18% and the total poultry population increased 0.36%. No change was assumed in the horse, goat, and sheep population.

While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 4, enteric fermentation emissions are primarily driven by cattle. This is because cattle emit more CH_4 than other ruminant animals due to their unique stomach. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 7.

Table 7: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2017a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.2 – 139.7
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Figure 4: 2017 Iowa Animal Populations (USDA 2017, 2018b)[5]



Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 5.64% from 2016 and accounted for 28.93% of agricultural GHG emissions in 2017. The increase in emissions in 2017 can be linked to increases of 1,500,000 swine and 269,000 poultry produced in 2017 (USDA 2017 and USDA 2018b).

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 5. While several different crops are produced in Iowa, corn is the most prevalent as shown in Table 8. N_2O emissions from agricultural soils decreased 1.93% from the previous year. N_2O emissions from agricultural soils accounted for 49.74% of all agricultural GHG emissions and 15.04% of total statewide GHG emissions in 2017.

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

Figure 5: 2016 - 2017 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)

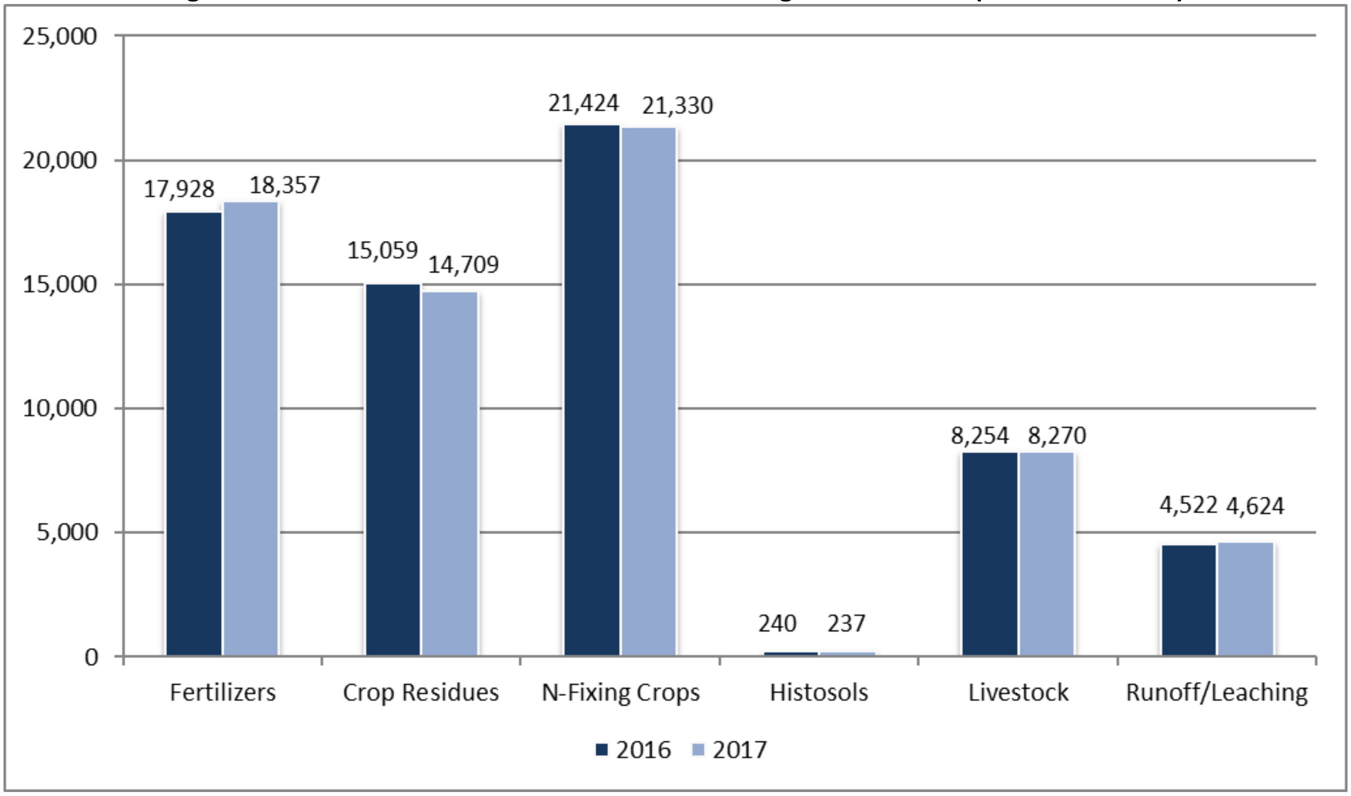


Table 8: Iowa Crop Production 2016 – 2017 (USDA 2017b)

Crop	2016 (1000 Bushels)	2017 (1000 Bushels)
Barley	85	85
Corn for Grain	2,740,500	2,605,800
Oats	3,268	3,234
Rye	46	46
Sorghum for Grain	59	59
Soybeans	566,400	561,610
Wheat	1,071	544
Total	**3,311,239**	**3,171,188**
Crop	**2016 (1000 tons)**	**2017 (1000 tons)**
Alfalfa	2,310	2,520

Uncertainty[6]

Enteric Fermentation

The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the quality of the animal population estimates and the emission factors used for each animal type. Uncertainty is also introduced as animal populations are not constant, but vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. The emission factors for a given animal type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2017a).

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[6] This information is largely excerpted from the *SIT Agriculture Module* (ICF 2017a).

Manure Management

As with enteric fermentation, uncertainty occurs in animal populations and the emission factors used for each animal. However, the largest contributor to uncertainty in manure management emissions in the SIT is the lack of Iowa-specific data describing manure management systems and the CH_4 and N_2O emission factors used for these systems. In addition, there is uncertainty in the maximum CH_4 producing potential (B_0) used for each animal group. This value varies with both animal and diet characteristics, so estimating an average across an entire population introduces uncertainty. While the B_0 values used in the SIT vary by animal subcategory to attempt to represent as many of these differences as possible, there is not sufficient data available at this time to estimate precise values that accurately portray the B_0 for all animal types and feeding circumstances (ICF 2004).

Agricultural Soils

The N_2O emissions from managed soils is dependent on a large number of variables other than N inputs. They include soil moisture, pH, soil temperature, organic carbon availability, oxygen partial pressure, and soil amendment practices. The effect of the combined interaction of these variables on N_2O flux is complex and highly uncertain. The methodology used in the SIT is based only on N inputs, does not include other variables, and treats all soils, except histosols, equally. In addition, there is limited knowledge regarding N_2O productions from soils when N is added to soils. It is not possible to develop emission factors for all possible combinations of soil, climate, and management conditions.

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

Uncertainties in the estimation method for agricultural residue burning are noted above under the “Method” heading.

Chapter 3 – Fossil Fuel Consumption

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

Method

Residential, Commercial, Industrial (RCI)

GHG emissions were calculated using two SIT modules – the CO_2FFC module for carbon dioxide (CO_2) emissions and the Stationary Combustion module for CH_4 and N_2O emissions (ICF 2017a-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

Iowa-specific 2017 energy consumption data will not be published by the U.S. Energy Information Administration until June 2019, so the DNR projected 2017 energy consumption. This was done by using the EIA's *Annual Energy Outlook (AEO) 2018 with Projections to 2050* (EIA 2018a) and 2016 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2018b). The AEO2018 includes several different projection cases, each addressing different uncertainties. The DNR used the AEO2018 "Reference Case," which models projections of what may happen given certain assumptions and methodologies. The AEO uses the

National Energy Modeling System (NEMS), which has the objective to show various interactions of economic changes and energy supply, demand, and prices (EIA 2018a). The projections in the Reference Case are done at the regional level, and Iowa is in the West North Central U.S. Census Region. The 2017 energy consumption was estimated for each fuel type using one of two methods as described below and shown in Table 10:

Fuel Method 1

The percent change in the regional consumption of each fuel type in the AEO2018 was calculated. The percent change was then applied to the Iowa 2016 fuel consumption in SEDS. This method was used for the fuel types listed in Table 10.

Fuel Method 2

These sectors were not included in the AEO Reference Case, so it was assumed that 2017 fuel consumption was equal to the 2016 fuel consumption. This method was used for the fuel types listed in Table 10.

Table 10: Method Used to Estimate 2017 Fuel Consumption

Fuel Type	Estimation Method
Commercial Distillate Fuel Oil	Method 1
Commercial Kerosene	Method 1
Commercial LPG	Method 1
Commercial Motor Gasoline	Method 1
Commercial Natural Gas	Method 1
Industrial Coal	Method 1
Industrial Distillate Fuel Oil	Method 1
Industrial LPG	Method 1
Industrial Motor Gasoline	Method 1
Industrial Natural Gas	Method 1
Industrial Other Coal	Method 1
Residential Distillate Fuel	Method 1
Residential LPG	Method 1
Residential Natural Gas	Method 1
Commercial Coal	Method 1
Commercial Residual Fuel	Method 2
Commercial Wood	Method 2
Industrial Asphalt and Road Oil	Method 2
Industrial Aviation Gasoline Blending Components	Method 2
Industrial Coking Coal	Method 2
Industrial Crude Oil	Method 2
Industrial Feedstocks, Naphtha less than 401 F	Method 2
Industrial Feedstocks, Other Oils greater than 401 F	Method 2
Industrial Kerosene	Method 2
Industrial Lubricants	Method 2
Industrial Misc. Petro Products	Method 2
Industrial Motor Gasoline Blending Components	Method 2
Industrial Pentanes Plus	Method 2
Industrial Petroleum Coke	Method 2
Industrial Residual Fuel	Method 2
Industrial Special Naphthas	Method 2

Fuel Type	Estimation Method
Industrial Still Gas	Method 2
Industrial Unfinished Oils	Method 2
Industrial Waxes	Method 2
Industrial Wood	Method 2
Residential Coal	Method 2
Residential Kerosene	Method 2
Residential Wood	Method 2

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 2018) or EPA's federal GHG Reporting Program (EPA 2018) were used as follows:

2005 – 2009
CO_2 emissions reported to EPA by individual facilities subject to CAMD's reporting requirements (generally speaking, those power plants that serve a generator with a nameplate capacity greater than 25 megawatts and sell at least one-third of their electricity to the grid) were used. This data is more accurate than the values from EIA because the CO_2 emissions reported by facilities to CAMD are actual measured emissions values from continuous emission monitoring systems (CEMS) located on electric generating units.

2010 - 2017
Power plants became subject to the federal GHG reporting program starting with calendar year 2010. Facilities are required to report CO_2, CH_4, and N_2O emissions. This CO_2 data is also from CEMS and is more accurate than EIA data. In addition, the CH_4 and N_2O emissions are calculated using facility-specific fuel heating values. The CO_2 data reported to the federal GHG reporting program is consistent with the CO_2 emissions reported by the same facilities to CAMD.

Adjustments
The DNR previously forecasted 2017 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2017 energy data was released by EIA in June 2018 (EIA 2018b), so the DNR used the data to recalculate 2016 emissions as shown in Table 11.

Table 11: Recalculated RCI Emissions ($MMtCO_2e$)

Category	2016 Value (Published Dec. 2017)	2016 Updated Value
Residential	4.55	4.43
Commercial	4.76	3.74
Industrial	22.59	21.14
Total	**29.45**	**29.32**

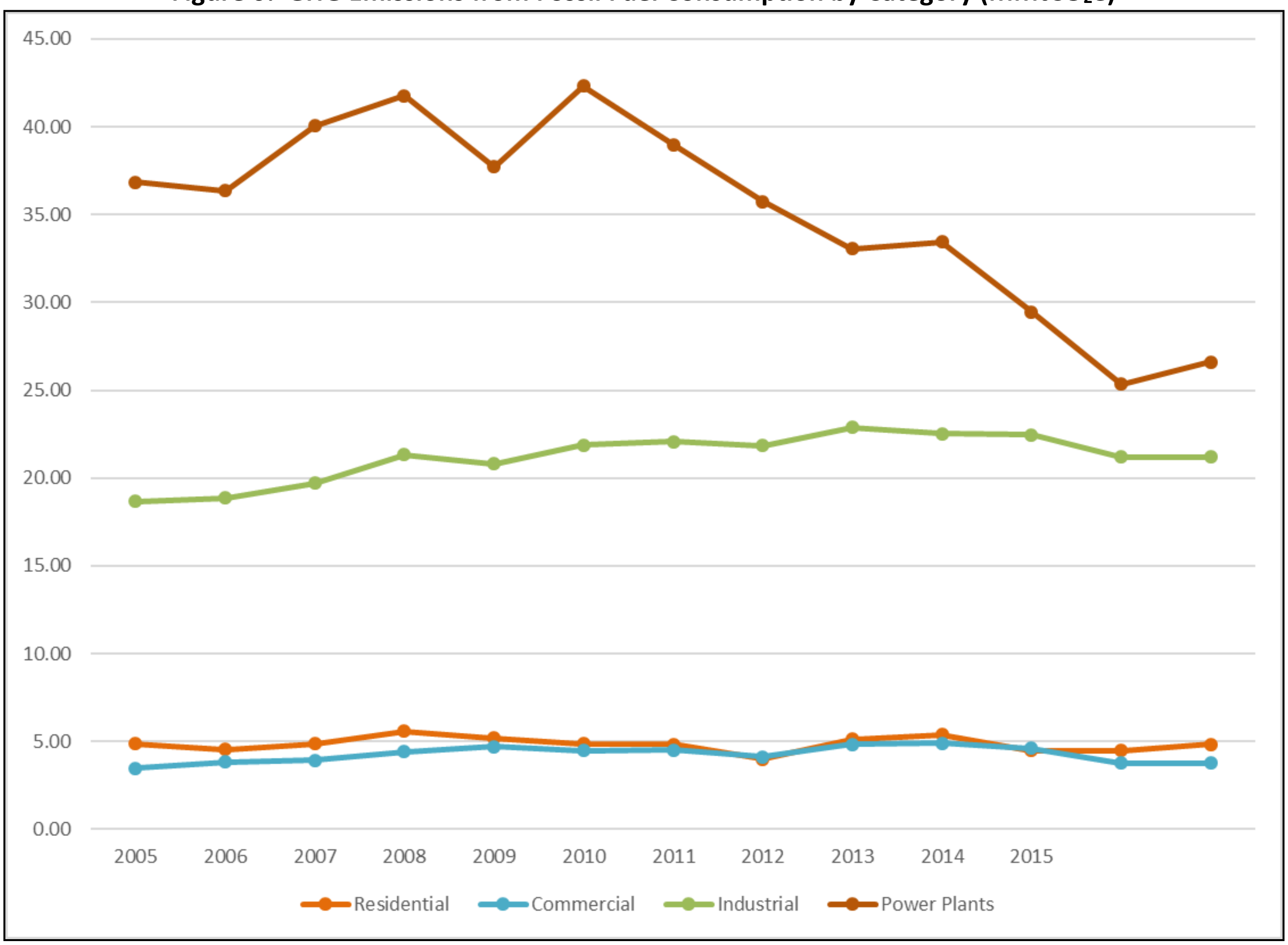
Results
Total GHG emissions from fossil fuel consumption in 2017 was 56.43 $MMtCO_2e$, an increase of 3.01% from 2016 and a decrease of 22.82% from 2008 levels as shown in Table 12 and Figure 6. Emissions from three categories (residential, commercial, and power plants) increased due to increased consumption of fossil fuels, while emissions from the industrial category held steady:

- residential fuel use emissions increased 8.14%
- commercial fuel use emissions increased 0.02%
- industrial fuel use emissions did not increase or decrease
- power plant emissions increased 5.02%

Table 12: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)[7]

Category	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Residential	5.58	5.21	4.88	4.85	4.01	5.12	5.38	4.49	4.48	4.84
Commercial	4.42	4.70	4.48	4.52	4.11	4.83	4.92	4.60	3.77	3.77
Industrial	21.34	20.82	21.88	22.07	21.84	22.87	22.52	22.44	21.21	21.21
Power Plants	41.78	37.71	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62
Total	**73.12**	**68.44**	**73.56**	**70.42**	**65.72**	**65.89**	**66.26**	**61.00**	**54.78**	**56.43**

Figure 6: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)



Despite the increase in 2017 of the amount of electricity generated from zero-emitting sources, such as wind and solar, emissions from fossil-fuel fired power plants increased 5.02%. This may be due to several factors:

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

- more efficient power plants operated more hours
- a new natural-gas fired power plant did not start up until mid-2016, but operated all of 2017, leading to higher emissions in 2017 than 2016
- differences in how electricity generation was dispatched by the Midcontinent Independent System Operator (MISO) in 2017 compared to 2016
- differences in temperatures and wind conditions in 2017 compared to 2016
- increased electricity demand by customers
- other market forces and factors

CO_2 Uncertainty[8]

The amount of CO_2 emitted from energy consumption depends on the type and amount of fuel that is consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Therefore, the more accurate these parameters are, the more accurate the estimate of direct CO_2 emissions will be. 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 takes into account the variability of carbon contents of coal by state; these coefficients are also provided in the SIT.

Uncertainty is also introduced by the complexity in calculating emissions from the import/export of electricity. The precise fuel mix used to generate the power crossing state lines is very difficult to determine, so, an average fuel mix for all electricity generation within a specific region of the grid must usually be used. Moreover, these emissions factors are generated by emission monitors (rather than carbon contents of fuels), which may overestimate CO_2 emissions to a small extent.

CH_4 and N_2O Uncertainty[9]

The amount of CH_4 and N_2O emitted depends on the amount and type of fuel used, the type of technology in which it is combusted (e.g., boilers, water heaters, furnaces), and the type of emission control used. In general, uncertainty is improved by using more detailed combustion activity information. However, as noted in the Revised 1996 IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997), the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain.

Uncertainties also exist in both the emission factors and the EIA energy consumption data used to calculate emissions. For example, the EIA state-specific datasets do not fully capture the wood used in fireplaces, wood stoves, and campfires. As with CO_2, uncertainty is also introduced with allocating energy consumption data to the individual end-use sectors and estimation of the fraction of fuels used for non-energy.

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[8] This information is largely excerpted from the *SIT CO_2FFC Module* (ICF 2017a).

[9] This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2017b).

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 13. Emissions from these industries do not include emissions from fossil fuel combustion, which are included in *Chapter 3 – Fossil Fuel Combustion.*

Table 13: Industrial Processes and GHG Emissions

Category	GHGs Emitted
Ammonia Production & Urea Consumption	CO_2
Cement Production	CO_2
Electric Power Transmission & Distribution	SF_6
Iron and Steel Production	CO_2
Lime Manufacture	CO_2
Limestone and Dolomite Use	CO_2
Nitric Acid Production	N_2O
Ozone Depleting Substances (ODS) Substitutes	HFCs, PFCs, and SF_6
Semiconductor Manufacturing	HFCs, PFCs, and SF_6
Soda Ash Use	CO_2

Ammonia Production and Urea Consumption

CO_2 is released during the manufacture of ammonia. The chemical equations to calculate the release of CO_2 are complex, but in general, anhydrous ammonia is synthesized by reacting nitrogen with hydrogen. The hydrogen is typically acquired from natural gas. The majority of direct CO_2 emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO_2. Other emissions of CO_2 can occur during condensate stripping or regeneration of the scrubbing solution. CO_2 emissions may also be captured for use in urea synthesis or carbon sequestration and storage (WRI 2008). Three facilities in Iowa currently produce ammonia.

Cement Production

Carbon Dioxide (CO_2) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO_2. The CO_2 is vented to the atmosphere and the lime is then mixed with silica-containing materials such as clay to form clinker, an intermediate product that is made into finished Portland cement (ICF 2004). Two facilities in Iowa currently produce Portland cement.

Electric Power Transmission and Distribution

Sulfur hexafluoride (SF_6) is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2018b).

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 2016). There are currently no pig iron mills operating in Iowa. All three steel production facilities currently operating in Iowa use EAFs to produce steel from scrap. These furnaces use carbon electrodes, coal, natural gas, and other substances such as limestone and dolomite to aid in melting scrap and other metals, which are then improved to create the preferred grade of steel. In EAFs,

CO_2 emissions result primarily from the consumption of carbon electrodes and from the consumption of supplemental materials used to augment the melting process (EPA 2016).

Lime Manufacture

Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO_2. The CO_2 is typically released to the atmosphere, leaving behind a product known as quicklime, which can then be used to produce other types of lime (ICF 2004). One facility currently manufactures lime in Iowa.

Limestone and Dolomite Use

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

Nitric Acid Production

Nitrous Oxide (N_2O) is produced when ammonia is oxidized to produce nitric acid. Two facilities in Iowa currently produce nitric acid.

Consumption of ODS Substitutes

Ozone Depleting Substances (ODS) are often used in refrigeration, air conditioning, aerosols, solvent cleaning, fire extinguishers, etc. However, ODS are being phased out per the Montreal Protocol and the 1990 Clean Air Act Amendments. The most common ODS are HFCs, but PFCs and SF_6 may also be used (ICF 2018b).

Semiconductor Manufacturing

The DNR has added emissions from semiconductor manufacturing to the inventory for the first time this year. It was previously assumed that semiconductors were not manufactured in Iowa. However, the 2012 Economic Census identifies seventeen businesses in Iowa under the North American Industry Classification System (NAICS) for code 33441 – Semiconductor and Other Electronic Manufacturing (U.S. Census 2018b).

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 2018b). 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 2017 emissions from industrial processes were calculated using either the SIT (ICF 2018a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2018a) as shown in Table 14.

Table 14: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2017	40 CFR 98 Subpart G	GHGRP (EPA 2018a)
Cement Production	2017	40 CFR 98 Subpart H	GHGRP (EPA 2018a)
Electric Power Transmission & Distribution	2016 as proxy for 2017	SIT	National GHG Inventory (EPA 2018b)
Iron and Steel Production	2017	40 CFR 98 Subpart Q	GHGRP (EPA 2018a)
Lime Manufacture	2017	40 CFR 98 Subpart S	GHGRP (EPA 2018a)
Limestone and Dolomite Use	2015 as proxy for 2016 & 2017	SIT	USGS 2017
Nitric Acid Production	2017	40 CFR 98 Subpart V	GHGRP (EPA 2018a)
ODS Substitutes	2015 as proxy for 2016 & 2017	SIT	SIT default value
Semiconductor Manufacturing	2016 as proxy for 2017	SIT	National GHG Inventory (EPA 2018a)
Soda Ash Use	2017	SIT	(USGS 2018)

Categories Calculated using the SIT

Because current emissions data was not available for the electric power transmission and distribution, the 2016 emissions were used as a proxy for 2017. The 2016 value was calculated by determining the ratio between 2016 Iowa retail sales to 2016 national retail sales (EIA 2018), and applying that ratio to 2016 national emissions of SF_6.

Emissions in 2015 from the use of limestone and dolomite in industrial processes were used as a proxy for 2016 and 2017 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 2015 from ODS substitutes and soda ash consumption were used as proxy for 2016 and 2017. The 2015 values were calculated by assuming that Iowa emissions were 0.97% of national emissions because Iowa's population is 0.97% of the total U.S. Population (U.S. Census 2018b).

Emissions in 2016 from semiconductor manufacturing were used as a proxy for 2017. They were calculated by assuming that Iowa emissions were 0.97% of national emissions because Iowa's population is 0.97% of the total U.S. Population (U.S. Census 2018b).

<u>Adjustments</u>

A math error made last year for 2013 emissions from limestone and dolomite use was corrected, lowering the emissions from 0.33 $MMtCO_2e$ to 0.18 $MMtCO_2e$.

Emissions from electric power transmission and distribution from 2008 - 2016 were recalculated as shown in Table 15, by using the most current national emissions data (EPA 2018b), adjusted for Iowa retail electricity sales compared to U.S. retail electricity sales. (U.S. Census 2018b).

Table 15: Recalculated Emissions from Electric Power T & D ($MMtCO_2e$)[10]

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Value Published Dec. 2017	0.098	0.089	0.075	0.065	0.056	0.053	0.053	0.049	0.049
Updated Value	0.074	0.072	0.071	0.073	0.058	0.056	0.059	0.054	0.055

Results

GHG emissions from industrial processes in 2017 were 7.25 $MMtCO_2e$, or 5.54% of total statewide GHG emissions. Emissions from this sector increased 31.73% from 2016 as shown in Table 16 and Figure 7, primarily due to a 181.09% increase in emissions from ammonia production. The emissions from three types of processes – ammonia and urea production, cement manufacture, and consumption of ODS substitutes, accounted for over 80% of the industrial process emissions in 2017.

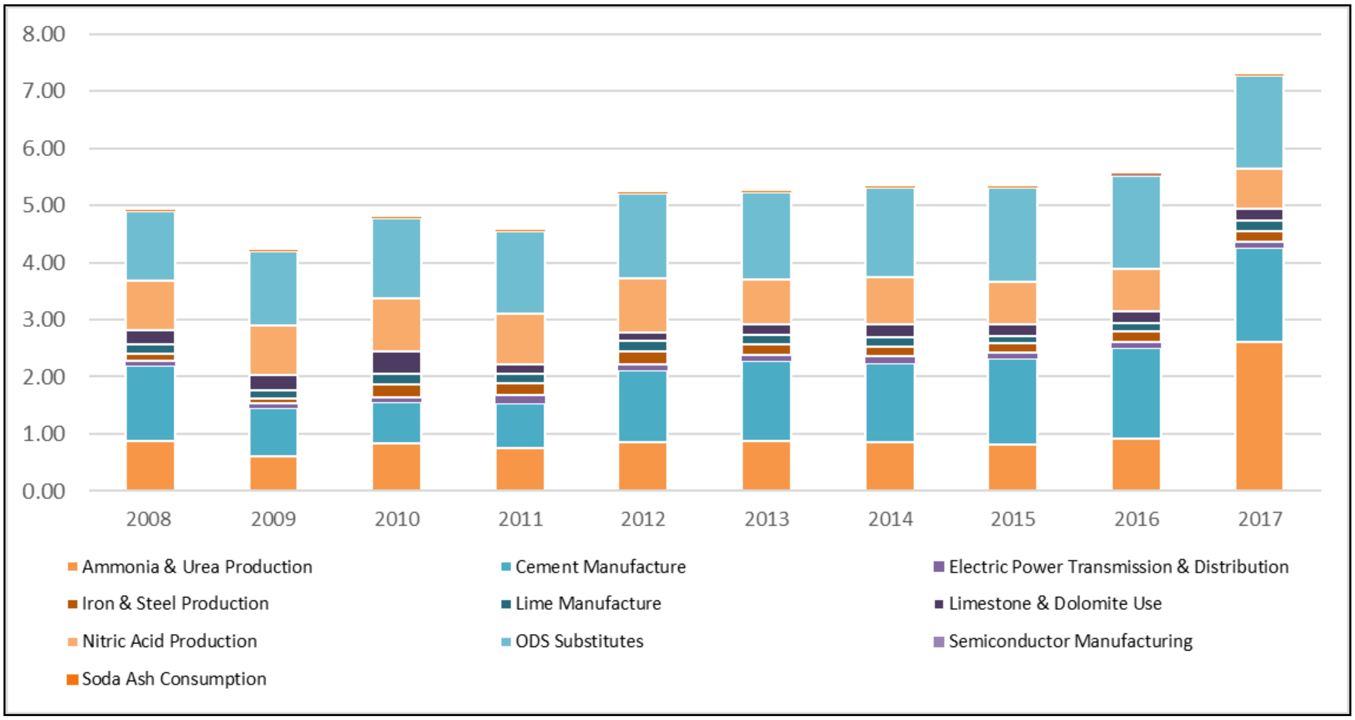
Table 16: GHG Emissions from Industrial Processes ($MMtCO_2e$)[11]

Category	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ammonia & Urea	0.87	0.60	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60
Cement Manufacture	1.31	0.84	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66
Electric Power T&D	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06
Iron & Steel Production	0.12	0.09	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20
Lime Manufacture	0.17	0.13	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18
Limestone & Dolomite Use	0.25	0.29	0.39	0.16	0.15	0.18	0.21	0.21	0.21	0.21
Nitric Acid Production	0.86	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70
ODS Substitutes	1.21	1.30	1.39	1.43	1.47	1.51	1.57	1.64	1.63	1.63
Semiconductor Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	**4.89**	**4.21**	**4.79**	**4.50**	**5.18**	**5.20**	**5.28**	**5.28**	**5.51**	**7.25**

[10] DNR 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.

[11] Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2008 – 2017 rounded to 0.001 $MMtCO_2e$ or less.

Figure 7: 2017 GHG Emissions from Industrial Processes ($MMtCO_2e$)



<u>Uncertainty</u>

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

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

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

[12] This information is largely excerpted from the *SIT Industrial Processes Module* (ICF 2018a).

Chapter 5 - Natural Gas Transmission & Distribution

This chapter includes GHG emissions from natural gas transmission and distribution (T & D) in Iowa. In this sector, methane (CH_4) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO_2) emissions from venting and flaring was not calculated due to lack of data. GHG emissions from coal mining, natural gas production, oil production, oil transmission, and oil transportation are not included as those industries are currently not active in Iowa.

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2017b).

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 2018). The Iowa Utilities Board confirmed that the number of natural gas compressor and gas storage stations did not change from the previous year (Munyon 2017).

Natural Gas Distribution

Natural gas is distributed through large networks of small, low-pressure pipelines. Natural gas flows from the transmission system to the distribution network at municipal gate stations, where the pressure is reduced for distribution within municipalities. CH_4 is emitted from leaks, meters, regulators, and accidents (ICF 2017b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2018). 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.

Natural Gas Venting and Flaring

The DNR is unable to find data on the annual amount of natural gas vented and flared from natural gas transmission pipelines. This data is not tracked by the EIA (Little 2011), and the DNR has previously requested, but not received, this information from the Federal Energy Regulatory Agency (FERC). Therefore, no GHG emissions were calculated from natural gas venting and flaring.

Results

Total GHG emissions from natural gas transmission and distribution were 1.2657 $MMtCO_2e$[13] in 2017, a decrease of 10.06% from 2016 and a decrease of 9.29% from 2008 as shown in Table 17 and Figure 8. Emissions decreased in 2017 due to decreases in the miles of pipeline and number of services (e.g. gas meters) in the state. GHG emissions from this sector account for 0.97% of 2017 statewide GHG emissions.

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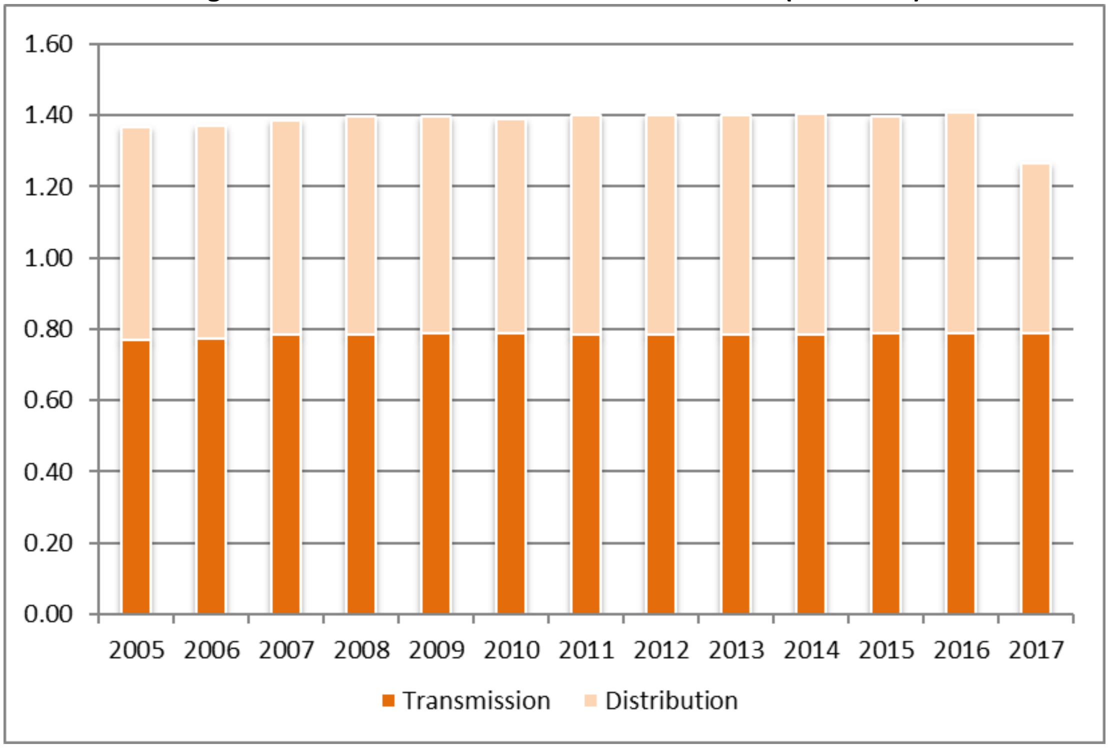
[13] DNR uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

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

Category	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Transmission	0.7857	0.7868	0.7871	0.7858	0.7862	0.7865	0.7864	0.7868	0.7867	0.7868
Distribution	0.6095	0.6084	0.6031	0.6132	0.6158	0.6135	0.6168	0.6118	0.6205	0.4789
Total	**1.3953**	**1.3952**	**1.3901**	**1.3990**	**1.4020**	**1.4000**	**1.4031**	**1.3986**	**1.4073**	**1.2657**

Figure 8: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)



Uncertainty[14]

The main source of uncertainty in the SIT calculation methods is the emission factors. The emission factors used are based on a combination of statistical reporting, equipment design data, engineering calculations and studies, surveys of affected facilities and measurements. In the process of combining these individual components, the uncertainty of each individual component is pooled to generate a larger uncertainty for the overall emission factor. In addition, statistical uncertainties arise from natural variation in measurements, equipment types, operational variability, and survey and statistical methodologies. The method also does not account for regional differences in natural gas infrastructure and activity levels (ICF 2017a).

[14] This information is largely excerpted from the *SIT Natural Gas and Oil Systems Module* (ICF 2017a).

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 2017a), which was updated by EPA in 2016 to calculate CO_2, CH_4, and N_2O emissions from highway vehicles based on vehicle miles traveled. This is a more accurate than previous methods as it accounts for the vehicle type and vehicle age in the calculation, as well as accounting for the annual vehicle miles traveled. Emissions from non-highway vehicles were calculated based on fossil fuel consumption.

Highway Vehicles (CH_4 and N_2O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH_4 and N_2O emissions from highway vehicles were calculated using the SIT as follows:

1. The vehicle miles traveled (VMT) for each vehicle type was calculated using the total 2017 annual VMT of 33,751 million miles from the Iowa Department of Transportation (IDOT 2018). 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-97 and A-98 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016* (EPA 2018). The classes and the national distribution percentages are shown in Table 18.

Table 18: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2016 (EPA 2018)	2017 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.50%	2,868
Heavy duty gas vehicle	HDGV	1.06%	358
Light duty diesel truck	LDDT	0.77%	261
Light duty diesel vehicle	LDDV	0.34%	114
Light duty gasoline truck	LDGT	20.48%	6,913
Light duty gasoline vehicle	LDGV	70.34%	23,840
Motorcycle	MC	0.66%	224
Total		**100.00%**	**33,751**

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-102 in the most recent national inventory (EPA 2018).
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-104, A-105, and A-106 in Annex 3 of the most recent national inventory (EPA 2018). The 2016 Tier 2 value was used as a proxy for 2017.

Non-highway Vehicles (CH_4 and N_2O)
Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH_4 and N_2O emissions from non-highway vehicles were calculated using data from either the Energy Information Administration (EIA) or Federal Highway Administration as shown in Table 19.

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

Vehicle Type	Fuel Type	Year	Data Source
Aviation	Gasoline	2016 used as proxy for 2017	EIA SEDS (EIA 2018b)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2016 used as proxy for 2017	FHWA 2017
Heavy Duty Utility			
Tractors			
Construction			
Locomotives	Distillate Fuel	2016 used as proxy for 2017	EIA Adjusted Sales (EIA 2018a)
Tractors			
Construction	Distillate Fuel	2015 used as proxy for 2016-2017	SIT default value
Heavy Duty	Distillate Fuel		
Small Utility	Gasoline		
Alternative Fuel Vehicles			

Adjustments
Emissions from non-highway vehicles were recalculated for 2015 and 2016 as shown in Table 20 by using updated fuel activity data from EIA and the FHWA.

Table 20: Recalculated Emissions from Transportation ($MMtCO_2e$)

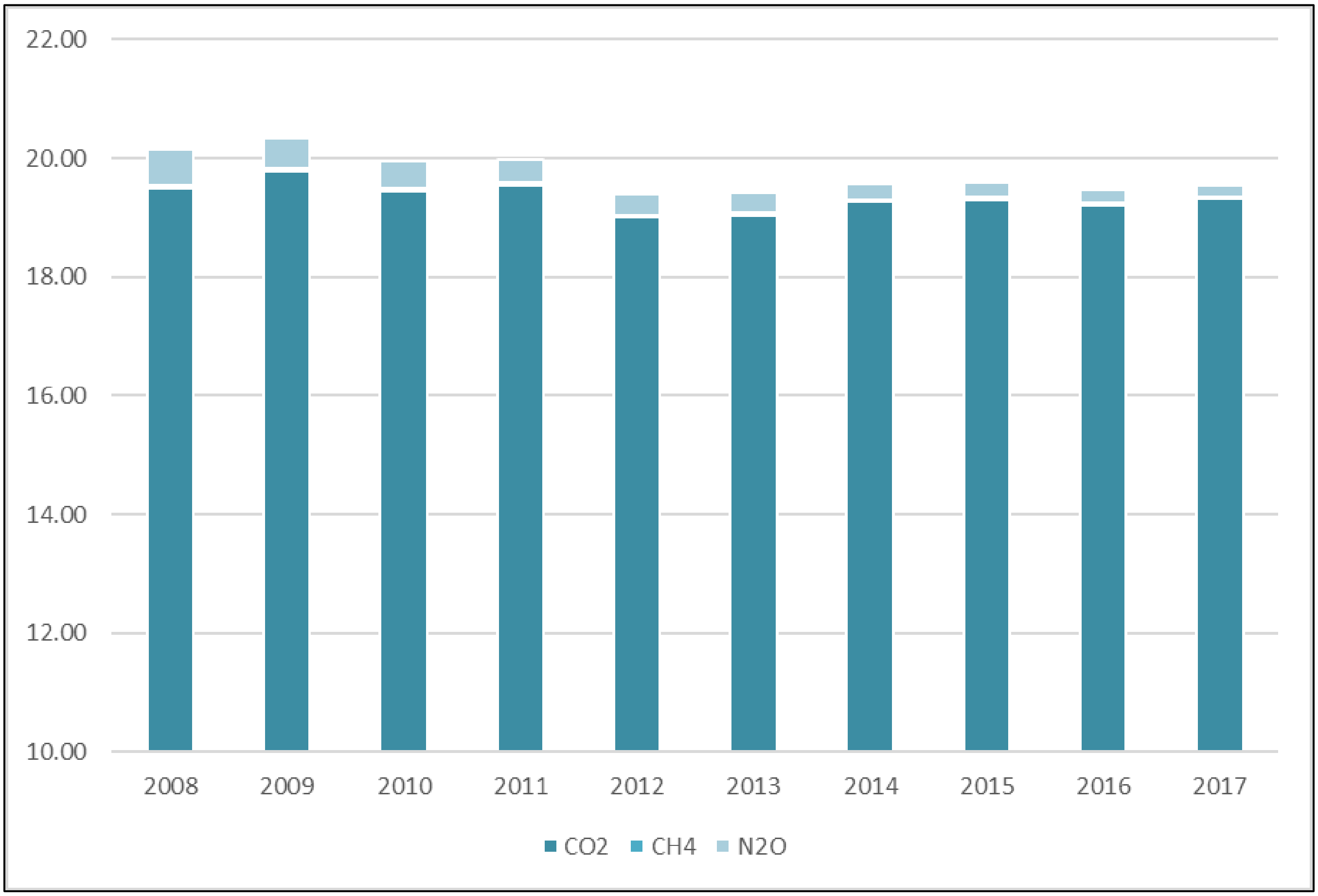
Pollutant	2015 Value (Published Dec. 2017)	2015 Updated Value	2016 Value (Published Dec. 2017)	2016 Updated Value
CO_2	19.10	19.81	19.17	19.93
CH_4	0.04	0.03	0.03	0.03
N_2O	0.17	0.18	0.16	0.16
Total	**19.31**	**20.02**	**19.36**	**20.12**

Results
Total GHG emissions from transportation were 20.34 $MMtCO_2e$ in 2017 as shown in Table 21. This is an increase of 1.10% from 2016. CO_2 accounts for nearly all the Iowa transportation GHG emissions (99.14%) as shown in Figure 9. The majority of the transportation emissions (56.42%) are from gasoline highway vehicles as shown in Figure 10.

Table 21: GHG Emissions from Transportation ($MMtCO_2e$)[15]

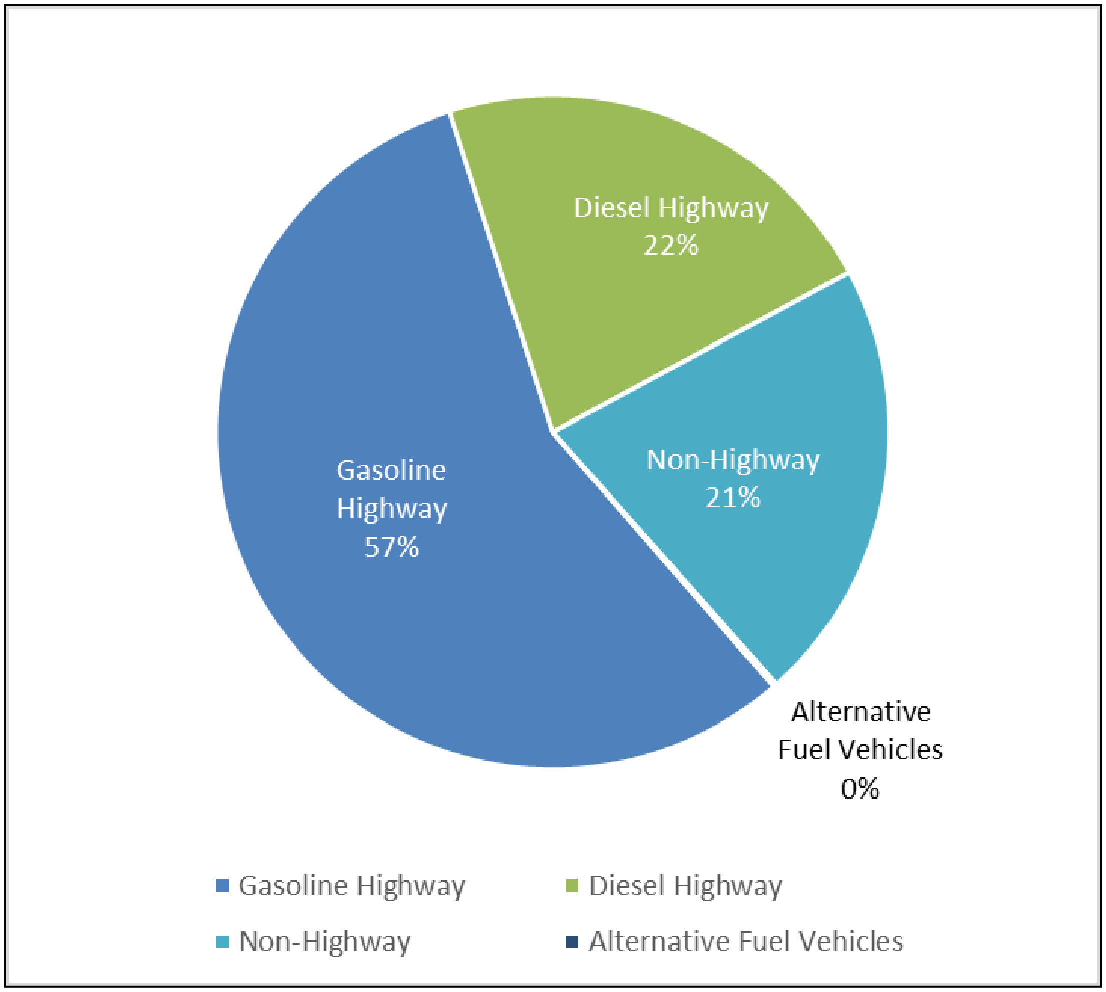
Pollutant	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2	19.5400	18.9991	19.0439	19.2677	19.3073	19.2092	19.3243	19.8096	19.9291	20.1688
CH_4	0.0428	0.0412	0.0413	0.0385	0.0381	0.0362	0.0361	0.0316	0.0305	0.0298
N_2O	0.4024	0.3628	0.3253	0.2702	0.2420	0.2138	0.1944	0.1828	0.1617	0.1450
Total	**19.9852**	**19.4030**	**19.4104**	**19.5763**	**19.5874**	**19.4593**	**19.5549**	**20.0240**	**20.1213**	**20.3436**

Figure 9: Transportation Emissions by Pollutant ($MMtCO_2e$)



[15] 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 year to year.

Figure 10: 2017 GHG Emissions by Fuel/Vehicle Type



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 2018). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable locate Iowa-specific VMT data. Uncertainty may be introduced if the fuel consumption data or emission factors used do not reflect Iowa scenarios, such as using default national emission factors. In addition, it is assumed that all fuel purchased is consumed in the same year (ICF 2017b).

Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH_4) emissions from municipal solid waste landfills and carbon dioxide (CO_2) and nitrous oxide (N_2O) emitted from the combustion of municipal solid waste to produce electricity. CH_4 emissions from landfills are a function of several factors, including:

- The total quantity of waste in municipal solid waste landfills,
- The characteristics of the landfills such as composition of the waste, size, and climate; the quantity of CH_4 that is recovered and flared, and
- The quantity of CH_4 oxidized in landfills instead of being released into the atmosphere.

Fluctuations in CH_4 emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, the frequency of composting, and the rate of recovery of degradable materials such as paper and paperboard (EPA 2011).

Method

Municipal Solid Waste (MSW) Landfills

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2018), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO_2e or more to report their emissions. This included twenty-four Iowa landfills in 2017. 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_4 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 21,071 tons of municipal solid waste in 2017 (Trower 2019). The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO_2 emissions from MSW combustion using SIT (ICF 2017a). These state-specific proportion values are from the 2017 Iowa Statewide Waste Characterization Study (SCS 2017). The earlier, 2011 version of the study (MSW 2011), was used to calculate emissions from 2010 – 2016. The state-specific proportions of discards used are shown in Table 22.

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

Material	SIT Default Value	2011 Iowa Study	2017 Iowa Study
Plastics	17.0 – 18.0%	16.7%	18.3%
Synthetic Rubber	2.3 – 2.6%	1.0%	1.2%
Synthetic Fibers	5.6 – 6.3%	4.1%	4.5%

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. Therefore, the DNR did subcategorize the proportion of municipal solid waste discards.

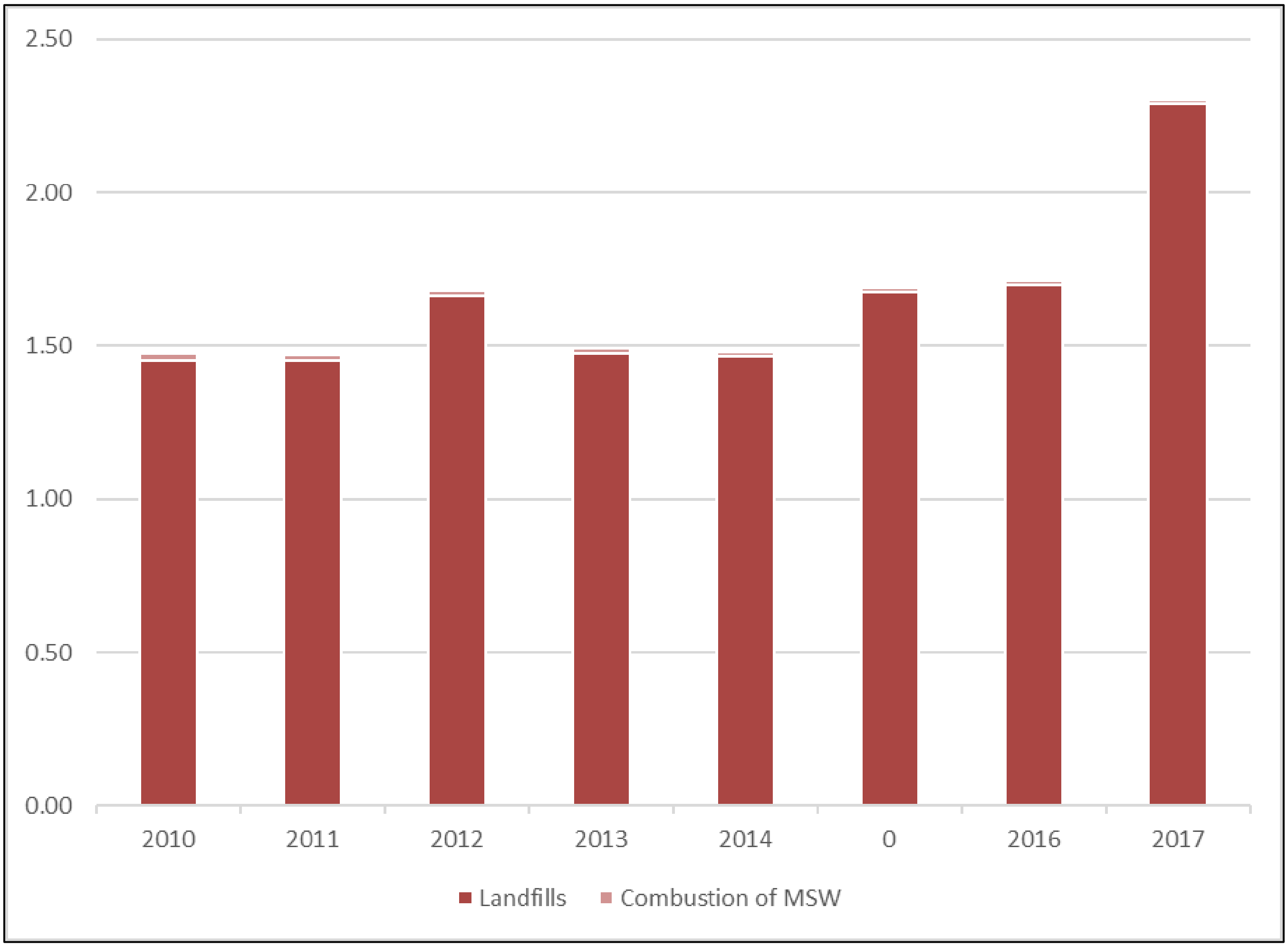
Results

Total GHG emissions from the solid waste category were 2.30 $MMtCO_2e$ in 2017, an increase of 34.61% from 2016 as shown in Table 23 and Figure 11 even though the cumulative amount of waste in landfills increased by 6.30% (DNR 2018). This is due to the length of time the waste is stored in the landfill and because the decomposition rate of the waste fluctuates according to the amount of waste in the landfill, the climate, the quantity of CH_4 that is recovered and flared, and varying oxidation rates.

Table 23: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$)[16]

Pollutant	2010	2011	2012	2013	2014	2015	2016	2017
MSW Landfills	1.45	1.45	1.66	1.48	1.46	1.68	1.70	2.29
MSW Combustion	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Total	**1.47**	**1.47**	**1.68**	**1.49**	**1.48**	**1.69**	**1.71**	**2.30**

Figure 11: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$)[17]



[16] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[17] Emissions from 2008 – 2009 are not included in the chart because they were calculated using the old method and are not directly comparable to emissions from 2010 – 2017.

Uncertainty[18]

MSW Combustion

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

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

The SIT assumes that all carbon in textiles is non-biomass carbon and the category of rubber and leather is almost all rubber. This may result in CO_2 emissions being slightly over-estimated (ICF 2017b).

[18] This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2017b).

Chapter 8 – Waste: Wastewater Treatment

This chapter includes GHG emissions from the treatment of municipal and industrial wastewater. The pollutants from this sector are methane (CH_4) and nitrous oxide (N_2O). CH_4 is emitted from the treatment of wastewater, both industrial and municipal. CH_4 is produced when organic material is treated in an anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N_2O is produced through nitrification followed by incomplete denitrification of both municipal and industrial wastewater containing both organic and inorganic nitrogen species. Production and subsequent emissions of N_2O is a complex function of biological, chemical, and physical factors, and emission rates depend on the specific conditions of the wastewater and the wastewater collection and treatment system. Human sewage makes up a signification portion of the raw material leading to N_2O emissions (ICF 2017b).

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 2017 (U.S. Census 2018). For example, to calculate CH_4 emissions, the state population was multiplied by the quantity of biochemical oxygen demands (BOD) per person emission factor, by the fraction that is treated anaerobically, and by the quantity of CH_4 produced per metric ton. It does not account for any digester methane that is collected and combusted instead of fossil fuels in equipment such as boilers, generators, or flares.

SIT default emission factors and assumptions were used to calculate both CH_4 and N_2O emissions, except that N_2O was calculated using the most recent protein (kg/person-year) value (44.7) from Table 7-15 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016* (EPA 2018b). The protein values for 2012 – 2015 have been updated by EPA and were used, resulting in annual decreases in emissions of 0.001 – 0.003 $MMtCO_2e$. Because the 2017 protein value was not available at the time of publication, the 2016 value was used as a surrogate for 2017.

The Iowa fraction of population without septic systems, 76%, from EPA's *Onsite Wastewater Treatment Systems Manual* (EPA 2002), was also used to estimate N_2O emissions. This value taken from the *1990 Census of Housing* and is lower than the SIT default value of 79%. The *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_2e or more to report to the federal greenhouse gas reporting program (GHGRP) starting with year 2011 emissions. In Iowa, this includes emissions from four food processing facilities and fifteen 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 fifteen ethanol production facilities and five food processing facilities emitted more than 25,000 metric tons CO_2e or more (EPA 2018a).

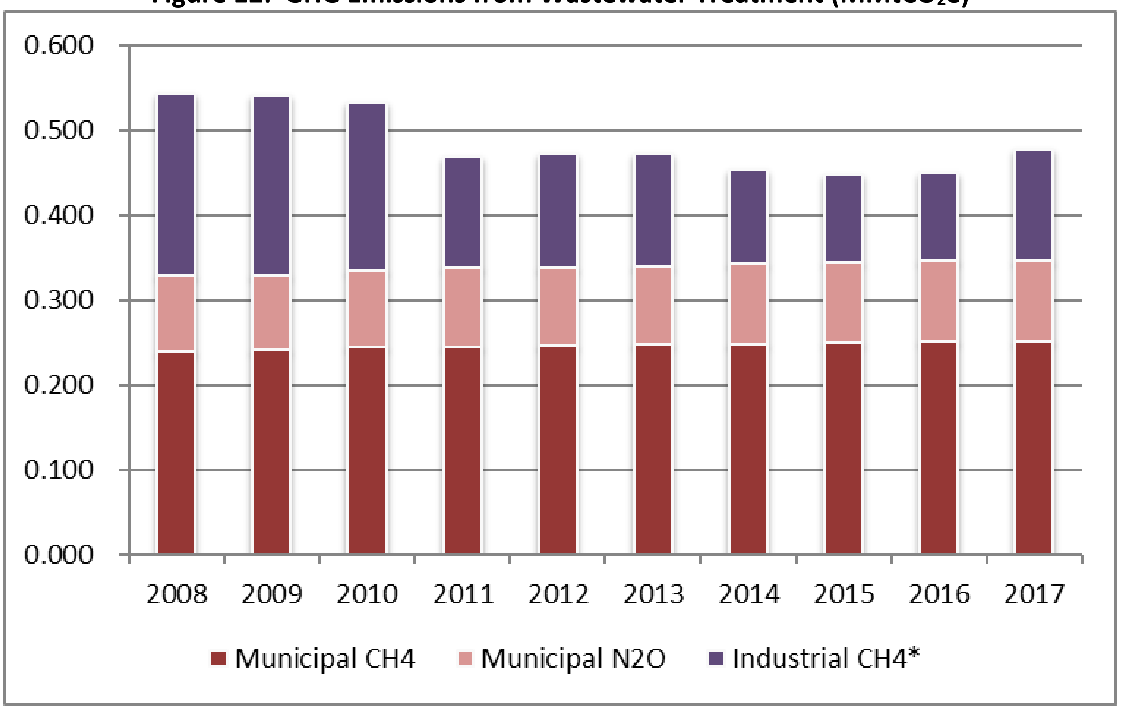
<u>Results</u>

Wastewater emissions account for 0.36% of total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.48 $MMtCO_2e$ in 2017, a 6.17% increase from 2016 and a 12.11% decrease from 2008 as shown in Table 24. This is due to increases in wastewater produced by industrial meat processing facilities and the amount of municipal wastewater produced by humans as the state's population increases. CH_4 and N_2O from municipal wastewater treatment accounted for 72.64% (0.35 $MMtCO_2e$) of total wastewater treatment GHG emissions as shown in Figure 12.

Table 24: GHG Emissions from Wastewater ($MMtCO_2e$)[19]

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Municipal CH_4	0.240	0.241	0.244	0.245	0.246	0.247	0.249	0.250	0.251	0.252
Municipal N_2O	0.090	0.089	0.090	0.093	0.092	0.093	0.094	0.095	0.095	0.095
Industrial CH_4	0.214	0.211	0.199	0.130	0.134	0.132	0.111	0.104	0.104	0.131
Total	**0.543**	**0.541**	**0.533**	**0.468**	**0.472**	**0.472**	**0.454**	**0.449**	**0.450**	**0.478**

Figure 12: GHG Emissions from Wastewater Treatment ($MMtCO_2e$)



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

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[19] DNR 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[20]

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the Iowa-specific percentage of the population without septic systems was used to calculate emissions, the value is from 1990. There can also be variation in the per-capita BOD production association with food consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors that can be attributed to differences in wastewater treatment facilities (ICF 2017a).

N_2O emissions are dependent on nitrogen (N) inputs into the wastewater and the characteristics of wastewater treatment methods. Estimates of U.S. population, per capita protein consumption data, and the fraction of nitrogen in protein are believed to be accurate. However, the fraction that is used to represent the ratio of non-consumption nitrogen also contributes to the overall uncertainty of these calculations, as does the emission factor for effluent, which is the default emission factor from IPCC (1997). Different disposal methods of sewage sludge, such as incineration, landfilling, or land-application as fertilizer also add complexity to the GHG calculation method (ICF 2017a).

Industrial Wastewater

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 $mtCO_2e$ or more are required to report to the federal greenhouse gas reporting program. Future improvements to the inventory could include identifying all of the industrial wastewater facilities that are not required to report to the federal program and developing a method to calculate their emissions.

[20] This information is largely excerpted from the *SIT Wastewater Module* (ICF 2017a).

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

This chapter addresses carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from liming of agricultural soils and fertilization of settlement soils,[21] as well as carbon sequestered by forests, urban trees, and yard trimmings and food scraps that are sent to the landfill.

<u>Method</u>

Forest Carbon Flux

CO_2 is taken in by plants and trees and converted to carbon in biomass during photosynthesis. "Growing forests store carbon naturally in both the wood and soil. Trees are about fifty percent carbon, and wood products from harvested trees continue to store carbon throughout their lives as well" (Flickinger 2010). CO_2 is emitted by live tree respiration, decay of dead material, fires, and biomass that is harvested and used for energy (Strait et al. 2008). The balance between the emission of carbon and the uptake of carbon is known as carbon flux (ICF 2017b).

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 (FIDO) to calculate carbon flux. The FIDO database is no longer publically available, but the Design and Analysis Toolkit for Inventory and Monitoring (DATIM) is. It has similar functionality to FIDO, but has additional emphasis on National Forest Service data and attributes. FIDO contained Iowa-data for each individual year 2008 – 2015, but DATIM sums the data by groups, 2004 – 2008, 2009 – 2013, and 2010 – 2015. This summed data is not helpful for calculating carbon flux between individual years. Using the FIDO data, DNR calculated a 2015 carbon flux value of +2.87 $MMtCO_2e$ and used it as a proxy for 2016 and 2017. The DNR hopes to improve this calculation method in future inventories after spending more time researching the differences between FIDO and DATIM.

Liming of Agricultural Soils

CO_2 is emitted when acidic agricultural soils are neutralized by adding limestone or dolomite. The Iowa Limestone Producers Association (ILPA) provided the DNR with the total annual amount of limestone produced for agricultural use as reported by their members (Hall 2018). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (IDOT) tracks general information for active aggregate sources used for construction, including whether the material is limestone or dolomite. They do not track that information for limestone produced for agricultural purposes. The IDOT indicated that some areas

[21] Settled soils such as landscaping, lawns, and golf courses (ICF 2017b).

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.

Urea Fertilization
Urea emissions were calculated using the amount of urea applied annually (IDALS 2017). Because the amount of urea fertilizer applied in the in last six months of 2017 was not available, the amount applied from July 2016 – December 2016 (52,000 tons) was used as a surrogate for the amount applied from July 2017 – December 2017.

Urban Tree Flux
Carbon sequestration estimations from this sector were refined by using a new DNR data set that is a mix of land cover/remote sensing data with about a one-meter resolution. The data set includes the amount of forested acres and total acres of land for 946 incorporated areas in Iowa (Hannigan 2014).

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 2017b). N_2O emissions from settlement soils were calculated using 10% of the total annual growing year synthetic fertilizer value from the SIT Agriculture module. For more information on how the 2017 values were derived, please see *Chapter 2-Agriculture* of this report.

Non-CO_2 Emissions from Forest Fires
CH_4 and N_2O emissions from forest fires in Iowa were not estimated because the majority of wildfires and prescribed burns in Iowa that are reported to DNR occur on grasslands (Kantak 2014). In addition, the SIT calculation method uses combustion efficiencies and emission factors that are provided for primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forest, eucalypt forest, other temperate forests, shrub lands, and savanna woodlands, which are not reflective of Iowa vegetation.

Yard Trimmings and Food Scraps Stored in Landfills
GHG estimations from this sector were refined by applying the estimated percentages of yard trimmings and food waste in municipal solid waste from the *2017 Iowa Statewide Waste Characterization Study* (MSW 2017) to the total amount of municipal solid waste sent to landfills in 2017 (DNR 2018). 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.

Adjustments
Urea Fertilization
Emissions from 2016 were recalculated using the most recent activity data available (IDALS 2017) as shown in Table 25. This resulted in an increase of 0.03 $MMtCO_2e$ tons in 2016.

Table 25: Recalculated Emissions from Urea Fertilization ($MMtCO_2e$)

Sector	2016 Value published Dec. 2017	2016 Updated Value
Urea Fertilization	+0.15	+0.19

Results

The majority of forest carbon is stored in above ground living trees (37%) and in the forest soil (42%) as shown in Figure 13. Overall, sources in the LULUCF sector released more carbon than they stored in 2017, emitting 3.33 MMtCO_2e as shown in Table 26 and Figure 14. This is an increase of 9.63% from 2016 and an increase of 188.90% from 2008. Emissions of CO_2 are shown above the x-axis in Figure 14 and carbon sinks are shown below the x-axis.

Figure 13: 2017 Where Forest Carbon is Stored (MMtCO_2e)

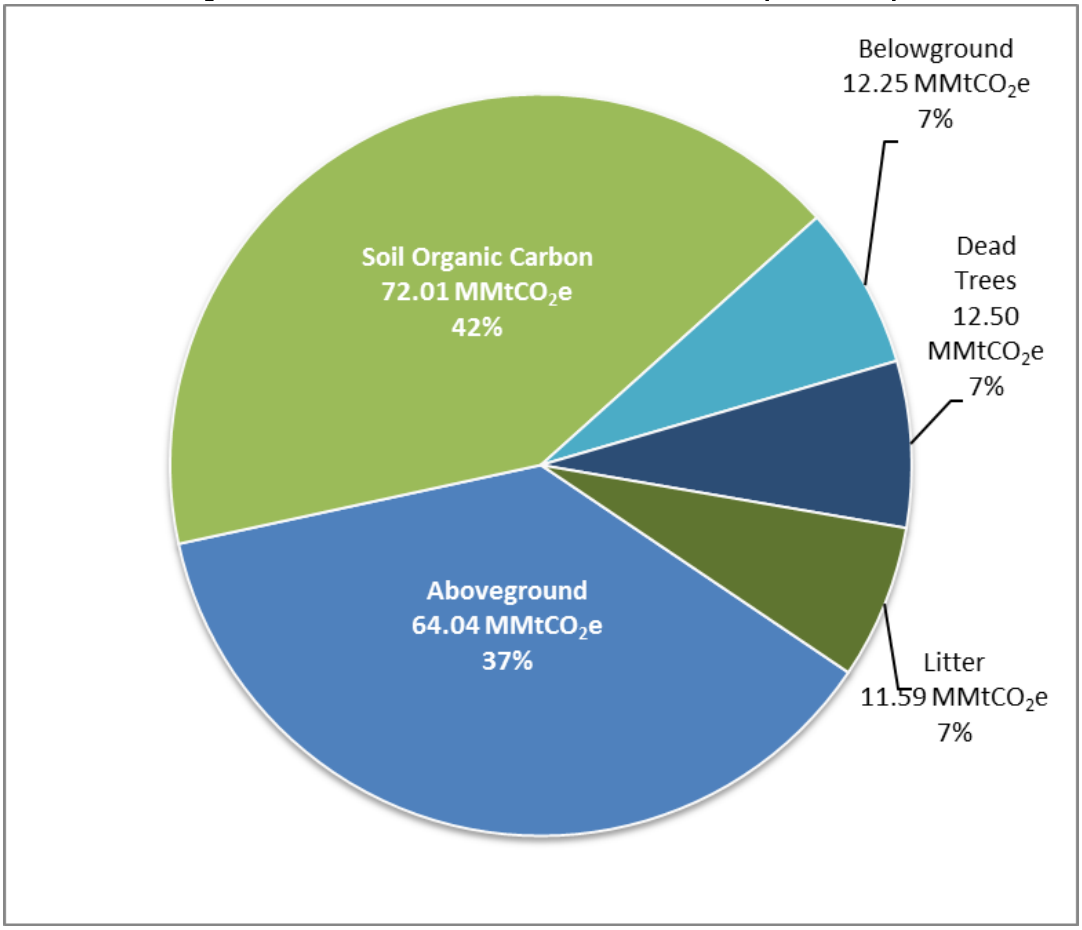
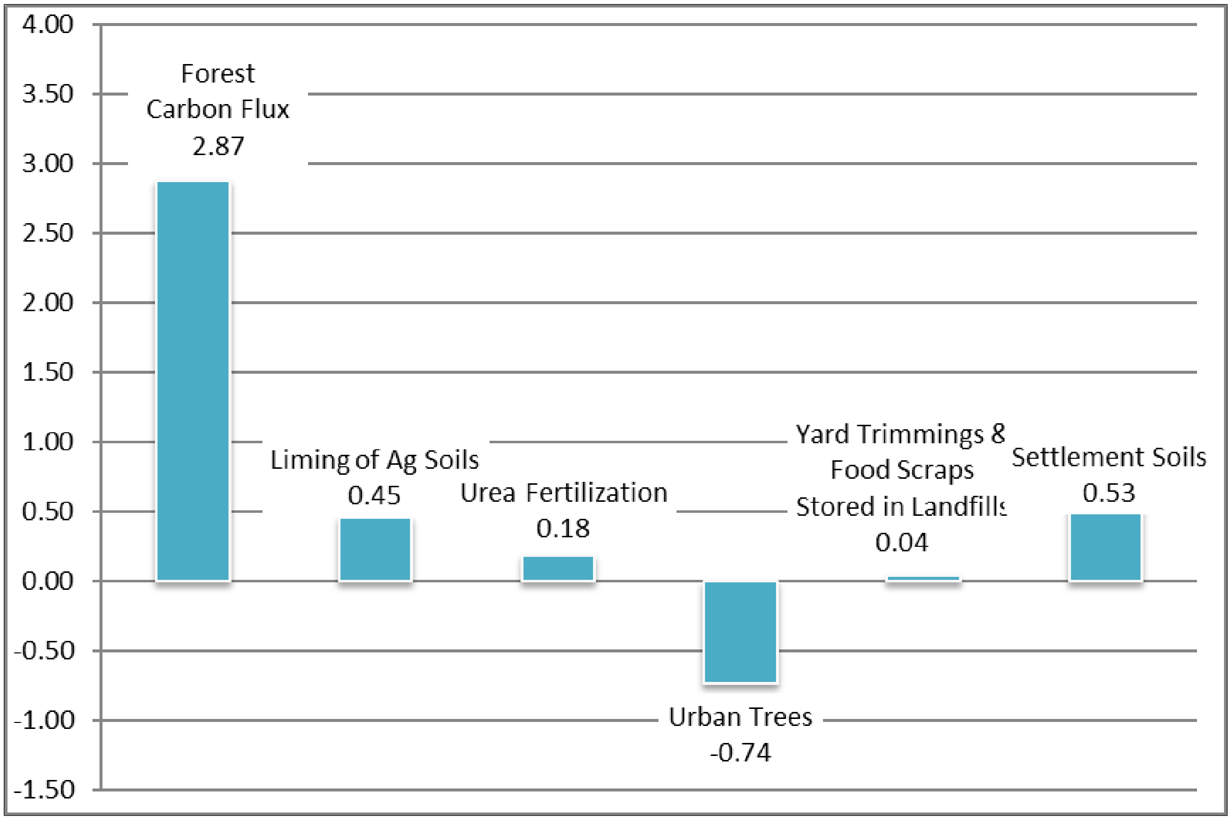


Table 26: GHG Emissions and Sinks from LULUCF (MMtCO_2e)[22]

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Forest Carbon Flux	-4.48	-5.47	-2.68	-0.14	-0.47	-1.02	+3.04	+2.87	+2.87	+2.87
Liming of Ag Soils	+0.28	+0.27	+0.47	+0.51	+0.65	+0.47	+0.41	+0.34	+0.46	+0.45
Urea Fertilization	+0.15	+0.12	+0.11	+0.12	+0.13	+0.11	+0.15	+0.15	+0.19	+0.18
Urban Trees	-0.26	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74	-0.74	-0.74
Yard Trimmings & Food Scraps Stored in Landfills	-0.09	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	+0.04
N_2O from Settlement Soils	+0.48	+0.44	+0.48	+0.57	+0.57	+0.57	+0.49	+0.49	+0.51	+0.53
Total	**-3.92**	**-5.00**	**-2.01**	**+0.67**	**+0.48**	**-0.71**	**+3.27**	**+2.99**	**+3.18**	**+3.33**

[22] 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 14: 2017 GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)



Uncertainty

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

- Using surrogate urea data for the last six months of 2017,
- 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%, and
- 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.

In addition, due to the high uncertainty in soil carbon flux from tillage practices, it was not included in the DNR's calculations. Refer to *Chapter 2 – Agriculture* for more information.

Chapter 10 – Electricity Consumption

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

Electricity consumed by Iowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2018b). 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 2018a).

Residential, Commercial, and Industrial

2017 emissions were projected by applying the forecasted percent change in energy consumption for each sector for the West North Central Region in the EIA's *Annual Energy Outlook (AEO) 2018 with Projections to 2050* (EIA 2018a) to Iowa's 2016 electricity consumption data from EIA (EIA 2018b).

Transportation

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the June 2016 report *Advancing Iowa's Electric Vehicle Market* (IEDA 2016), 1,017 electric vehicles were registered in Iowa as of June 2016. This is 0.02% of the total number of vehicles, 4.41 million, registered in the state in 2016 (IDOT 2017). Emissions were calculated assuming that each electric vehicle consumes 4,250 kWh of electricity per year (IEDA 2016) and rounded to less than 0.005 $MMtCO_2e$ (as shown below in Table 29). This does not include emissions from electric propulsion, other electric batteries, or non-highway electric vehicles such as golf carts. Emissions from 2016 were used as a proxy for 2017.

Adjustments

2015 and 2016 emissions have been recalculated since the DNR's 2016 GHG Inventory Report was published in December 2017. The DNR previously forecasted 2016 emissions due to a lack of Iowa-specific energy consumption data. However, the 2016 energy data was released by EIA in June 2018 (EIA 2018b), so the DNR used the data to recalculate 2016 emissions as shown in Table 27 and Table 28. In addition, EPA updated consumption values for 2015 as well as the electricity emission factor and transmission loss factors as shown in Table 27.

Table 27: Updated 2016 Activity Data

Category	2015 Value Published Dec. 2017	2015 Updated Value	2016 Value Published Dec. 2017	2016 Updated Value
Electricity Consumption (kWh)				
Residential	13,786,000,000	13,787,121,967	13,929,374,400	14,094,000,000
Commercial	12,072,000,000	12,260,272,500	12,087,693,600	12,291,000,000
Industrial	21,289,000,000	21,290,477,105	21,059,078,800	22,046,000,000
Total	**47,146,000,000**	**47,337,871,572**	**47,076,146,800**	**48,431,000,000**
Electricity Emission Factor (lbs. CO_2e/kWh)	1.35	1.18	1.35	1.00
Transmission Loss Factor (%)	4.97%	4.73%	4.97%	4.49%

Table 28: Recalculated Electricity Emissions (MMtCO_2e)

Category	2015 Value Published Dec. 2017	2015 Updated Result	2016 Value Published Dec. 2017	2016 Updated Result
Residential	8.88	7.72	8.97	6.72
Commercial	7.77	6.76	7.78	5.86
Industrial	13.71	11.92	13.56	10.51
Total	**30.35**	**26.41**	**30.31**	**23.09**

Results

Indirect GHG emissions from electricity consumption were 23.16 MMtCO_2e in 2017, increasing 0.32% since 2016, due to a projected 0.98% increase in industrial electricity consumption (EIA 2018a) as shown in Table 29 and Figure 15. Industrial users consumed 45.82% of electricity in the state, while residential users consumed 28.94% and commercial users consumed 25.23% as shown in Figure 16.

Table 29: GHG Emissions from Electricity Consumption (MMtCO_2e)[23]

Category	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Residential	12.22	10.80	11.45	11.27	9.85	10.30	9.29	7.72	6.72	6.70
Commercial	10.58	9.21	9.46	9.51	8.60	8.77	7.64	6.76	5.86	5.84
Industrial	16.71	14.33	14.84	15.14	13.74	13.83	13.16	11.92	10.51	10.61
Transportation	*not calculated**							0.00	0.00	0.00
Total	**39.51**	**34.35**	**35.76**	**35.92**	**32.19**	**32.90**	**30.39**	**26.41**	**23.09**	**23.16**

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

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

Figure 15: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)

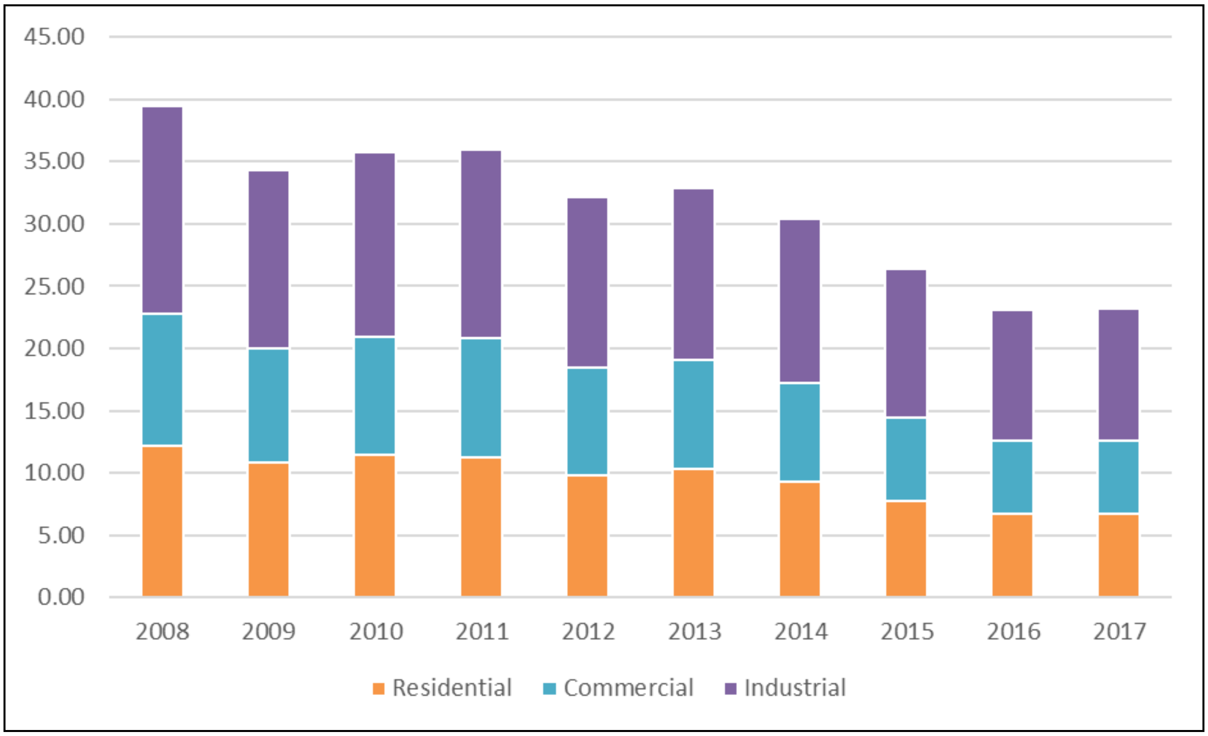
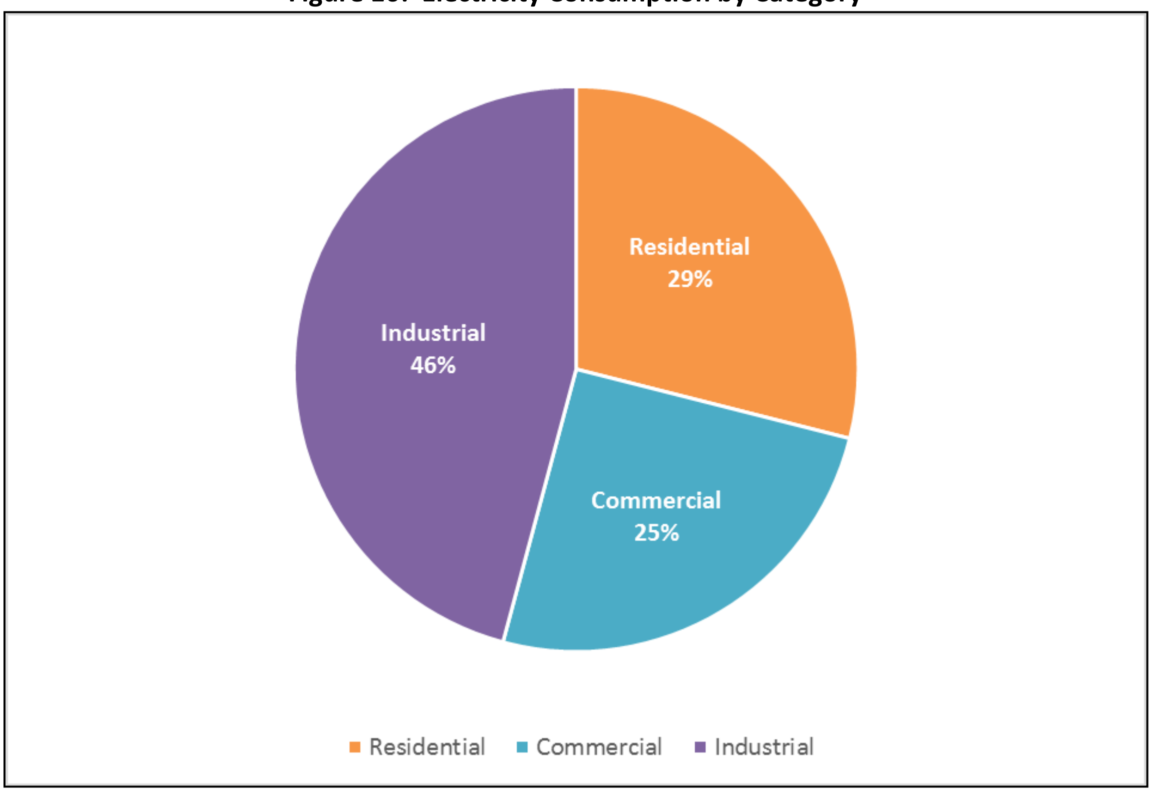


Figure 16: Electricity Consumption by Category



Forecasting

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

Method

The DNR projected emissions out to 2030 using the SIT Projection Tool (ICF 2018). The Projection Tool predicts that Iowa's population decreases every year from 2012 – 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 -2017 (U.S. Census 2018) and the 2020, 2025, and 2030 projections from Woods & Poole Economics (Woods & Poole, 2009). The data points for the intervening years were calculated using linear interpolation.

The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2015, using a combination of data sources and national projections for activity data. The Projection Tool would ideally include data through 2017 to be consistent with the DNR's 2017 calculated GHG inventory, but this discrepancy is unavoidable. Additionally, the energy forecast in the SIT Projection Tool is based on projected energy consumption values from the EIA's *Annual Energy Outlook (2017) with Projections to 2050* (EIA 2017), while the DNR's 2017 inventory uses activity data from the most recent version of EIA's *Annual Energy Outlook*, which is 2018. It would be preferable to forecast emissions using the DNR's 2017 calculated GHG inventory as the baseline, but it is not reasonable to fully updated the data in the SIT Projection Tool to eliminate all such inconsistencies.

Results

The DNR's calculated 2017 GHG inventory and projected emissions from the SIT Projection Tool for 2020, 2025, and 2030 for each category are shown in Table 30 (intervening year forecasts are available from the DNR upon request).

Table 30: Projected Gross GHG Emissions 2017 – 2030 (MMtCO$_2$e)

	Calculated	Projected		
Sector	**2017**	**2020**	**2025**	**2030**
Agriculture	39.61	39.43	39.31	39.97
Power Plants	26.60	29.19	26.06	24.03
RCI Fossil Fuel Use	29.83	29.16	30.06	29.73
Industrial Processes	7.25	3.99	4.84	5.59
Natural Gas T & D	1.27	1.21	1.30	1.30
Transportation	20.34	23.50	22.36	20.88
Waste	2.78	3.69	3.87	4.05
Total	**127.69**	**130.17**	**127.79**	**125.55**

Uncertainty

As with many forecasts, numerous factors affect the significant level of uncertainty associated with emissions projections. 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. In sectors where the Projection Tool predicts future emissions based on historical emissions (industrial processes, agriculture, and waste), it only uses emissions from 1990 – 2015 and does not consider 2016 - 2017 data.
4. The Projection Tool forecasts emissions from fossil fuel use based on the reference case from the EIA's *Annual Energy Outlook (AEO) 2017 with Projections to 2050*, which projects emissions at the regional level and not the state level. A more current reference case, *AEO 2018,* has been published but is not used by the tool.
5. The Projection Tool does not address publicly announced changes to Iowa's fossil fuel generation mix:
    - In April 2016, MidAmerican Energy Company announced their vision to provide 100% renewable energy for their Iowa customers. When the company's 591 MW Wind XII project is completed in 2020, it will reach renewable energy generation equivalent to more than 90% of MidAmerican customers' annual retail usage (MidAmerican 2018).
    - Alliant Energy announced in August 2018 that it plans to spend $2 billion on renewable energy sources from 2016 – 2030 and plans to stop using coal in its power plants by 2050 (Wisconsin 2018).

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Appendix A – Iowa GHG Emissions 2008 – 2017 by Sector[24]

Emissions (MMtCO2e)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	36.65	36.48	36.38	37.91	**36.78**	**35.77**	**36.75**	**39.00**	**39.49**	39.61
Enteric Fermentation	8.05	8.02	8.39	8.41	**8.40**	**8.38**	**8.19**	**8.36**	**8.43**	8.33
Manure Management	9.52	9.59	8.83	9.53	**10.86**	**10.85**	**10.42**	**11.07**	**10.96**	11.58
Agricultural Soil Management	19.07	18.87	19.16	19.98	**17.53**	**16.55**	**18.14**	**19.58**	**20.09**	19.71
Fossil Fuel Combustion	73.12	68.44	73.56	70.42	65.72	65.88	66.26	61.00	**54.78**	56.43
Electric Generating Facilities	41.78	37.71	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62
Residential, Commercial, Industrial	31.34	30.73	31.23	31.44	29.96	32.82	32.82	31.54	**29.45**	29.81
Industrial Processes	**4.89**	**4.21**	**4.79**	**4.50**	**5.18**	**5.20**	**5.28**	**5.28**	**5.51**	7.25
Ammonia & Urea Production	0.87	0.60	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60
Cement Manufacture	1.31	0.84	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66
Electric Power Transmission and Distribution Systems	**0.07**	**0.07**	**0.07**	**0.07**	**0.06**	**0.06**	**0.06**	**0.05**	**0.06**	0.06
Iron and Steel Production	0.12	0.09	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20
Lime Manufacture	0.17	0.13	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18
Limestone and Dolomite Use	0.25	0.29	0.39	0.16	0.15	**0.18**	0.21	0.21	0.21	0.21
Nitric Acid Production	0.86	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70
ODS Substitutes	1.21	1.30	1.39	1.43	1.47	1.51	1.57	1.64	1.63	1.63
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF[25]	-3.92	-5.00	-2.01	0.67	0.48	-0.71	3.27	2.99	**3.18**	3.33
Forest Carbon Flux	-4.48	-5.47	-2.68	-0.14	-0.47	-1.02	3.04	2.87	2.87	2.87
Liming of Agricultural Soils	0.28	0.27	0.47	0.51	0.65	0.47	0.41	0.34	0.46	0.45
Urea Fertilization	0.15	0.12	0.11	0.12	0.13	0.11	0.15	0.15	**0.19**	0.18
Urban Trees	-0.26	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74	-0.74	-0.74
Yard Trimmings and Food Scraps Stored in Landfills	-0.09	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	0.04
Fertilization of Settlement Soils	0.48	0.44	0.48	0.57	0.57	0.57	0.52	0.49	0.51	0.53

[24] 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.
[25] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Emissions ($MMtCO_2e$)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Natural Gas Transmission & Distribution	1.40	1.40	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27
Transmission	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Distribution	0.61	0.61	0.60	0.61	0.62	0.61	0.62	0.61	0.62	0.48
Transportation	19.99	19.40	19.41	19.58	19.59	19.46	19.55	**20.02**	**20.12**	20.17
Waste	3.10	3.06	2.01	1.94	2.15	1.96	1.94	2.14	2.16	2.78
Solid Waste	2.55	2.52	1.47	1.47	1.68	1.49	1.48	1.69	1.71	2.30
Wastewater	0.54	0.54	0.53	0.47	0.47	0.47	0.45	0.45	0.45	0.48
Gross Emissions	**139.14**	**132.98**	**137.54**	**136.40**	**131.31**	**129.67**	**134.45**	**131.84**	**126.64**	131.02
Sinks	-3.92	-5.00	-2.01	0	0	-0.71	0	0	0	0
Net Emissions	**135.22**	**127.99**	**135.53**	**136.40**	**131.31**	**128.96**	**135.45**	**131.84**	**126.64**	**131.02**
% Change from Previous Year (Gross)	**-1.61%**	**-4.43%**	+3.43%	**+0.64%**	**-3.74%**	**-1.24%**	**+3.68%**	**-1.95%**	**-3.94%**	+3.46%
% Change from 2008 (Gross)		**-4.43%**	-1.15%	-1.97%	**-5.63%**	**-6.80%**	**-3.37%**	**-5.25%**	**-8.98%**	-5.84%

Appendix B – Iowa GHG Emissions 2008 – 2017 by Pollutant[26]

Emissions (MMtCO$_2$e)	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Gross CO$_2$	95.06	89.08	94.54	**91.43**	87.32	**87.53**	90.76	**85.81**	**80.18**	83.96
Net CO$_2$	90.66	83.65	92.05	**91.43**	87.22	**86.24**	90.76	**85.81**	**80.18**	83.96
Stationary Fossil Fuel Combustion	72.76	68.09	73.09	69.96	65.30	65.47	65.85	60.64	**54.51**	56.12
Transportation	19.54	19.00	19.04	19.27	19.31	19.21	19.32	**19.81**	**19.93**	20.17
Industrial Processes	2.75	1.97	2.38	2.09	2.69	**2.83**	2.83	2.84	3.06	4.87
Solid Waste	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
LULUCF[27]	-4.40	-5.43	-2.49	0.09	-0.09	-1.29	2.75	2.50	**2.67**	2.80
CH$_4$	21.14	21.12	20.17	20.21	**21.72**	**21.50**	**20.86**	**21.88**	**21.80**	22.85
Stationary Fossil Fuel Combustion	0.10	0.11	0.19	0.19	0.17	0.17	0.17	0.14	**0.09**	0.13
Transportation	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.03**	0.03	0.03
Natural Gas and Oil Transmission and Distribution	1.40	1.40	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27
Enteric Fermentation	8.05	8.02	8.39	8.41	**8.40**	**8.38**	**8.19**	**8.36**	**8.43**	8.33
Manure Management	8.55	8.61	8.26	8.36	**9.67**	**9.67**	**9.24**	**9.91**	**9.79**	10.42
Solid Waste	2.54	2.50	1.45	1.45	1.66	1.48	1.46	1.68	1.70	2.29
Wastewater	0.45	0.45	0.44	0.38	0.38	0.38	0.36	0.35	0.36	0.38
N$_2$O	22.14	21.85	21.85	23.25	**20.83**	**19.65**	**21.20**	**22.46**	**22.98**	22.52
Stationary Fossil Fuel Combustion	0.26	0.24	0.28	0.27	0.25	0.24	0.24	0.21	0.19	0.18
Transportation	0.40	0.36	0.33	0.27	0.24	0.21	0.19	**0.18**	**0.16**	0.15
Industrial Processes	0.86	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70
Manure Management	0.97	0.98	0.57	1.17	**1.19**	**1.18**	**1.18**	**1.16**	**1.17**	1.16
Agricultural Soil Management	19.07	18.87	19.16	19.98	**17.53**	**16.55**	**18.14**	**19.58**	**20.09**	19.71
N$_2$O from Settlement Soils	0.48	0.44	0.48	0.57	0.57	0.57	0.52	0.49	**0.51**	0.53
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	0.10	0.10	0.10
HFC, PFC, and SF$_6$	**1.29**	**1.37**	**1.46**	**1.50**	**1.53**	**1.57**	**1.63**	**1.69**	**1.69**	1.68
Industrial Processes	**1.29**	**1.37**	**1.46**	**1.50**	**1.53**	**1.57**	**1.63**	**1.69**	**1.69**	1.68
Gross Emissions	**139.62**	**133.42**	**138.02**	**136.40**	**131.40**	**130.25**	**134.45**	**131.84**	**126.65**	131.02
Sinks	-4.40	-5.43	-2.49		-0.09	-1.29				
Net Emissions (Sources and Sinks)	**135.22**	**127.99**	**135.53**	**136.40**	**131.31**	**128.96**	**134.45**	**131.84**	**126.65**	131.02

[26] 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.

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