December 31, 2020

The Honorable Kim Reynolds and
Iowa General Assembly
State Capitol
1007 E. Grand Avenue
Des Moines, Iowa 50319

Dear Governor Reynolds and Iowa General Assembly:

I am pleased to submit to you the Department's *2019 Iowa Statewide Greenhouse Gas Emissions Inventory Report* and *Technical Support Document* as required by Iowa Code 455B.104. This policy-neutral report is thirteenth statewide greenhouse gas inventory conducted for Iowa.

We hope this report is useful for policy makers as they continue to discuss this important issue.

Sincerely,

Kayla Lyon

Kayla Lyon
Director
Department of Natural Resources

With Enclosures

IOWA DEPARTMENT OF
NATURAL RESOURCES

2019 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Required by Iowa Code 455B.104

December 31, 2020

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

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Background

This report is required by Iowa Code 455B.104, which requires the Iowa Department of Natural Resources (DNR) to estimate greenhouse gas (GHG) emissions during the previous year and forecast trends in emissions. The report must be submitted to the Governor and Iowa General Assembly by December 31 each year and is beneficial because it provides an opportunity to evaluate Iowa-specific GHG emissions trends, is more detailed and more accurate than national efforts, and can be used to establish a baseline for tracking emissions reductions progress in Iowa. This report focuses on calendar year 2019 GHG emissions and includes emissions of six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFC), hydrofluorocarbons (HFC), and sulfur hexafluoride (SF_6).

The emissions are based on statewide activity data from the following sectors:

- agriculture
- fossil fuel combustion
- industrial processes
- natural gas transmission and distribution
- transportation
- solid waste
- wastewater treatment
- land use, land use change, and forestry (LULUCF)

Emissions were calculated using the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT) and self-reported emissions data from landfills, industrial facilities, and power plants. The calculation method and uncertainty for each sector are discussed in depth in the DNR's Technical Support document (TSD), available on the DNR's Greenhouse Gas Emissions webpage.

2019 Statewide GHG Emissions

In 2019, total gross Iowa greenhouse gas emissions were 130.07 million metric tons carbon dioxide equivalent ($MMtCO_2e$) as shown in Table 1 and Figure 1. This is a decrease of 2.35 $MMtCO_2e$ (1.77%) from 2018 and a decrease of 5.43% from 2010. The 2.35 $MMtCO_2e$ decrease in emissions since the end of 2018 is largely attributed to the following combination of reductions and partially offsetting increases:

- A 6.30 $MMtCO_2e$ decrease in emissions from power plants, due to decreased generation of electricity from fossil fuels,
- A 0.78 $MMtCO_2e$ decrease in emissions from the agriculture sector, due to decreased emissions from agriculture soil management,
- A 4.52 $MMtCO_2e$ increase in emissions from residential, commercial and industrial fuel use, and
- A 0.23 $MMtCO_2e$ increase in emissions from mobile combustion due to an increase in vehicle miles traveled.

Emissions fluctuations from other sectors were much smaller in magnitude, as shown in Figure 2, and differed by less than 0.10 $MMtCO_2e$ per sector from 2018.

Table 1: GHG Emissions 2009 – 2019 by Sector (Million Metric Tons Carbon Dioxide Equivalents ($MMtCO_2e$))[1]

Emissions ($MMtCO_2e$)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Change from 2018		
											$MMtCO_2e$	%	Trend
Agriculture	36.38	37.91	36.78	35.77	37.39	39.00	39.49	41.71	38.60	37.82	-0.78	-2.02%	↓
Power Plants	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57	-6.30	-20.41%	↓
Residential, Commercial, and Industrial Fuel Use	31.23	31.44	29.96	32.82	32.82	31.54	29.45	32.05	32.07	36.58	4.52	14.08%	↑
Industrial Processes	4.79	4.50	5.18	5.07	5.12	5.09	5.34	7.10	7.40	7.37	-0.03	-0.35%	↓
Natural Gas Transmission and Distribution	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42	0.01	0.64%	↑
Transportation	19.41	19.58	19.59	19.46	19.55	20.02	20.12	20.42	19.92	20.15	0.23	1.14%	↑
Waste	2.01	1.94	2.15	1.96	1.93	2.14	2.16	2.15	2.15	2.16	0.00	0.21%	↑
Total Gross Emissions	**137.54**	**135.74**	**130.82**	**129.55**	**131.67**	**128.65**	**123.30**	**131.32**	**132.42**	**130.07**	**-2.35**	**-1.77%**	↓
Carbon Stored in LULUCF[2]	-9.08	-11.78	-12.64	-8.46	-6.44	-7.26	-9.77	-9.49	-8.72	-8.82	-0.10	1.15%	↑
Total Net Emissions	128.45	123.96	118.18	121.09	125.23	121.39	113.53	121.83	123.70	121.25	-2.45	-1.98%	↓

[1] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values may not match values in the previous inventory published by the DNR in December 2019. Any adjustments are described in detail in the Technical Support Document.

[2] Carbon stored by the LULUCF sector is shown as a negative number.

Figure 1: Iowa Gross GHG Emissions 2010 – 2019 ($MMtCO_2e$)

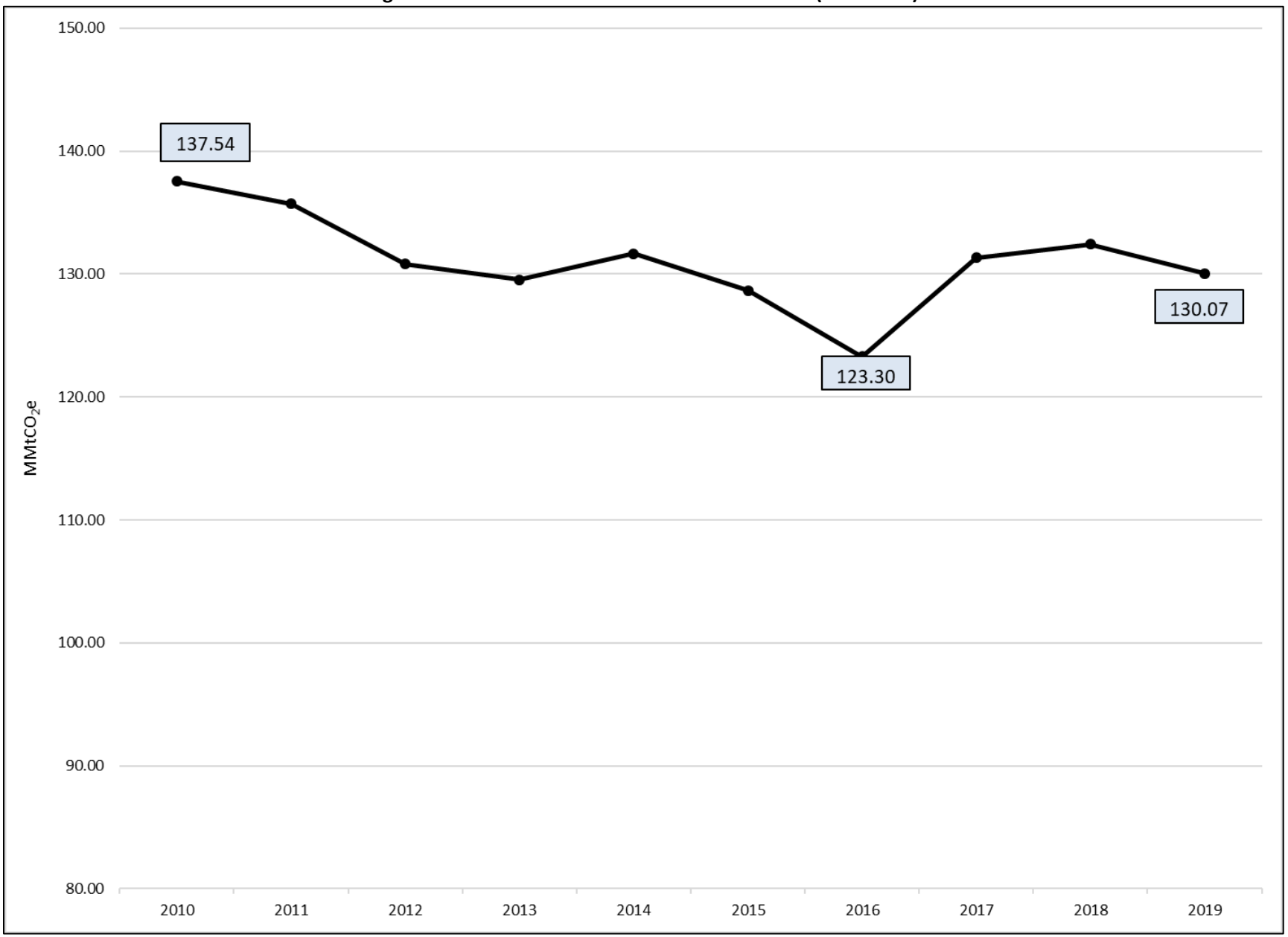
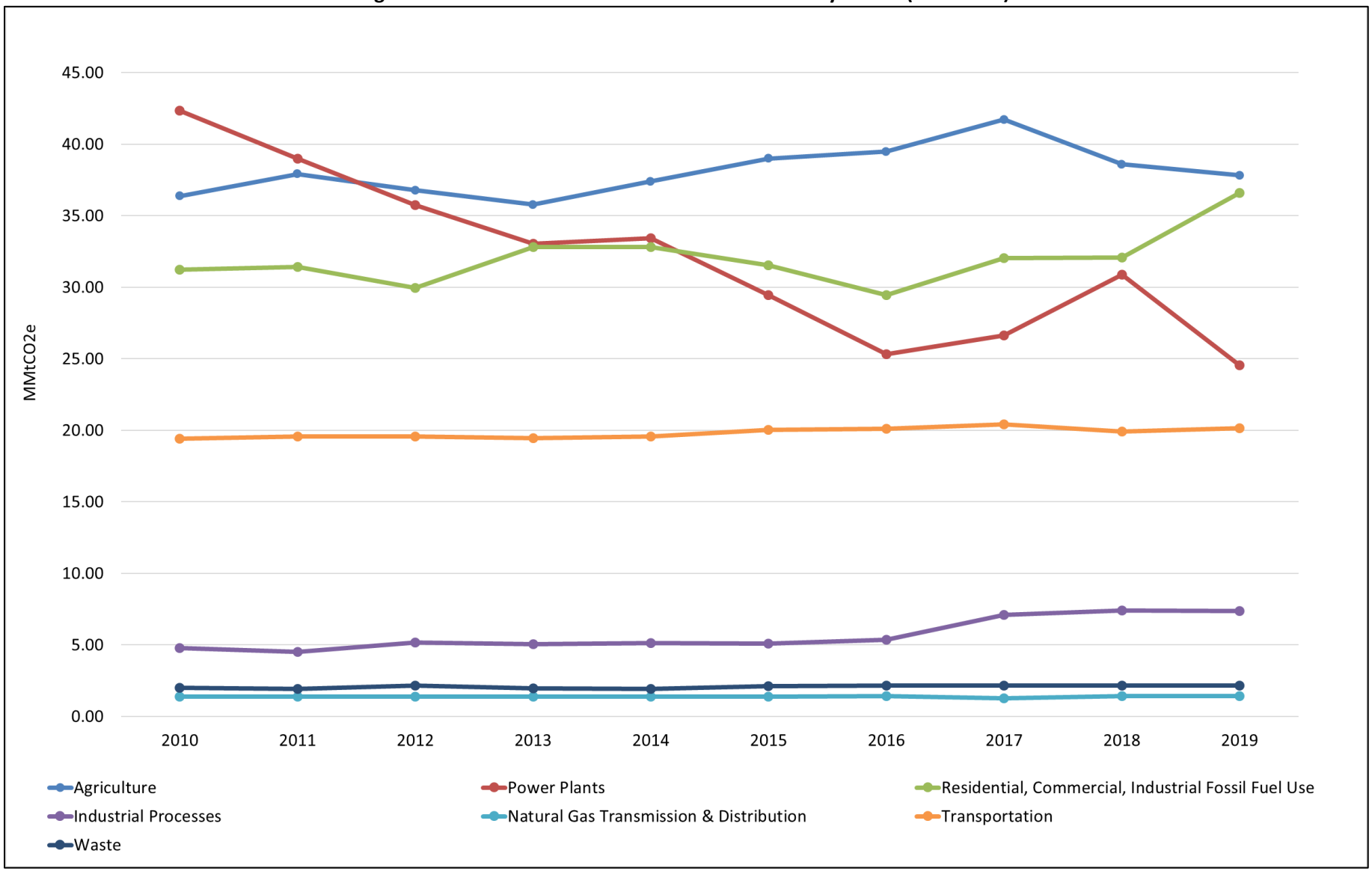


Figure 2: Iowa Gross[3] GHG Emissions 2010 – 2019 by Sector ($MMtCO_2e$)

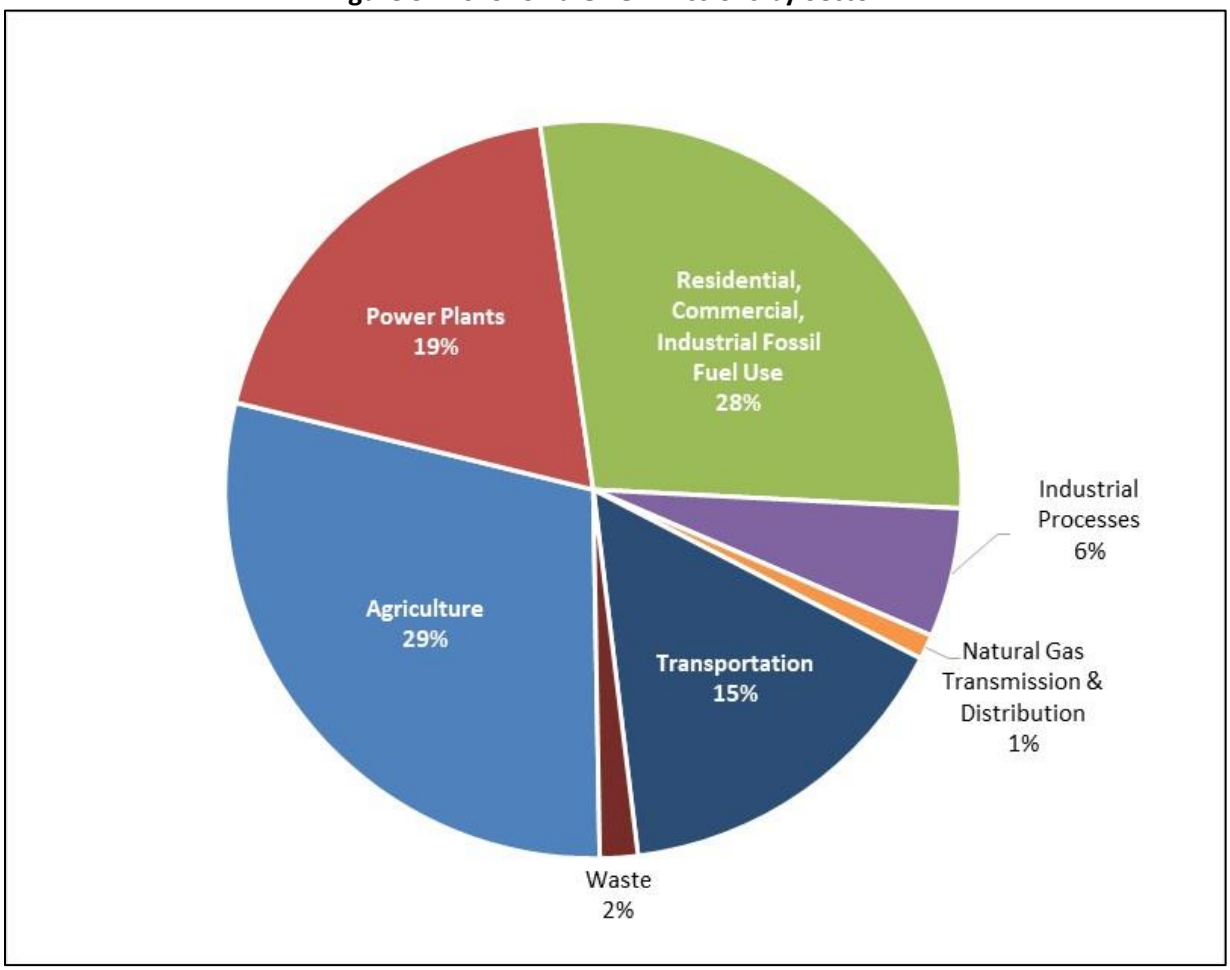


[3] Does not include carbon storage from land use, land use change, and forestry (LULUCF).

GHG Emissions by Sector

The majority of GHG emissions in Iowa in 2019 were from the agriculture sector (29%), followed by emissions from the residential/commercial/industrial (RCI) sector (28%), and fossil fuel use by power plants (19%), as shown in Figure 3. The emissions from these, and other sectors, are summarized below and are ordered as presented in the TSD. Please refer to the 2019 GHG Inventory Technical Support Document for more information on a specific sector, such as sources of input data, calculations, and uncertainty.

Figure 3: 2019 Iowa GHG Emissions by Sector[4,5]



Agriculture

This sector includes GHG emissions from livestock and crop production, such as enteric fermentation, manure management, and agricultural soils. Enteric fermentation includes emissions from the digestive systems of ruminant animals. Emissions from agricultural soils include emissions from manure, runoff, plant fertilizers, plant residues, and cultivation of highly organic soils. GHG emissions from fossil-fuel fired agricultural equipment (such as tractors) are included in the transportation sector. As shown in Table 2, total agriculture emissions

[4] Industrial fossil fuel use refers to GHG emissions from fossil fuels combusted by industrial facilities. Industrial processes means GHGs emitted during the production of or use of specific products such as ammonia, urea, nitrogen, cement, iron, steel, lime, etc.

[5] Does not include Land Use, Land Use Change, and Forestry (LULUCF). LULUCF was an emissions sink in 2019.

decreased 2.02% between 2018 and 2019. Emissions from agricultural soil management exhibited the largest change, decreasing 3.38%, due to a decrease in the amount of soybeans grown, which fix nitrogen but also emit N_2O from the integration of plant residues. Manure management emissions were lower, as the cattle population decreased. Emissions from enteric fermentation decreased slightly, due to the mainly stable animal census with a slight decrease in heifer stockers.

Table 2: GHG Emissions from Agriculture ($MMtCO_2e$)

Category	2018	2019	% Change
Enteric Fermentation	8.69	8.66	-0.37%
Manure Management	8.20	8.19	-0.18%
Agricultural Soil Management	21.70	20.97	-3.38%
Total	**38.60**	**37.82**	**-2.02%**

Fossil Fuel Combustion

This sector includes GHG emissions from fossil fuels combusted in four categories: power plants, residential, industrial, and commercial (the residential, industrial, and commercial categories combine into one category called RCI). Together, these four categories account for 47.01% of Iowa's total GHG emissions. Table 3 shows an increase of 14.08% in emissions from RCI and a decrease of 20.41% in power plant emissions between 2018 and 2019.

Table 3: GHG Emissions from Fossil Fuel Combustion ($MMtCO_2e$)

Category	2018	2019	% Change
Residential, Commercial, Industrial (RCI)	32.07	36.58	14.08%
Residential	*4.42*	*5.31*	*20.23%*
Commercial	*3.83*	*4.14*	*8.17%*
Industrial	*23.83*	*27.14*	*13.89%*
Power Plants	30.87	24.57	-20.41%
Total	**62.93**	**61.15**	**-2.83%**

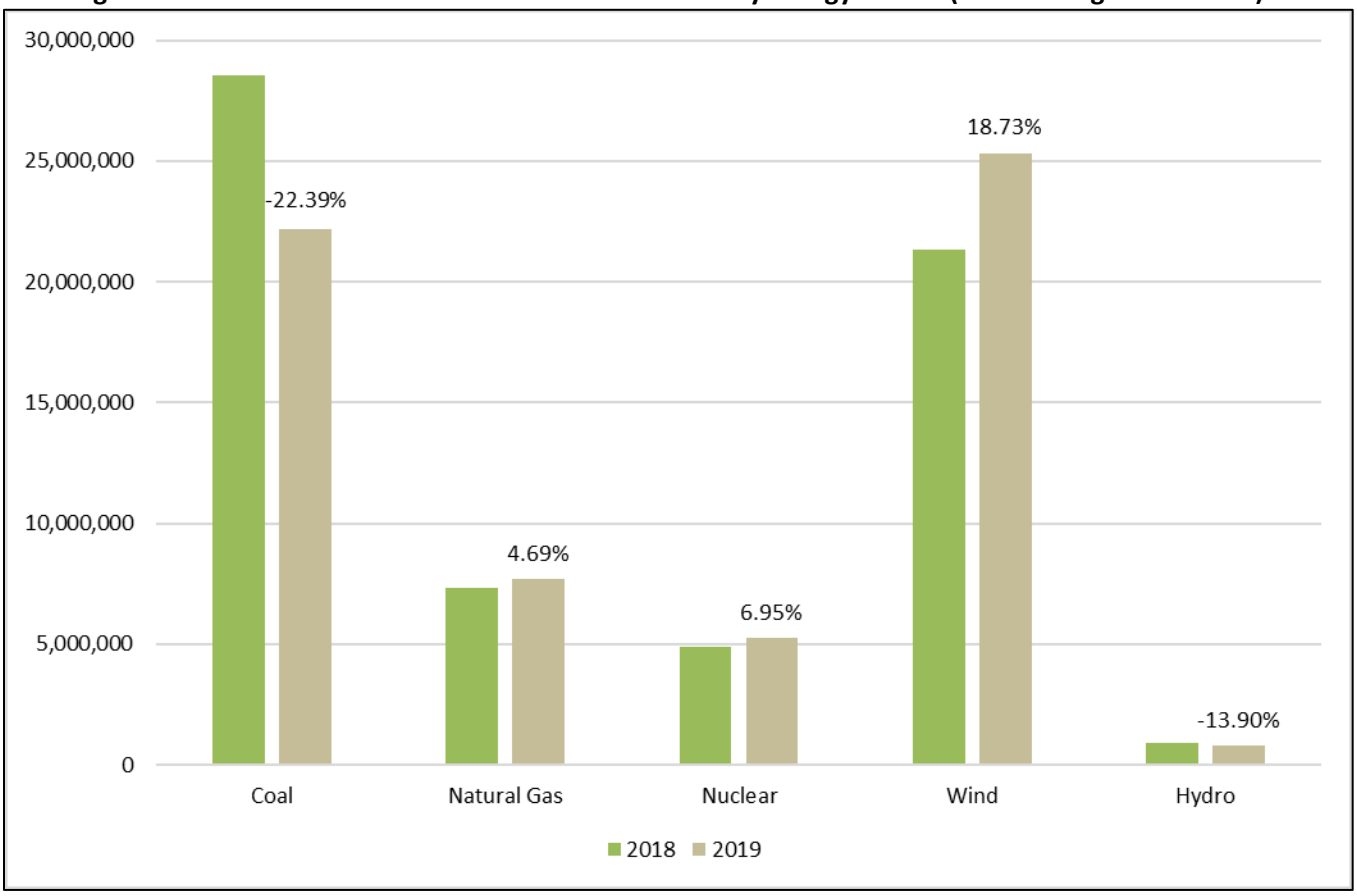
Residential, Commercial, and Industrial (RCI)

Actual fuel use data for 2019 for the RCI sector was not available from the U.S. Energy Information Administration (EIA), so emissions were calculated based on projected energy consumption values from the EIA's *Annual Energy Outlook 2019 with Projections to 2040.* Emissions predicted for 2018 from the RCI sector in last year's inventory (32.06 $MMtCO_2e$) were replaced with actual 2018 consumption values now available from EIA. The resulting recalculated 2018 emissions were 32.07 $MMtCO_2e$.

Power Plants

This category includes emissions from fossil fuels that are combusted at power plants to generate electricity. The DNR used emissions reported by power plants to EPA as required by the federal GHG reporting program (40 Code of Federal Regulations Part 98). Continuous emission monitoring systems (CEMS) measure the CO_2 emissions from these facilities. Emissions from power plants decreased 6.30 $MMtCO_2e$ (20.41%) from the previous year. As shown in Figure 4, from 2018 to 2019 electricity generation from nuclear and wind increased by 6.95% and 18.73% respectively (electricity generated by these sources does not contribute to GHG emissions).

Figure 4: 2018 and 2019 Net Iowa Electric Generation by Energy Source (Million Megawatt Hours)[6]



Industrial Processes

This sector includes non-combustion GHG emissions from a variety of processes including cement production, lime manufacturing, limestone and dolomite use, soda ash use, iron and steel production, ammonia production, nitric acid production, substitutes for ozone depleting substances (ODS), and electric power transmission and distribution. GHG emission trends in each process category vary, but overall total industrial process emissions decreased 0.35% from 2018 to 2019, as shown in Table 4.

GHG emissions reported by industrial facilities to EPA as required by the federal GHG reporting program were used for these categories: ammonia and urea production, cement manufacturing, iron and steel production, lime manufacturing, and nitric acid production. Emissions from the other categories were calculated using EPA's SIT.

[6] U.S. EIA: Net Generation by State by Type of Producer by Energy Source, September 22, 2020.

Table 4: GHG Emissions from Industrial Processes ($MMtCO_2e$)

Category	2018	2019	% Change[7]
Ammonia and Urea Production	3.26	3.14	-3.58%
Cement Manufacturing	1.30	1.21	-6.98%
Electric Power Transmission & Distribution Systems	0.06	0.05	-13.14%
Iron and Steel Production	0.19	0.18	-2.70%
Lime Manufacturing	0.16	0.17	+1.93%
Limestone and Dolomite Use	0.21	0.21	NA
Nitric Acid Production	0.73	0.78	+6.99%
Ozone Depleting Substances Substitutes	1.47	1.61	+9.53%
Soda Ash Consumption	0.02	0.02	-1.30%
Total	**7.40**	**7.37**	**-0.35%**

Natural Gas Transmission and Distribution (T & D)

This sector includes emissions from natural gas transmission and distribution systems in the state. GHG emissions increased 0.64% from 2018 as shown in Table 5, due to increases in the miles of pipeline and the number of customers/entities connected to natural gas service in the state.

Table 5: GHG Emissions from Natural Gas Transmission and Distribution ($MMtCO_2e$)[8]

Category	2018	2019	% Change
Transmission	0.7864	0.7842	-0.28%
Distribution	0.6209	0.6321	+1.80%
Total	**1.4073**	**1.4163**	**+0.64%**

Transportation

The transportation sector includes GHG emissions from both highway and non-highway vehicles. Non-highway vehicles include aviation, boats, locomotives, tractors, other utility vehicles, and alternative fuel vehicles. Emissions from highway vehicles are calculated based on vehicle miles traveled, while emissions from non-highway vehicles are calculated based on fuel consumption. Total vehicle miles traveled by Iowans increased 0.81% between 2018 and 2019, which contributed significantly to the overall 1.14% increase in transportation GHG emissions shown in Table 6.

Table 6: GHG Emissions from Transportation ($MMtCO_2e$)

Category	2018	2019	% Change[7]
Gasoline Highway	11.39	11.48	+0.75%
Diesel Highway	4.51	4.65	+3.15%
Non-Highway	4.00	4.00	NA
Alternative Fuel Vehicles	0.01	0.01	NA
Total	**19.92**	**20.15**	**1.14%**

[7] For categories marked as "NA," the DNR assumed 2019 values equal 2018 values due to a lack of more current data.

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

Waste

The waste sector includes GHG emissions from both solid waste landfills and the treatment of municipal and industrial wastewater. DNR used facility-specific emissions data directly reported to EPA by both solid waste landfills and industrial wastewater facilities. EPA's LandGEM model was used to estimate emissions from smaller landfills that are not required to report to EPA. Overall, GHG emissions from waste increased 0.21% from 2018 as shown in Table 7. Solid waste emissions increased because the quantity of waste landfilled increased 8.25%. Emissions from wastewater decreased primarily due to decreased wastewater emissions from industrial facilities

Table 7: GHG Emissions from Waste ($MMtCO_2e$)

Category	2018	2019	% Change
Solid Waste	1.671	1.677	+0.32%
Wastewater	0.483	0.482	-0.15%
Total	**2.154**	**2.159**	**+0.21%**

Land Use, Land Use Change, and Forestry (LULUCF)

The LULUCF sector includes emissions from liming agricultural soils and fertilizing lawns, golf courses, and other landscaping (settlement soils). It also includes carbon sequestered by forests and urban trees, carbon stored in yard trimmings and food scraps sent to landfills, and agricultural soil carbon flux.

Overall, 8.82 $MMtCO_2e$ of carbon was stored in the LULUCF sector in 2019, as shown in Table 8. This is a 1.15% increase in the amount of CO_2e being stored compared to 2018. This is attributed to a decrease in emissions from liming of agricultural soils.

Table 8: GHG Emissions by LULUCF ($MMtCO_2e$)

Category	2018	2019	% Change[9]
Forest Carbon Flux	-2.66	-2.66	NA
Liming of Agricultural Soils	0.40	0.28	-29.91%
Urea Fertilization	0.13	0.13	NA
Urban Trees	0.34	0.34	NA
Yard Trimmings & Food Scraps in Landfills	-0.08	-0.08	+0.16%
Fertilization of Settlement Soils	0.48	0.50	3.97%
Agricultural Soil Carbon Flux	-6.65	-6.65	NA
Total	**-8.72**	**-8.82**	**1.15%**

In previous years, the DNR used data from the USDA Forest Inventory Data Online (2010 – 2015) or Design and Analysis Toolkit for Inventory and Monitoring (2016 – 2018) to calculate forest carbon flux. However, in October 2020, EPA updated it's methodologies for states to calculate forest carbon flux. The new methodologies are consistent with those used by EPA in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2018*[10] and produced substantially different results than the former method used in previous years. Because 2019 forest carbon flux data is not available, 2018 was used as a proxy for 2019. More details are included in the 2019 GHG Inventory Technical Support Document.

[9] For categories marked as "NA," the DNR assumed 2019 values equal 2018 values due to a lack of more current data.

[10] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018, April 13, 2020.

GHG Emissions by Pollutant

The GHGs included in the inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFC), hydrofluorocarbons (HFC), and sulfur hexafluoride (SF_6). Table 9 shows the distribution of GHGs by pollutant in Iowa while Figures 5-8 show the distribution by both pollutant and by category.

Carbon dioxide is the greenhouse gas emitted in the highest amounts in Iowa, accounting for 65.67% of all greenhouse gas emissions in 2019. Nearly all CO_2 emissions are from fossil fuel combustion (at power plants and in the RCI sector) and transportation as shown in Figure 5, with a small percentage coming from industrial processes such as the production of cement, lime, ammonia, urea, iron and steel, as well as the use of limestone, dolomite, and soda ash in manufacturing.

Methane and nitrous oxide were emitted in smaller amounts, and the majority of these two pollutants are from agriculture as shown in Figures 6 and 7. Methane emissions were 19.31 $MMtCO_2e$ or 14.79% of total 2019 GHG emissions. Nitrous oxide emissions in 2019 were 23.85 $MMtCO_2e$ or 18.26% of total GHG emissions.

Emissions of HFCs, PFCs and SF_6 are accounted for in sub-sectors of the Industrial Processes sector as shown in Figure 8. They are emitted either from substitutes for ODS or from insulation (SF_6) in electric power transmission and distribution systems. In 2019, emissions of these three pollutants totaled 1.66 $MMtCO_2e$, or 1.27% of Iowa's 2019 total GHG emissions.

Table 9: 2019 GHG Emissions by Pollutant ($MMtCO_2e$)

Pollutant	2019
CO_2	85.75
CH_4	19.31
N_2O	23.85
HFC/PFC/SF_6	1.66
Total	**130.57**[11]

[11] Includes 0.50 $MMtCO_2e$ N_2O from settlement soils that is accounted for in the LULUCF category.

Figure 5: 2019 Carbon Dioxide Emissions by Sector

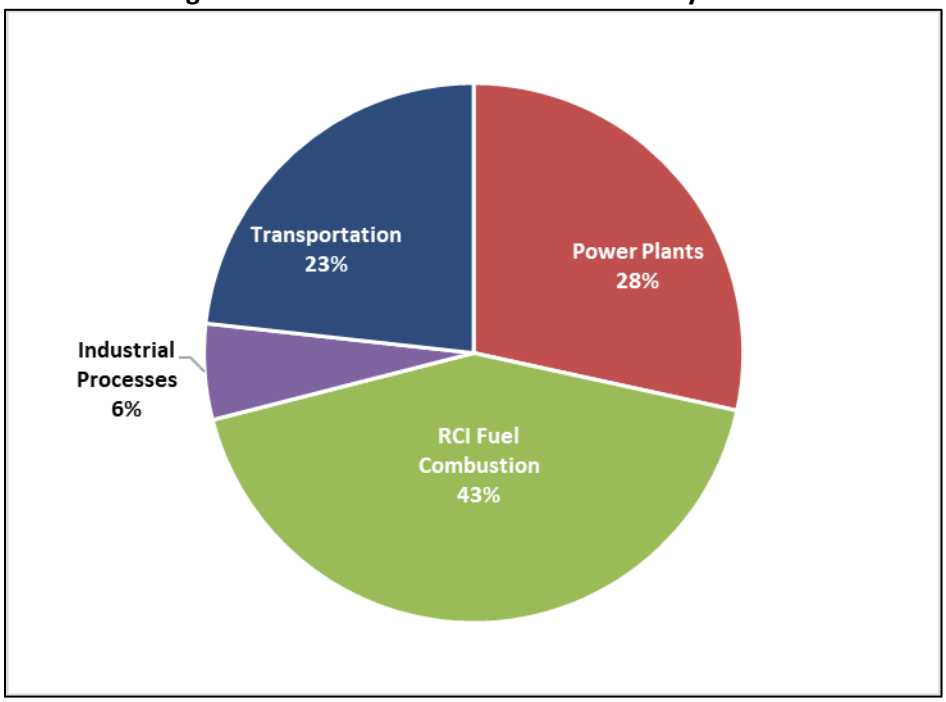


Figure 6: 2019 Methane Emissions by Sector

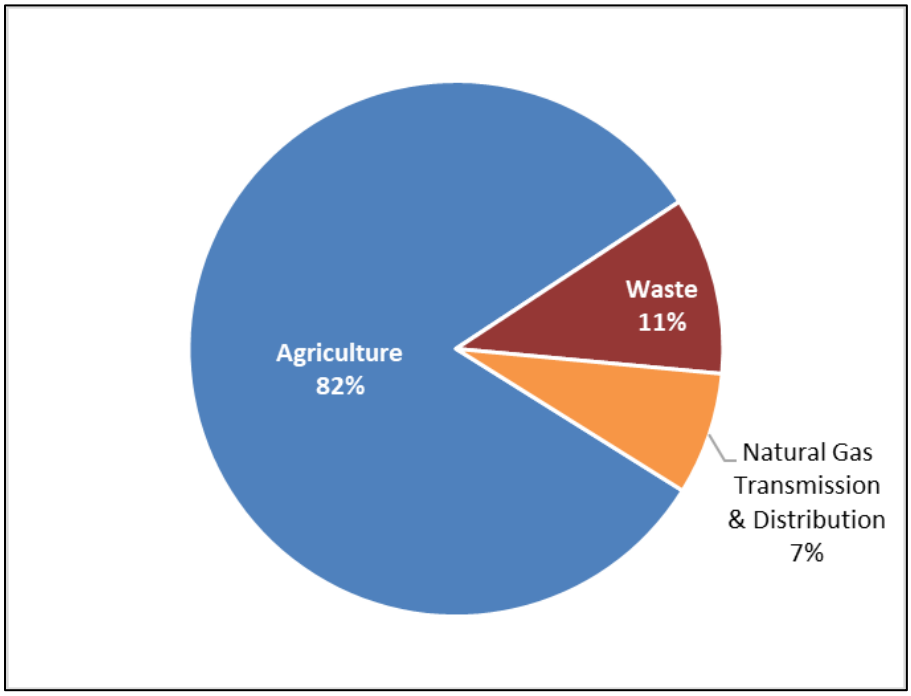


Figure 7: 2019 Nitrous Oxide Emissions by Sector

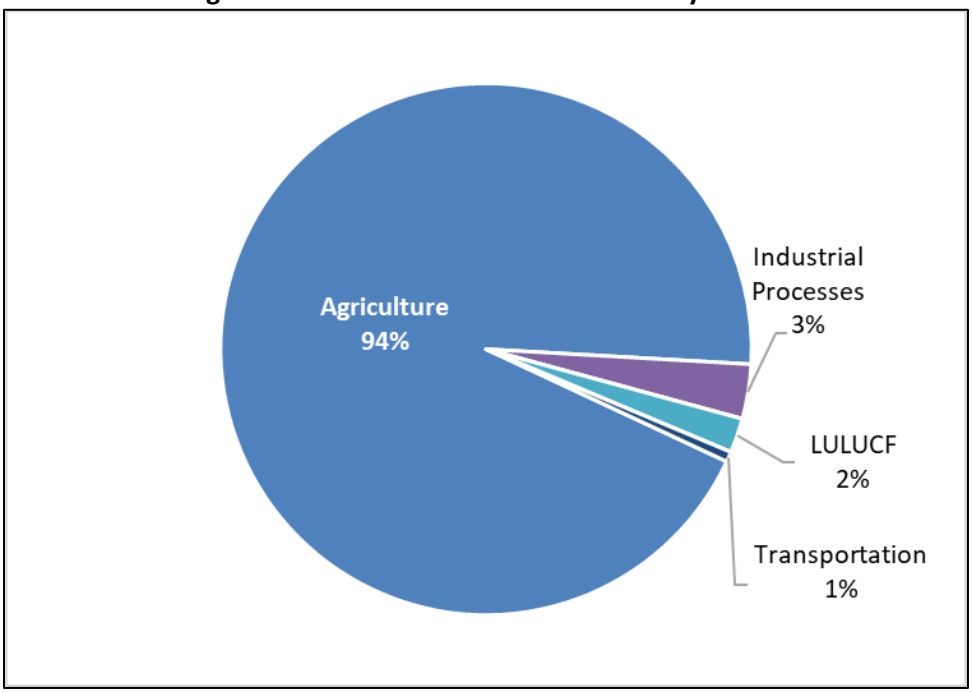
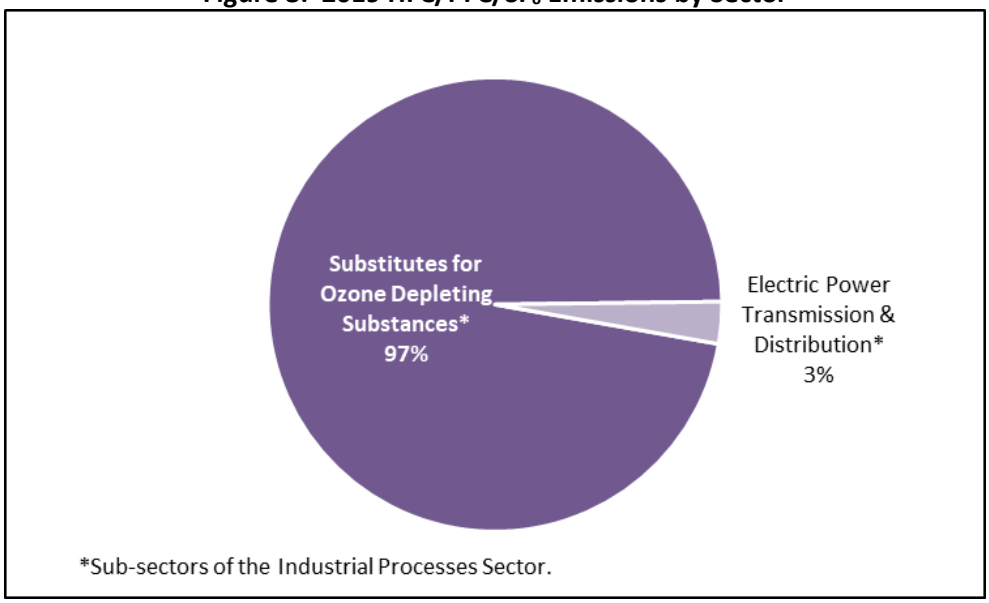


Figure 8: 2019 HFC/PFC/SF_6 Emissions by Sector



Comparison with U.S. Emissions

Comparing Iowa's GHG emissions with U.S. emissions requires the use of 2018 data because the 2019 national GHG inventory is not available yet. Figures 9 and 10 compare national and Iowa GHG emissions by sector. The fossil fuel combustion, natural gas transmission and distribution, and transportation sectors are combined into one sector called "Energy" to be consistent with the national GHG inventory. Nationally, the Energy sector represents a larger fraction of total GHG emissions than in Iowa. Agricultural emissions account for a greater percentage of GHG emissions in Iowa than in the total U.S., which is logical given Iowa's substantial agricultural

economy. Overall, Iowa's gross GHG emissions in 2018 were 132.42 $MMtCO_2e$. This represents 1.98% of the total 2018 U.S. gross GHG emissions of 6,676.60 $MMtCO_2e$.

Figure 9: 2018 U.S. GHG Emissions by Sector

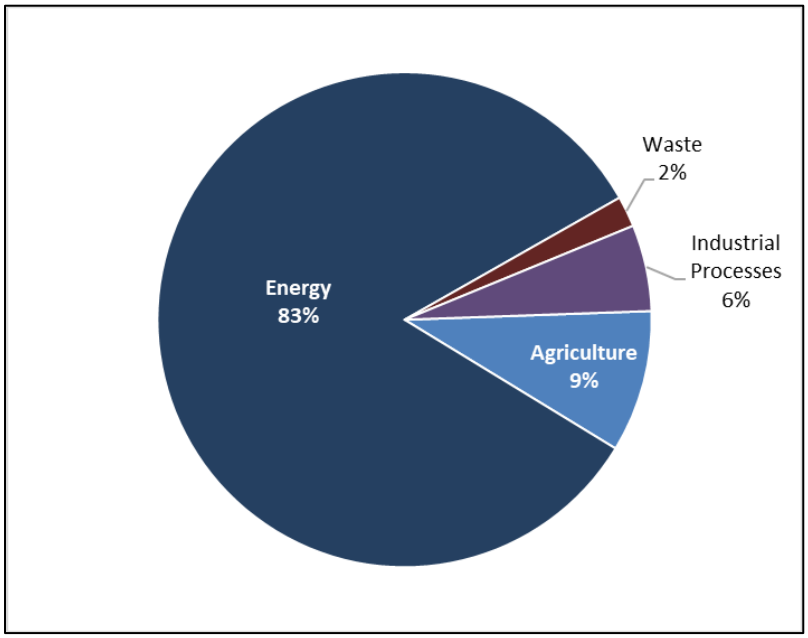
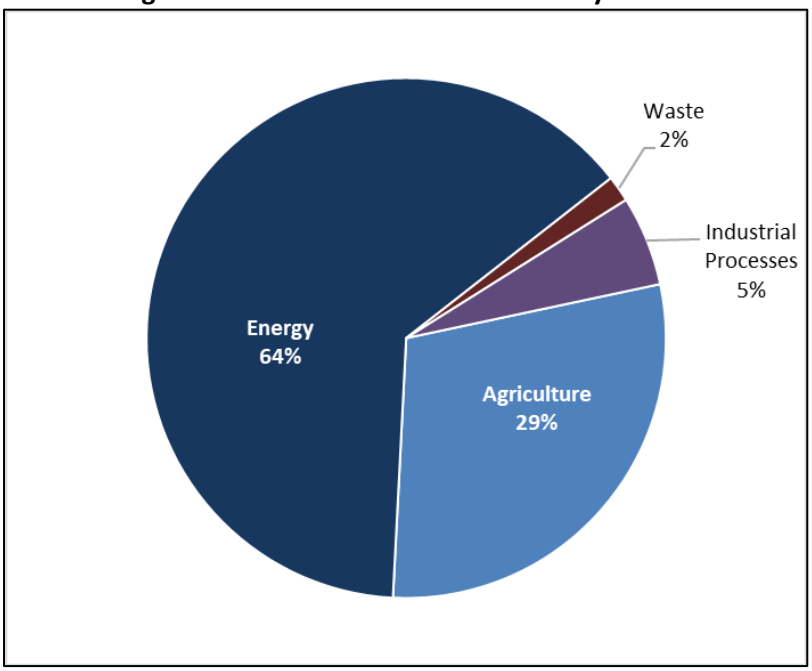


Figure 10: 2018 Iowa GHG Emissions by Sector



Future Emissions

Iowa Code 455B.104 requires that the DNR forecast trends in GHG emissions. Using the SIT Projection tool, the DNR projected emissions to 2020, 2025, and 2030 as shown in Table 10. The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2018, using a

combination of data sources and national projections for activity data. A 2019 "forecast" was also produced to help gauge the reasonableness of the projections.

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

1. Global Pandemic
   The global pandemic has affected the way Americans use energy. The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* on December 9, 2020, predicting that U.S. CO_2 emissions will "fall by 19% for coal, by 13% for petroleum, and by 2% for natural gas. Many of this year's changes in energy-related CO_2 emissions are attributable to the economic and behavioral effects the COVID-19 pandemic has had on energy consumption"[12] such as working at home and driving less.

2. Derecho
   On August 10th, a derecho caused severe crop and tree damage across portions of central and eastern Iowa. The DNR estimates 724,480 acres of forest and trees were lost across the 27 counties most directly impacted.[13] This will likely reduce the amount of carbon sequestered by forests in 2020, and it may continue to decrease in future years as damaged trees are affected by pests and disease. GHG emissions from crop production and agricultural soils will likely also be affected as about 20% of Iowa's total cropland was damaged by the derecho, affecting yields.[14]

3. Emissions from Power Plants
   Emissions from power plants will likely decrease as Iowa utilities shift away from burning coal to burning natural gas and installing renewable generation. However, emissions from power plants may also be affected by the economy, weather, future environmental regulations, electricity demand by customers, how electricity generation is dispatched by the grid operator, and other market forces.

Table 10: Projected Gross GHG Emissions 2019 – 2030 ($MMtCO_2e$)

	Calculated	Projected			
Sector	**2019**	**2019**	**2020**	**2025**	**2030**
Agriculture	37.82	43.35	44.48	50.16	55.84
Power Plants	24.57	25.56	22.78	21.91	22.21
RCI Fossil Fuel Use	36.58	33.25	32.77	33.12	33.43
Industrial Processes	7.37	5.93	6.48	7.90	8.99
Natural Gas T & D	1.42	1.35	1.54	1.64	1.65
Transportation	20.15	22.20	22.23	20.91	19.93
Waste	2.16	3.11	3.14	3.27	3.41
Total	**130.07**	**134.74**	**133.41**	**138.92**	**145.46**

As with many forecasts, numerous factors affect the certainty of the predictions. Such factors include the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, and other variables. Discrepancies between the data used to calculate

[12] EIA expects U.S. energy-related carbon dioxide emissions to fall 11% in 2020, December 9, 2020.
[13] Iowa DNR rises to meet derecho challenges, helps Iowans and their trees recover, September 10, 2020.
[14] Iowa derecho in August was most costly thunderstorm disaster in U.S. history, October 17, 2020.

the 2019 GHG inventory and the assumptions within the SIT Projection Tool reduce confidence in the projections as the Tool is not configured to include 2019 activity data. For example, the Tool projects that agriculture emissions will continue to increase at the rate they did from 1990 – 2017, when 2018 and 2019 calculated agriculture emissions actually decreased. The TSD provides a more detailed discussion of forecast uncertainty.

Future Improvements

The DNR continually strives to make the annual statewide GHG inventory as accurate and timely as possible. Possible areas for enhancement include improved calculation methodologies for the wastewater sector to address land application of biosolids and improved forecasting.

IOWA DEPARTMENT OF
NATURAL RESOURCES

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	basic oxygen furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CEMS	continuous emission monitoring system
CH_4	methane
CO_2	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CRP	Conservation Reserve Program
DATIM	Design and Analysis Toolkit for Inventory and Monitoring
DNR	Iowa Department of Natural Resources
DOT	United States Department of Transportation
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GWP	global warming potential
HDGV	heavy duty gas vehicle
HDDV	heavy duty diesel vehicle
IDALS	Iowa Department of Agriculture and Land Stewardship
IDOT	Iowa Department of Transportation
IEA	International Energy Agency
IEDA	Iowa Economic Development Authority
ILPA	Iowa Limestone Producers Association
IPCC	Intergovernmental Panel on Climate Change
LDC	local distribution company
LDDT	light duty diesel truck
LDDV	light duty diesel vehicle
LDGT	light duty gasoline truck
LDGV	light duty gasoline vehicle
LULUCF	land use, land use change, and forestry
MC	motorcycle
MMtC	million metric tons carbon
$MMtCO_2e$	million metric tons carbon dioxide equivalent
MISO	Midcontinent Independent System Operator
MSW	municipal solid waste

Acronyms and Key Terms (Continued)

N	nitrogen
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NO_3-	nitrates
NO_2-	nitrites
NO_x	nitrogen oxides
N_2O	nitrous oxide
NRCS	Natural Resources and Conservation Service
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
RCI	residential, commercial, and industrial
SEDS	EIA's State Energy Data System
SF_6	sulfur hexafluoride
SIT	State Inventory Tool
T & D	transmission and distribution
TSD	technical support document
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	vehicle miles traveled
WRI	World Resources Institute

Chapter 1 – General Calculation Method

Iowa Code 455B.104 requires that "by December 31 of each year, the department shall submit a report to the governor and the general assembly regarding the greenhouse gas (GHG) emissions in the state during the previous calendar year and forecasting trends in such emissions…." This Technical Support Document (TSD) provides documentation and additional calculations to support the *2019 Iowa Statewide Greenhouse Gas Emissions Inventory Report*. Total Iowa GHG emissions from 2010 – 2019 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 – 2018, 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	10/06/20	CH_4, N_2O
Energy	CO_2FFC	11/05/18	CO_2
	Stationary Combustion	11/05/18	CH_4, N_2O
Industrial Processes	IP	10/06/20	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission & Distribution	Natural Gas and Oil	11/05/18	CH_4
Transportation	Mobile Combustion	10/06/20	CO_2, CH_4, N_2O
Waste	Solid Waste	11/05/18	CO_2, CH_4
	Wastewater	11/05/18	CH_4, N_2O
Land Use, Land Use Change, and Forestry	LULUCF	10/06/20	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	11/05/18	CO_2
Future Emissions	Projection Tool	10/06/20	CO_2, CH_4, N_2O, HFC, PFC, SF_6

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

Global Warming Potentials (GWP)

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

Equation 1:

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

Where:

GHG_i = Mass emissions of each greenhouse gas

GWP_i = Global warming potential for each greenhouse gas

n = the number of greenhouse gases emitted

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

Table 2: Global Warming Potentials

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

Chapter 2 - Agriculture

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

GHG emissions are emitted from four agricultural sectors in Iowa – enteric fermentation, manure management, agricultural soils, and agricultural burning. The GHGs emitted are methane (CH_4) and nitrous oxide (N_2O). Table 3 summarizes the source of GHG emissions in each sector. N_2O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2020b).

Table 3: Sources of Agricultural GHG Emissions in Iowa

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

Method

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated October 6, 2020 (ICF 2020a and 2020b).

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	2019	2019 Iowa Agricultural Statistics Bulletin (USDA 2019)
Beef cattle		
Sheep		
Breeding swine		
Market swine under 60 lbs.[2]		
Market swine 60 – 119 lbs.[3]		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Goats	2017 census value used as proxy for 2019	USDA-NASS Quick Stats (USDA 2020)
Horses		
Chickens		
Hens		
Broilers		
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 Soils

N_2O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2020). N_2O is emitted when the natural processes of denitrification and nitrification interact with agricultural practices that add or release nitrogen (N) in the soil profile. Denitrification is the process of converting nitrate to nitrogen gas. It is carried out by microorganisms in an oxygen-lacking environment. Nitrification occurs when ammonia is converted to nitrites and nitrates by naturally occurring, specialized bacteria in the environment.

Direct N_2O emissions occur at the site of application of both synthetic and organic fertilizers to the soil, production of N-fixing crops, and integration of crop residues into the soil by practices such as cultivation. Indirect emissions occur when N is made available or is transported to another location following volatilization, leaching or runoff, and is then converted to N_2O (EPA 2020).

Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2020) 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.

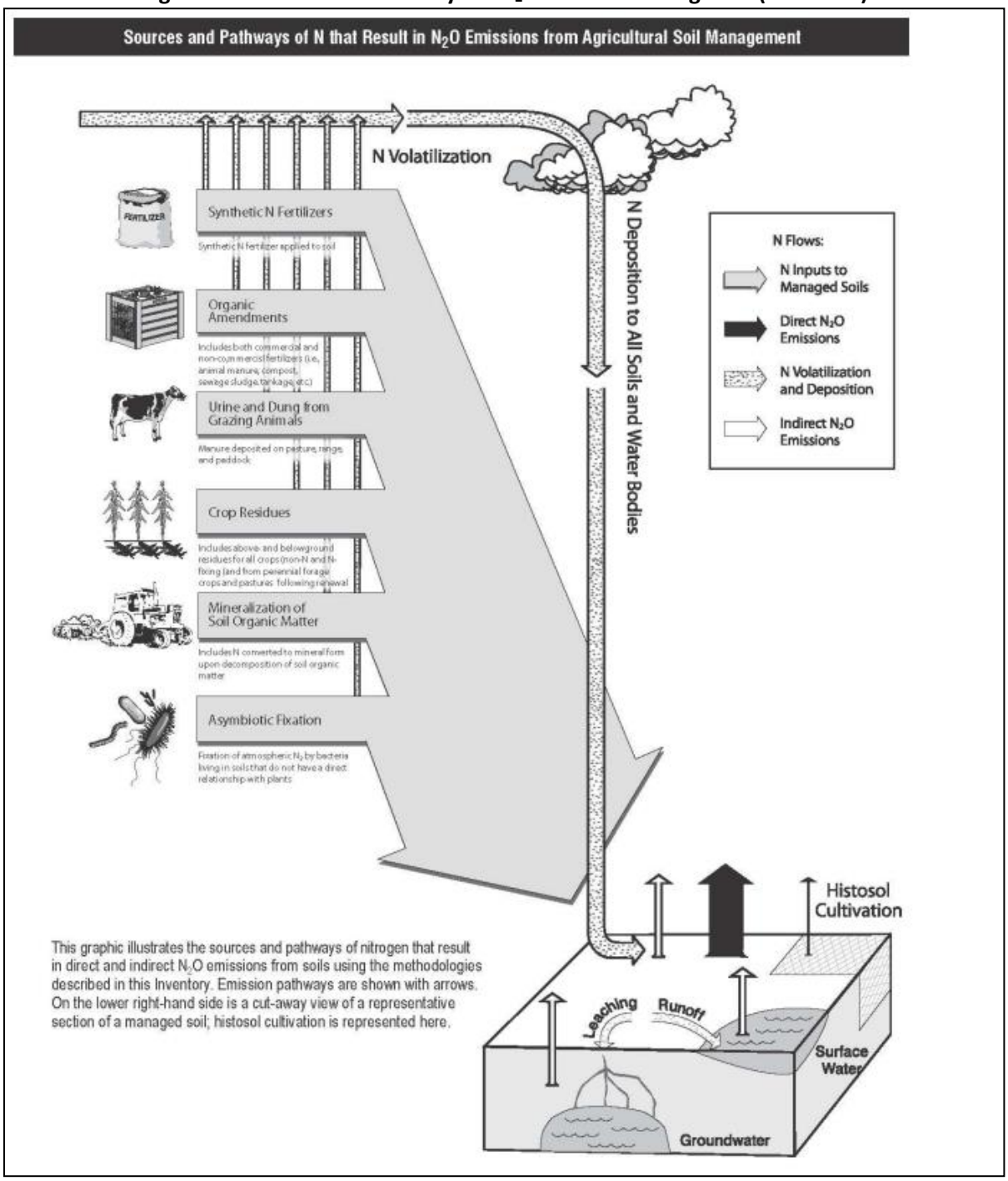
Soil Cultivation - Nitrous Oxide (N_2O)

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

[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.

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 2019) and by the average percentage of each crop that is tilled (Sucik 2011b). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, "…all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a histosol would require some type of artificial drainage in order to be consistently row cropped" (Sucik 2011a).

Figure 1: Sources and Pathways of N_2O Emissions in Ag Soils (EPA 2020)



Fertilizer Utilization

The DNR calculated fertilizer emissions for 2019 using fertilizer tonnages from the *2019 Iowa Agriculture Statistics Bulletin* (USDA 2019). The IDALS fertilizer data is provided per the 2018 growing season, which is from July 2017 – June 2018. Previous years have been calculated from data provided by the IDALS *Fertilizer Tonnage Distribution in Iowa* report (Krutzfeldt 2019), but IDALS no longer supports this report. Therefore, the 2018 growing season was then as a proxy for the 2019 growing season (July 2018 – June 2019) and the first half of the 2020 growing season (July 2019 – December 2019).

Agricultural Soil Carbon Flux

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

Adjustments

Since the DNR's 2018 GHG Inventory Report was published in December 2019, the 2018 emissions from enteric fermentation, manure management, and agricultural soils have been updated as shown in Table 5 using revised activity data (such as animal populations or fertilizer application) from USDA or IDALS as follows:

- 2018 populations of bulls, steer stockers, heifer stockers, market swine and breeding swine were updated to match revised values in the 2019 Iowa Annual Statistics Bulletin (USDA 2019).
- Tons of soybeans produced, acres of soybeans harvested, and acres of corn harvested in 2018 were updated to match revised values in the USDA's Quick Stats database (USDA 2020)

Table 5: Recalculated Agricultural Emissions ($MMtCO_2e$)

Category	2018 Value (Published Dec. 2019)	2018 Updated Value
Enteric Fermentation	8.45	8.69
Manure Management	11.70	8.20
Agricultural Soils	21.48	21.70
Total	**41.63**	**38.60**

Results

GHG emissions from agriculture decreased 3.38% from 2018 – 2019 but increased 3.96% from 2010 – 2019. Gross GHG emissions from agriculture were 37.82 $MMtCO_2e$ in 2019, or 29.08% of Iowa's total gross 2019 GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. Just over half of the agricultural emissions (55.45%) are from soils as shown in Figure 2 and Table 6.

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

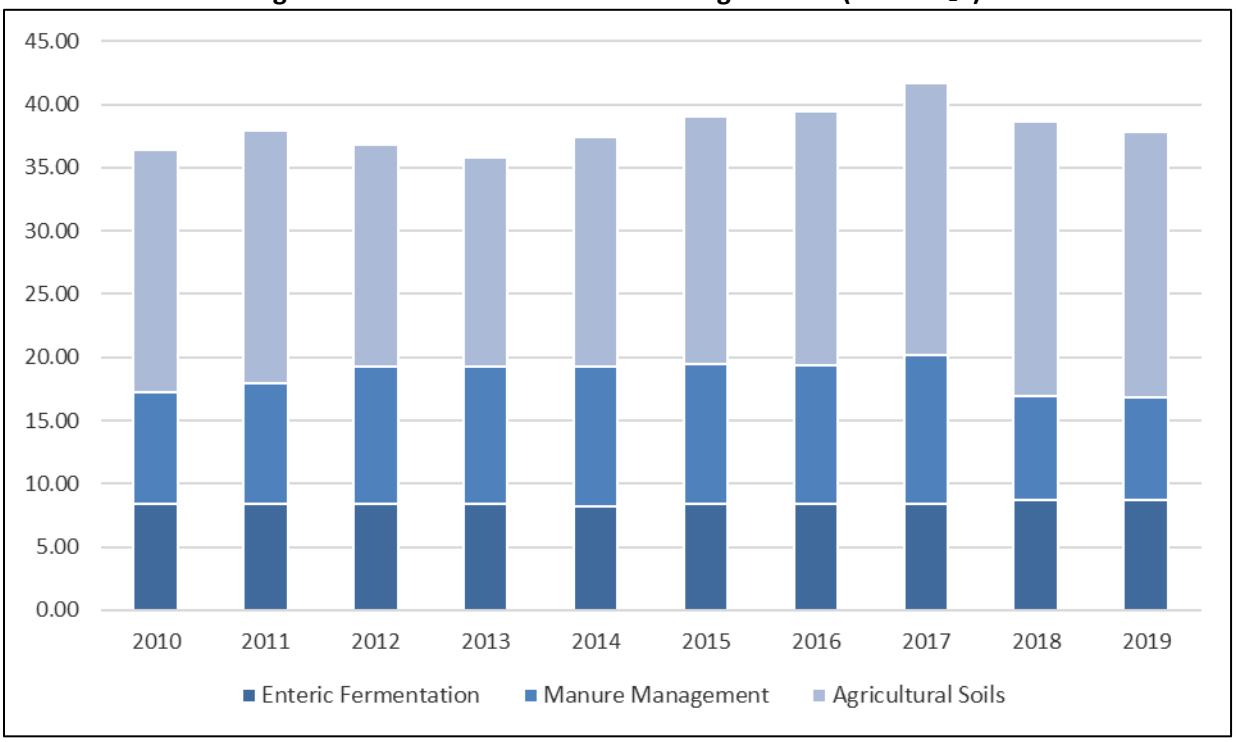


Table 6: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[4]

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Enteric Fermentation	8.39	8.41	8.40	8.38	8.19	8.36	8.43	8.40	8.69	8.66
Manure Management	8.83	9.53	10.86	10.85	11.06	11.07	10.96	11.75	8.20	8.19
Agricultural Soils	19.16	19.98	17.53	16.55	18.14	19.58	20.09	21.56	21.70	20.97
Total	**36.38**	**37.91**	**36.78**	**35.77**	**36.39**	**39.00**	**39.49**	**41.71**	**38.60**	**37.82**

Enteric Fermentation

CH_4 emissions from enteric fermentation were 8.66 $MMtCO_2e$ in 2019, decreasing 0.37% from 2018. This can be attributed to a 0.57% decrease in the total cattle population. While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 3, enteric fermentation emissions are primarily driven by cattle. This is because cattle emit more CH_4 than other ruminant animals due to their unique stomach. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 7.

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

Figure 3: 2019 Iowa Animal Populations (USDA 2019, 2020)[5]

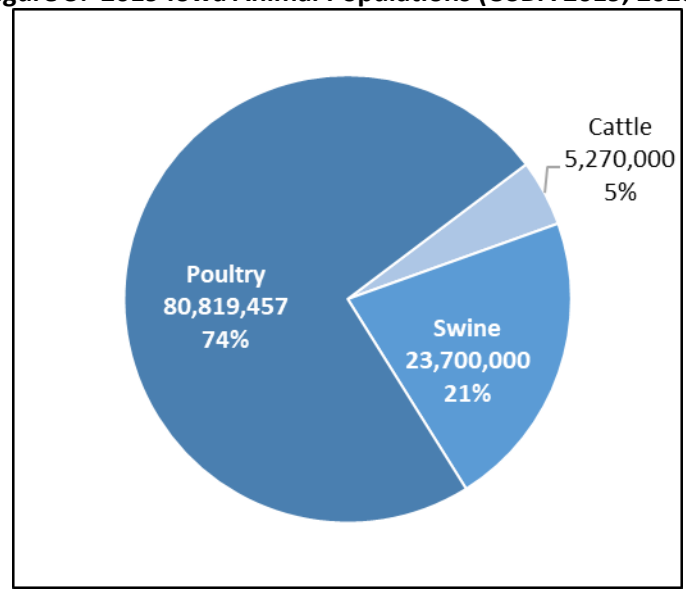


Table 7: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2020a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.2 – 139.7
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management decreased 0.18% from 2018 and accounted for 21.64% of agricultural GHG emissions in 2019.

Agricultural Soils

The majority of GHG emissions from agricultural soils can be attributed to crop production (fertilizers, crop residues, and nitrogen fixing) as shown in Figure 4. Production of corn and oats increased in 2019 while there was a decrease in production of soybeans, as shown in Table 8. Production of alfalfa and oats also increased while wheat, rye, pea, and sorghum production remained constant. This led to an overall decrease in N_2O emissions from agricultural soils of 3.38% from the previous year. N_2O emissions from agricultural soils accounted for 55.45% of all agricultural GHG emissions and 16.12% of total gross statewide GHG emissions in 2019.

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

Figure 4: 2018 - 2019 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)

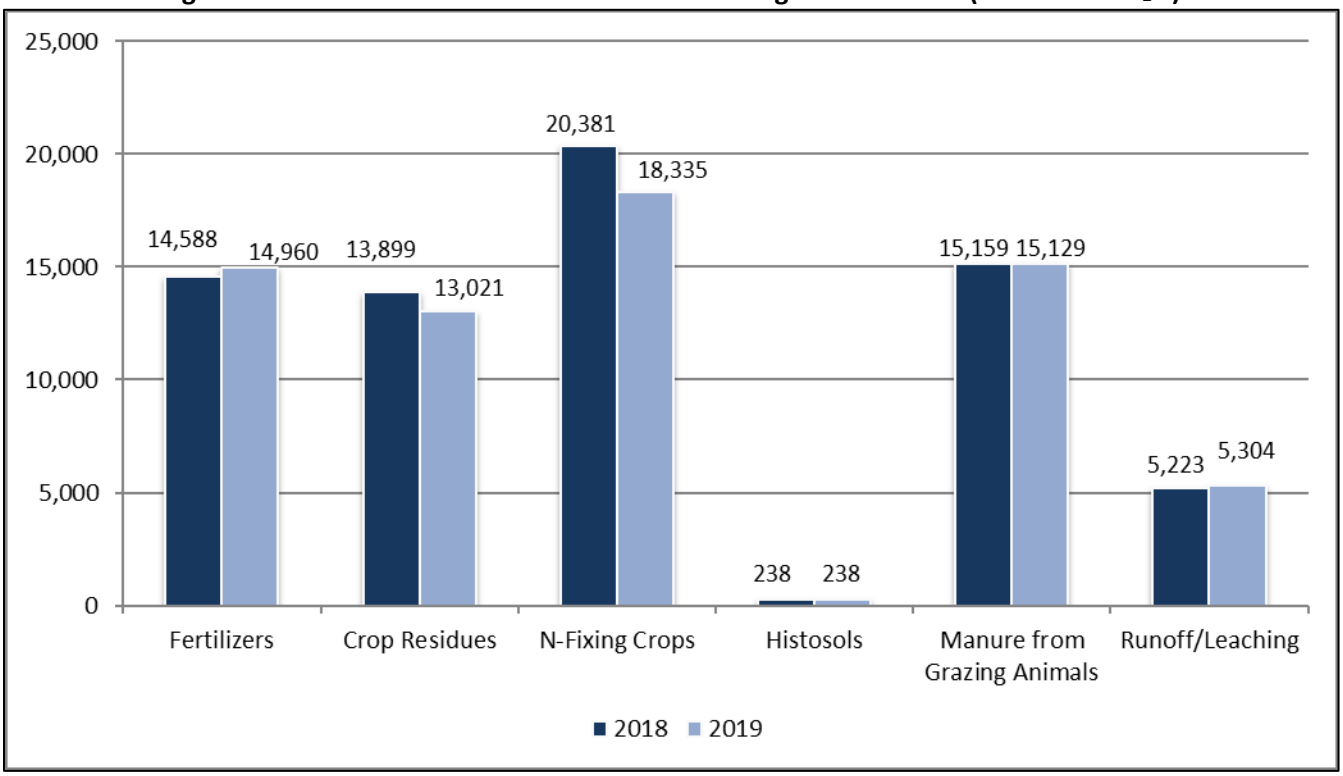


Table 8: Iowa Crop Production 2018 – 2019 (USDA 2020)

Crop	2018 (1000 Bushels)	2019 (1000 Bushels)
Barley	54	54
Corn for Grain	2,508,800	2,583,900
Oats	2,079	4,002
Rye	247	247
Sorghum for Grain	25	25
Soybeans	564,870	501,600
Wheat	348	348
Total	**3,076,424**	**3,090,176**
Crop	**2018 (1000 tons)**	**2018 (1000 tons)**
Alfalfa	2,294	2,690
Crop	**2018 (1000 CWT)**	**2018 (1000 CWT)**
Peas, Dry Edible	11	11

Uncertainty[6]

Enteric Fermentation

The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the quality of the animal population estimates and the emission factors used for each animal type. Uncertainty is also introduced as animal populations are not constant, but vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. The emission factors for a given animal type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2020a).

[6] This information is largely excerpted from the *SIT Agriculture Module* (ICF 2020a).

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.

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 2018a-d). These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 9:

Table 9: Fuel Types Included in Fossil Fuel Consumption

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

The modules include energy consumption data for 1990 – 2018 from U.S. Energy Information Administration (EIA) State Energy Data System (SEDS) (EIA 2020b). Because Iowa-specific 2019 energy consumption data will not be published by the EIA until June 2021, the DNR projected 2019 energy consumption using projections provided by EPA in the SIT Projection Tool (ICF 2020a). These projections are based on the EIA's *Annual Energy Outlook (AEO) 2020 with Projections to 2050* (EIA 2020a) and applied to the SEDS consumption data.

Power Plants
Emissions from electricity generation at power plants were not calculated using fuel consumption data. Depending on the year, emissions from either EPA's Clean Air Markets Division (CAMD 2020) or EPA's federal GHG Reporting Program (EPA 2020) 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 - 2019
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 2018 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2018 energy data was released by EIA in June 2020 (EIA 2020b), so the DNR used the data to recalculate 2018 emissions as shown in Table 10.

Table 10: Recalculated RCI Emissions ($MMtCO_2e$)

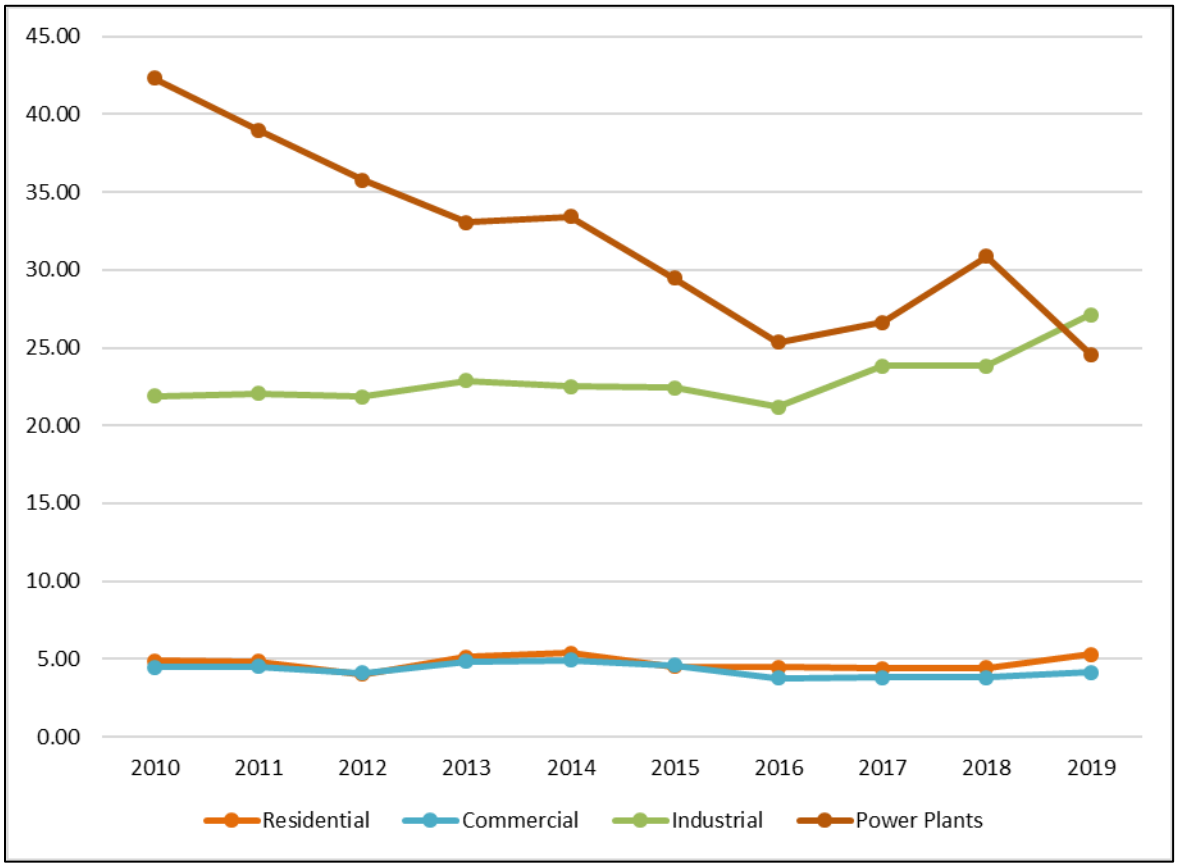
Category	2018 Value (Published Dec. 2019)	2018 Updated Value
Residential	4.41	4.42
Commercial	3.83	3.83
Industrial	23.83	23.83
Total	**32.06**	**32.07**

Results
Total GHG emissions from fossil fuel consumption in 2019 were 61.15 $MMtCO_2e$, a decrease of 2.83% from 2018 and a decrease of 16.87% from 2010 levels as shown in Table 11 and Figure 5. Emissions from three categories (residential, commercial, and industrial fuel use) increased from the previous year (+14.08%), while emissions from power plants decreased by 6.30 $MMtCO_2e$ (-20.41%).

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

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Residential	4.88	4.85	4.01	5.12	5.38	4.49	4.48	4.41	4.42	5.31
Commercial	4.48	4.52	4.11	4.83	4.92	4.60	3.77	3.82	3.83	4.14
Industrial	21.88	22.07	21.84	22.87	22.52	22.44	21.21	23.82	23.83	27.14
Power Plants	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57
Total	**73.56**	**70.42**	**65.72**	**65.89**	**66.26**	**61.00**	**54.78**	**58.97**	**62.93**	**61.15**

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



As noted above, emissions from fossil-fuel fired power plants in 2019 decreased to their lowest level within the 2010-2019 timeframe. Despite a 15.97% increase in emissions in 2018, the overall trend in power plant emissions is downward. Annual emissions from electric power plants fluctuate due to differences in how electricity generation is dispatched by the grid operator, electricity demand by customers, other market forces, and changes in weather that affect the number of heating and cooling days per year.

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

CO_2 Uncertainty[8]

The amount of CO_2 emitted from energy consumption depends on the type and amount of fuel that is consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Therefore, the more accurate these parameters, the more accurate the estimate of direct CO_2 emissions. Nevertheless, there are uncertainties associated with each of these parameters.

More uncertainty exists in state-level data than national total energy consumption data, especially when allocating consumption to the individual end-use sectors (i.e. residential, commercial, and industrial). The amount or rate at which carbon is emitted to the atmosphere can vary greatly depending on the fuel and use, and may vary at the state-level compared to the national default levels in the SIT.
The uncertainty in carbon content and oxidation are much lower than with fuel consumption data. Carbon contents of each fuel type are determined by EIA by sampling and the assessment of market requirements, and, with the exception of coal, do not vary significantly from state to state. EIA 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.

[8] This information is largely excerpted from the *SIT CO_2FFC Module* (ICF 2018a).
[9] This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2018b).

Chapter 4 - Industrial Processes

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

Table 12: Industrial Processes and GHG Emissions

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

Ammonia Production 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 2020b).

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 2020b). 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 2020b).

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 2020b).

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

Soda Ash Use
Soda ash is currently only produced in three states – Wyoming, Colorado, and California. However, commercial soda ash is used as a raw material in a variety of industrial processes and in many familiar consumer products such as glass, soap, and detergents (ICF 2020b). 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 2019 emissions from industrial processes were calculated using either the SIT (ICF 2020a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2020a) as shown in Table 13.

Table 13: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2019	40 CFR 98 Subpart G	GHGRP (EPA 2020a)
Cement Production	2019	40 CFR 98 Subpart H	GHGRP (EPA 2020a)
Electric Power Transmission & Distribution	2018 as proxy for 2019	SIT	National GHG Inventory (EPA 2020b)
Iron and Steel Production	2019	40 CFR 98 Subpart Q	GHGRP (EPA 2020a)
Lime Manufacture	2019	40 CFR 98 Subpart S	GHGRP (EPA 2020a)
Limestone and Dolomite Use	2015 as proxy for 2016 - 2019	SIT	(USGS 2017)
Nitric Acid Production	2019	40 CFR 98 Subpart V	GHGRP (EPA 2020a)
ODS Substitutes	2018 as proxy for 2019	SIT	National GHG Inventory (EPA 2020b)
Semiconductor Manufacturing	2019	SIT	SIT defaults
Soda Ash Use	2019	SIT	(USGS 2020)

Categories Calculated using the SIT

Because current emissions data was not available for electric power transmission and distribution, the 2018 national emissions were used as a proxy for 2019. The 2018 value was calculated by determining the ratio between 2018 Iowa retail sales to 2018 national retail sales (EIA 2020), and applying that ratio to 2018 national emissions of SF_6. The 2019 retail sales ratio was used for 2019.

Emissions in 2015 from the use of limestone and dolomite in industrial processes were used as a proxy for 2016 – 2019 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 2018 from ODS substitutes were used as proxy for 2019. The 2019 value was calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa's population is 0.96% of the total U.S. Population (U.S. Census 2020).

Emissions in 2019 from semiconductor manufacturing were calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa's population is 0.96% of the total U.S. Population (U.S. Census 2020).

Emissions in 2019 from soda ash consumption were calculated using the national consumption value and assuming that Iowa emissions were 0.96% of national emissions because Iowa's population is 0.96% of the total U.S. Population (U.S. Census 2020).

Adjustments

Emissions from electric power transmission and distribution from 2014 - 2018 were recalculated as shown in Table 14, by using the most current national emissions data (EPA 2020b), adjusted for Iowa retail electricity sales compared to U.S. retail electricity sales. (EIA 2020).

Table 14: Recalculated Emissions from Electric Power T & D ($MMtCO_2e$)[10]

Year	2014	2015	2016	2017	2018
Value Published Dec. 2018	0.058	0.051	0.055	0.056	0.054
Updated Value	0.055	0.044	0.049	0.050	0.049

Emissions from ODS substitutes from 2014 - 2018 were recalculated as shown in Table 15, by using the most current national emissions data (EPA 2020b), adjusted for Iowa population (U.S. Census 2020).

Table 15: Recalculated Emissions from ODS Substitutes ($MMtCO_2e$)

Year	2014	2015	2016	2017	2018
Value Published Dec. 2018	1.42	1.47	1.47	1.47	1.47
Updated Value	1.57	1.61	1.62	1.61	1.62

Results

GHG emissions from industrial processes in 2019 were 7.37 $MMtCO_2e$, or 5.67% of total statewide GHG emissions. Emissions from this sector decreased 0.35% from 2018 as shown in Table 16 and Figure 6, primarily due to decreases of emissions from ammonia and urea production (-0.12 $MMtCO_2e$) and cement manufacture (-0.09 $MMtCO_2e$), which were partially offset by an increase in emissions from nitric acid production (+0.05 $MMtCO_2e$).

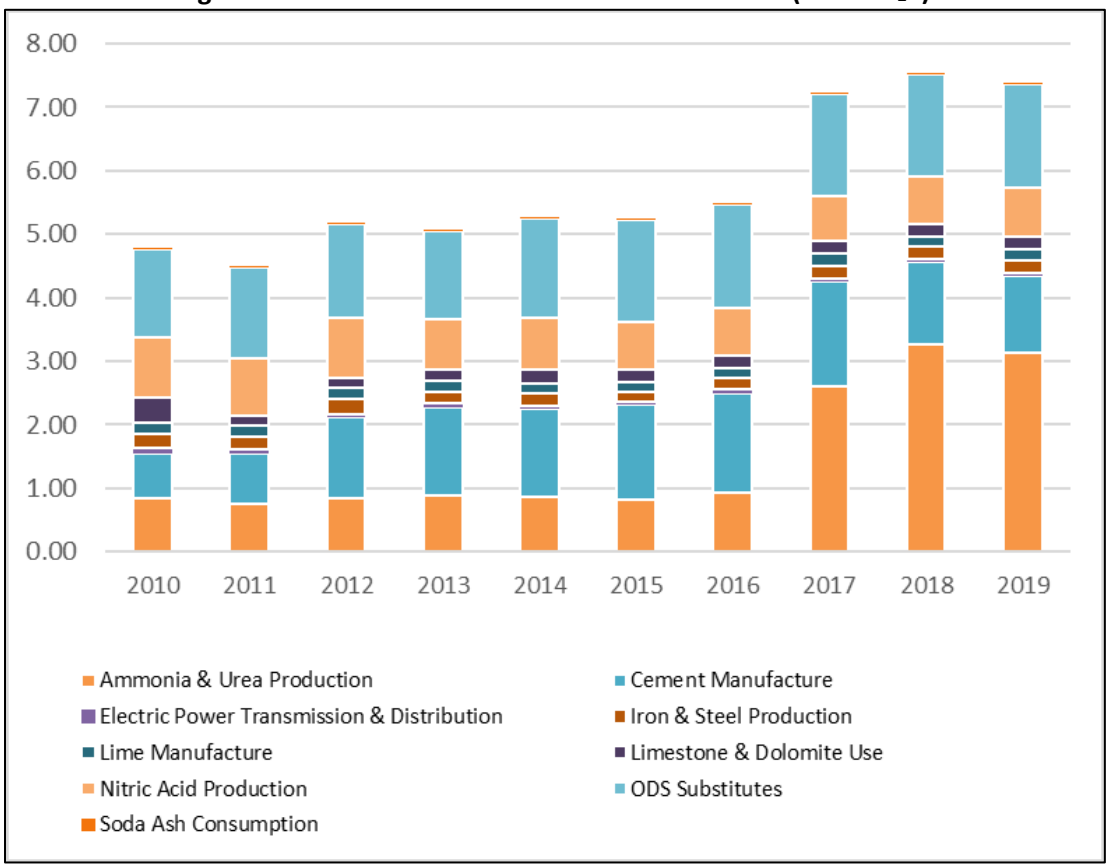
Table 16: GHG Emissions from Industrial Processes ($MMtCO_2e$)[11]

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ammonia & Urea	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60	3.26	3.14
Cement Manufacture	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66	1.30	1.21
Electric Power T&D	0.07	0.07	0.06	0.06	0.06	0.04	0.05	0.05	0.05	0.05
Iron & Steel Production	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20	0.19	0.18
Lime Manufacture	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18	0.16	0.17
Limestone & Dolomite Use	0.39	0.16	0.15	0.18	0.21	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78
ODS Substitutes	1.39	1.43	1.47	1.39	1.42	1.45	1.47	1.47	1.47	1.61
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	**4.79**	**4.50**	**5.18**	**5.07**	**5.12**	**5.09**	**5.34**	**7.10**	**7.40**	**7.37**

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

[11] Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2010– 2019 rounded to 0.001 $MMtCO_2e$ or less.

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



Uncertainty

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

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 2020a).

Chapter 5 - Natural Gas Transmission & Distribution

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

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2018b).

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 2020). The Iowa Utilities Board confirmed that the number of natural gas compressor and gas storage stations did not change from the previous year (Myers 2020).

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 2018b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2020). Data entered included miles of steel and cast iron distribution pipeline, unprotected and protected; number of services; and number of steel services, unprotected and protected.

Results

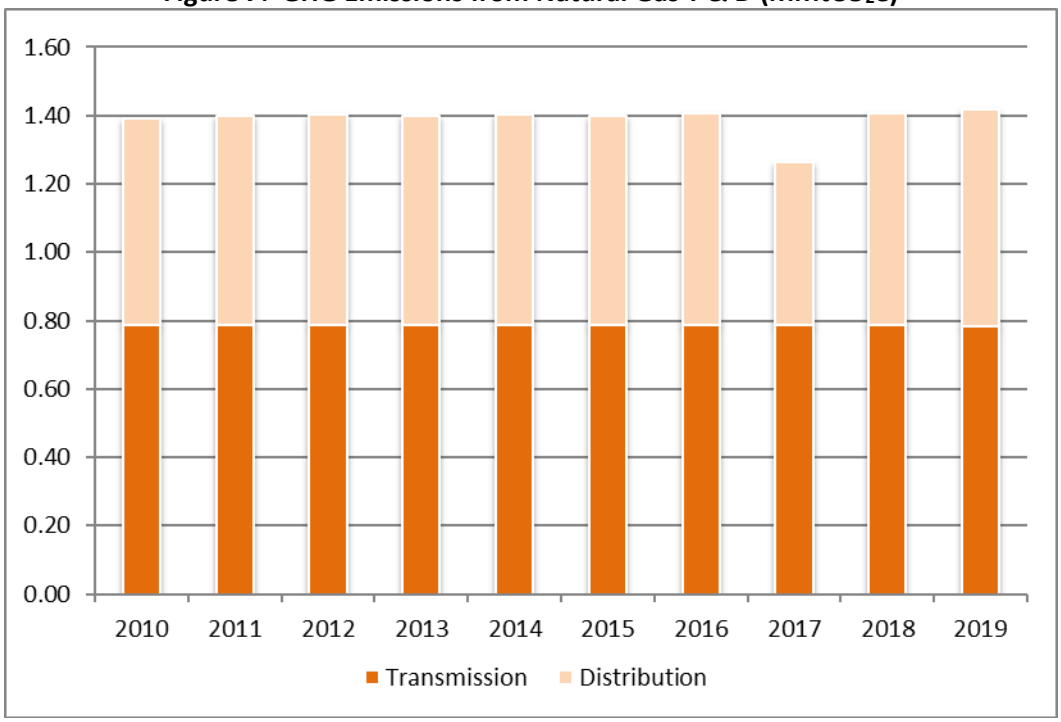
Total GHG emissions from natural gas transmission and distribution were 1.4163 $MMtCO_2e$[13] in 2019, an increase of 0.64% from 2018 and an increase of 1.88% from 2010 as shown in Table 17 and Figure 7. Emissions remained stable in 2019 due to the miles of pipeline and number of services (e.g. gas meters) in the state. GHG emissions from this sector account for 1.09% of 2019 statewide GHG emissions.

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

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Transmission	0.7871	0.7858	0.7862	0.7865	0.7864	0.7868	0.7867	0.7868	0.7864	0.7842
Distribution	0.6031	0.6132	0.6158	0.6135	0.6168	0.6118	0.6205	0.4789	0.6209	0.6321
Total	**1.3901**	**1.3990**	**1.4020**	**1.4000**	**1.4031**	**1.3986**	**1.4073**	**1.2657**	**1.4073**	**1.4163**

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

Figure 7: 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 2018a).

[14] This information is largely excerpted from the *SIT Natural Gas and Oil Systems Module* (ICF 2018a).

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 2020a), 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 2019 annual VMT of 33,779 million miles from the Iowa Department of Transportation (IDOT 2020). 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-99 and A-100 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018* (EPA 2020). The classes and the national distribution percentages are shown in Table 18.

Table 18: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2018 (EPA 2020)	2019 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.59%	2,900
Heavy duty gas vehicle	HDGV	1.08%	364
Light duty diesel truck	LDDT	0.79%	266
Light duty diesel vehicle	LDDV	0.33%	111
Light duty gasoline truck	LDGT	19.79%	6,685
Light duty gasoline vehicle	LDGV	68.81%	23,242
Motorcycle	MC	0.63%	211
Total		**100.00%**	**33,779**

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-104 in the most recent national inventory (EPA 2020).
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-107, A-108, and A-109 in Annex 3 of the most recent national inventory (EPA 2020).

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	2018 used as proxy for 2019	EIA SEDS (EIA 2020b)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2018 used as proxy for 2019	FHWA 2020
Heavy Duty Utility			
Tractors			
Construction			
Construction	Distillate Fuel	2018 used as proxy for 2019	EIA Adjusted Sales (EIA 2020a)
Locomotives			
Tractors			
Heavy Duty	Distillate Fuel	2016 used as proxy for 2018-2019	SIT default value
Small Utility	Gasoline		
Alternative Fuel Vehicles	Gasoline		

Adjustments

Emissions from non-highway vehicles were recalculated for 2018 as shown in Table 20 by using updated fuel activity data from EIA and the FHWA.

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

Pollutant	2018 Value (Published Dec. 2019)	2018 Updated Value
CO_2	20.18	19.74
CH_4	0.03	0.03
N_2O	0.17	0.14
Total	**20.38**	**19.91**

Results

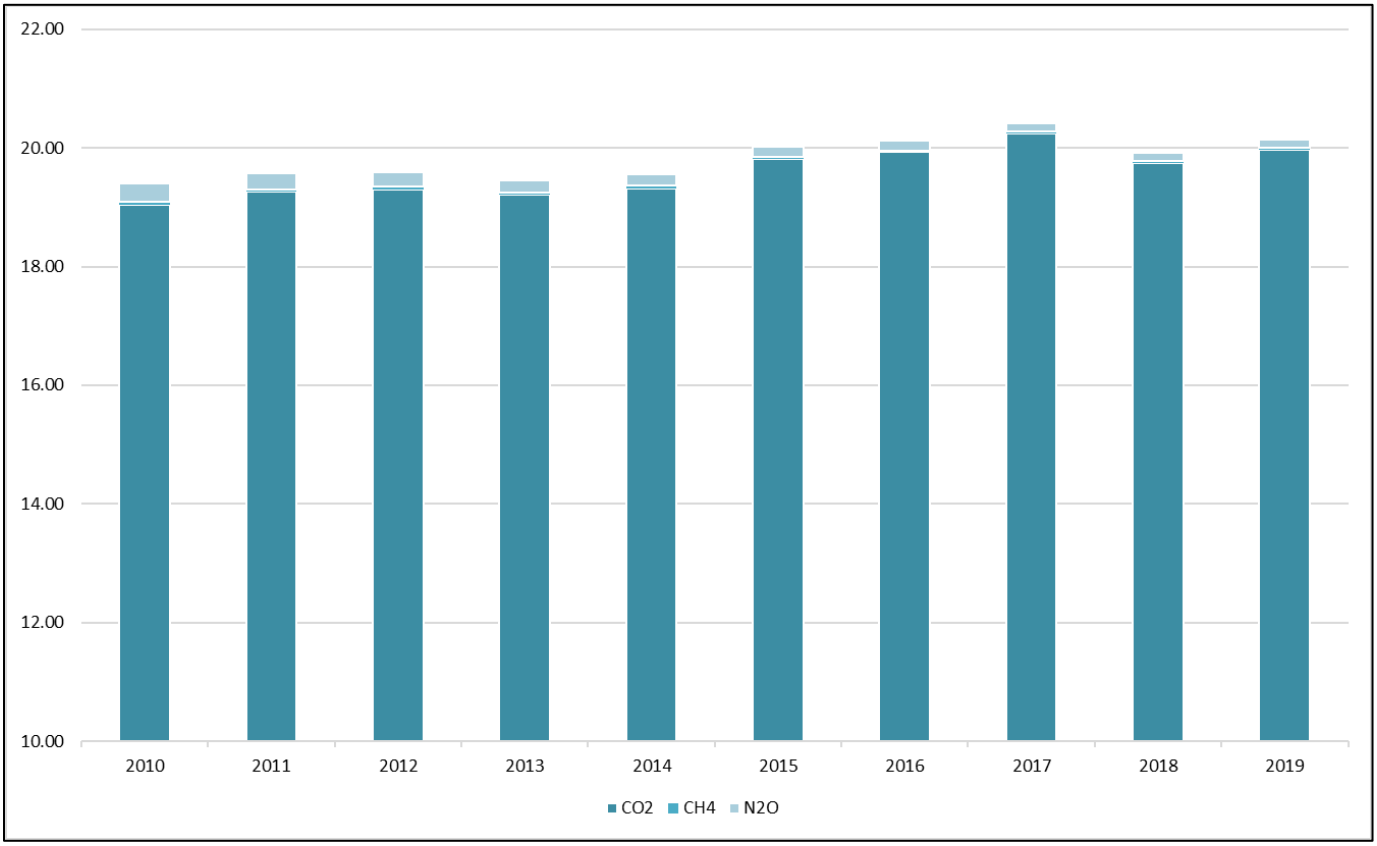
Total GHG emissions from transportation were 20.15 $MMtCO_2e$ in 2019 as shown in Table 21. This is an increase of 1.14% from 2018 and correlates to a 0.81% increase in VMT from 2018 - 2019. CO_2 accounts for nearly all the Iowa transportation GHG emissions (99.11%) as shown in Figure 8. The majority of the transportation emissions (56.96%) are from gasoline highway vehicles as shown in Figure 9.

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

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

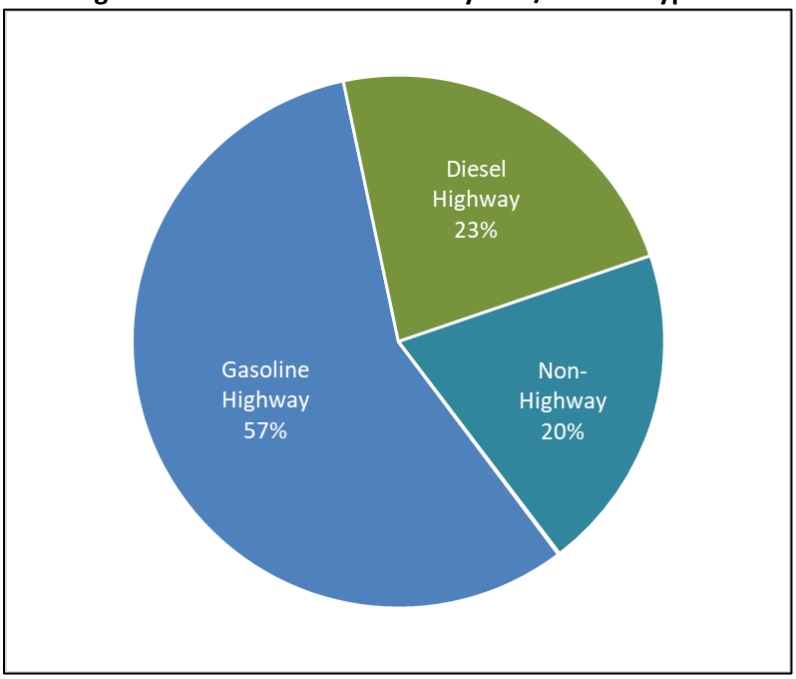
Pollutant	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2	19.04	19.27	19.31	19.21	19.32	19.81	19.93	20.25	19.74	19.97
CH_4	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
N_2O	0.33	0.27	0.24	0.21	0.19	0.18	0.16	0.14	0.14	0.15
Total	**19.41**	**19.58**	**19.59**	**19.46**	**19.55**	**20.02**	**20.12**	**20.42**	**19.92**	**20.15**

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



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

Figure 9: 2019 GHG Emissions by Fuel/Vehicle Type[17]



Uncertainty

Uncertainty occurs because national vehicle/fuel type, age distributions, and emission factors, which may not be reflective of Iowa conditions, were applied to Iowa-specific VMT data. There is also some uncertainty in the method EPA used to develop the national vehicle/fuel type distributions and to develop emission factors (EPA 2020). 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 2020b).

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

Chapter 7 – Waste: Solid Waste

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

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

Fluctuations in CH_4 emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, 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 2020), 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 2019. 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 12,763 tons of refuse derived waste in 2019 (Reed 2020). 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 2018a). 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.

Adjustments

Emissions from EPA's Landfill Gas Emissions Model (LandGEM) version 3.02 for 22 facilities were corrected for 2017 and 2018 as shown in Table 23. Previously, the CO_2 emission values were misreported as CH_4 emissions.

Table 23: Recalculated Emissions from MSW Landfills ($MMtCO_2e$)

Pollutant	2017 Value (Published Dec. 2019)	2017 Updated Value	2018 Value (Published Dec. 2019)	2018 Updated Value
CH_4	2.289	1.664	2.290	1.662

Results

Total GHG emissions from the solid waste category were 1.677 $MMtCO_2e$ in 2019, an increase of 0.32% from 2018 as shown in Table 24 and Figure 10. Solid waste emissions account for 1.29% of total statewide GHG emissions. Although emissions from combustion of MSW decreased 16.20%, overall solid waste emissions increased. This is because emissions from waste stored in landfills increased by 0.41% as the cumulative amount of waste in landfills increased by 8.25% (DNR 2020). It is important to note, however, that the relationship between emissions and the cumulative amount of waste is not linear as emissions vary due to the length of time the waste is 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.

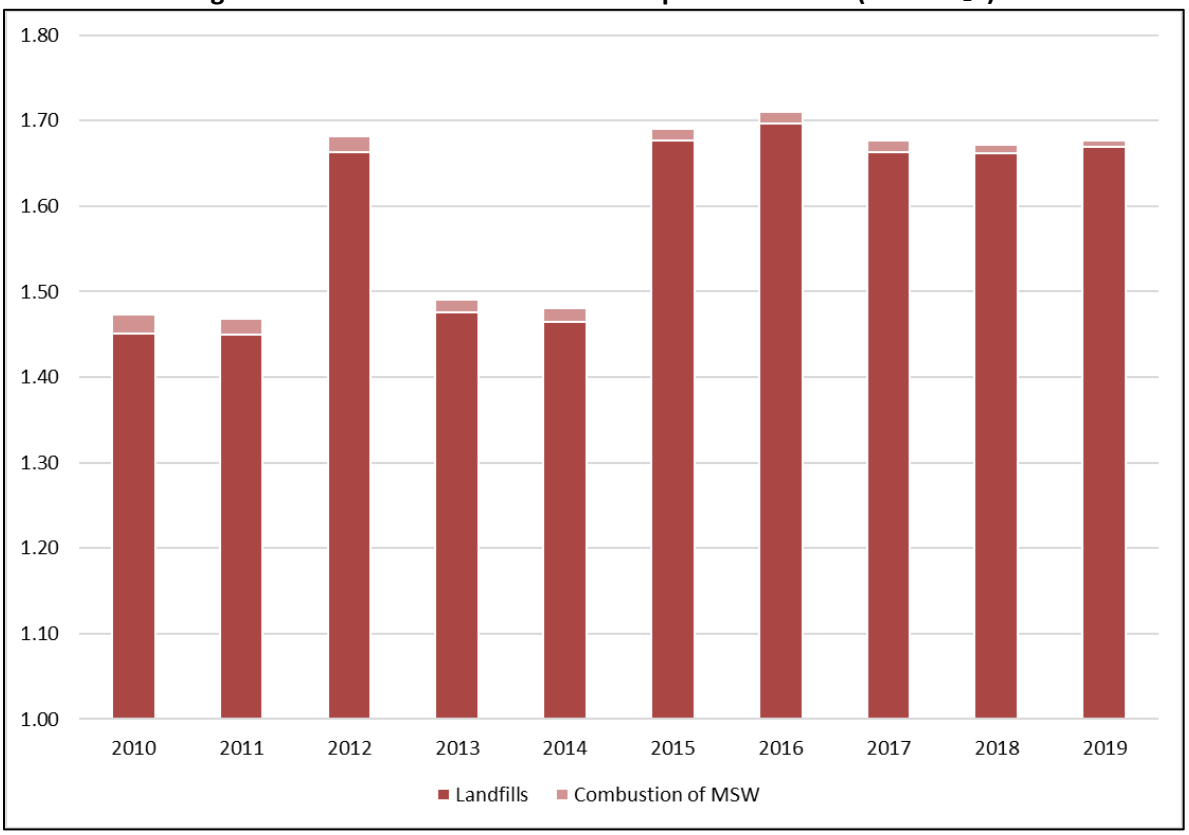
Table 24: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$)[18, 19]

Sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
MSW Landfills	1.45	1.45	1.66	1.48	1.46	1.68	1.70	1.664	1.662	1.669
MSW Combustion	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.013	0.009	0.008
Total	**1.47**	**1.47**	**1.68**	**1.49**	**1.48**	**1.69**	**1.71**	**1.676**	**1.671**	**1.677**

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

[19] DNR generally uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed to show the difference in emissions from 2018 to 2019.

Figure 10: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$)



Uncertainty[20]

MSW Combustion

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

- The combustion rate is not exact and varies by the quantity and composition of the waste.
- The oxidation rate varies depending on the type of waste combusted, moisture content, etc.
- The SIT uses average carbon contents instead of specific carbon contents for other plastics, synthetic rubber, and synthetic fibers.
- Non-biogenic CO_2 emissions vary depending on the amount of non-biogenic carbon in the waste and the percentage of non-biogenic carbon that is oxidized.

The SIT assumes that all carbon in textiles is non-biomass carbon and the category of rubber and leather is almost all rubber. This may result in CO_2 emissions being slightly over-estimated (ICF 2018b).

[20] This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2018b).

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 2018b).

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 2019 (U.S. Census 2020). 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 (44.3) from Table 7-16 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018* (EPA 2020b). Because the 2019 protein value was not available at the time of publication, the 2018 value was used as a surrogate for 2019.

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 food processing facilities and ethanol production facilities. The emissions reported to EPA have a higher level of accuracy than the SIT method because they are based on the unique characteristics and wastewater organic content of each facility. Last year eleven ethanol production facilities and five food processing facilities emitted more than 25,000 metric tons CO_2e or more (EPA 2020a). The number of ethanol faciliies decreased from fourteen in 2018. The number of food processors did not change.

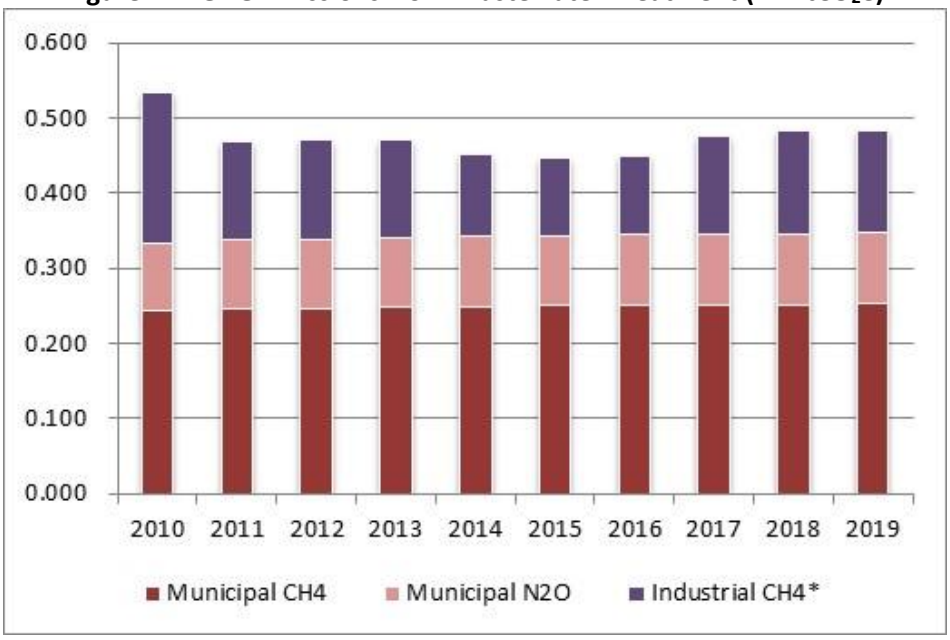
Results

Wastewater emissions account for 0.37% of the total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.482 $MMtCO_2e$ in 2019, a 0.15% decrease from 2018 and a 9.52% decrease from 2010 as shown in Table 25. This is due to a decrease in wastewater produced by industrial meat processing facilities and ethanol plants. CH_4 and N_2O from municipal wastewater treatment accounted for 71.95% (0.347 $MMtCO_2e$) of total wastewater treatment GHG emissions as shown in Figure 11.

Table 25: GHG Emissions from Wastewater ($MMtCO_2e$)[21]

Sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Municipal CH_4	0.244	0.245	0.246	0.247	0.249	0.250	0.251	0.252	0.252	0.253
Municipal N_2O	0.090	0.093	0.092	0.093	0.093	0.094	0.094	0.094	0.094	0.094
Industrial CH_4	0.199	0.130	0.134	0.132	0.111	0.104	0.104	0.131	0.137	0.135
Total	**0.533**	**0.468**	**0.472**	**0.472**	**0.453**	**0.447**	**0.449**	**0.477**	**0.483**	**0.482**

Figure 11: GHG Emissions from Wastewater Treatment ($MMtCO_2e$)



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

Uncertainty[22]

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the Iowa-specific percentage of the population without septic systems was used to calculate emissions, the value is from 1990. There can also be variation in the per-capita BOD production associated with food

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

[22] This information is largely excerpted from the *SIT Wastewater Module* (ICF 2018a).

consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors due to differences in wastewater treatment facilities (ICF 2018a).

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 2018a).

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.

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,[23] as well as carbon stored in forests, urban trees, agricultural soils, and landfills. This carbon storage is also called carbon sequestration.

Human activities such as cutting forests to create cropland, draining wet lands, reverting pastures to grassland, and replanting logged forests are land use, land use change and forestry (LULUCF) activities that affect the balance between the emission and uptake of GHGs, affecting their atmospheric concentration. This balance is known as GHG flux. CO_2 is also emitted from applying lime to agricultural soils and applying urea as a fertilizer. N_2O is emitted when fertilizers are applied to settled soils such as landscaping, lawns, and golf courses. CH_4 and N_2O are also emitted from forest fires (ICF 2020b).

Method

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). The calculated annual forest carbon flux includes sequestration/emissions in the following forest categories:

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

In previous years, the DNR used data from the USDA Forest Inventory Data Online (2010 – 2015) or the Design and Analysis Toolkit for Inventory and Monitoring (2016 – 2018) to calculate forest carbon flux. However, in October 2020, EPA updated the SIT methodologies to calculate forest carbon flux (IPC 2020b). The new methodologies are consistent with those used by EPA in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2018* (EPA 2020) and produced substantially different results than the former method used in previous years. Because 2019 forest carbon flux data is not available, 2018 was used as a proxy for 2019.

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 2020). 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

[23] Settled soils such as landscaping, lawns, and golf courses (ICF 2020b).

not track that information for limestone produced for agricultural purposes. The IDOT indicated that some areas of the state have 100% dolomite, some have 100% limestone, and some areas are mixed (Reyes 2011). Therefore, the DNR assumed that 50% of the material produced in Iowa for agricultural use is dolomite and 50% is limestone. In 2018, EPA moved liming of agricultural soils from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included liming in this chapter.

Urea Fertilization

2018 urea emissions were calculated using the amount of urea applied annually (USDA 2019). Because more current data is not available, 2018 was used as a proxy for 2019. EPA has moved urea fertilization from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included urea fertilization in this chapter.

Urban Tree Flux

Carbon sequestration in this sector was calculated using the total urban area and percent of urban area with tree cover provided in the SIT module (ICF 2020). The SIT extrapolates the 2011 – 2018 values from urban tree coverage measures in 1990, 2000, and 2010. 2018 was used as a proxy for 2019.

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 2018b). 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 2019 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 2019 (DNR 2020). While the DNR was able to use more accurate Iowa values for the annual amounts of yard trimmings and food scraps stored in landfills, the DNR used the SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon because Iowa-specific data was not available.

Agricultural Soil Carbon Flux

This is the first year that DNR has included agricultural soil carbon flux in the Iowa GHG inventory.
Carbon is continuously cycled through soils in both cropland and grassland (EPA 2020). The amount of carbon stored varies depending on crop type, management practices (e.g., rotation, tillage, drainage, irrigation), and soil and climate variables. Carbon may be emitted when soils are tilled. However, carbon may also be sequestered when soil conservation practices are used (no-till or reduced tillage), when cropland is enrolled in the

Conservation Reserve Program, or when cropland is converted to grass, trees, or wetlands. The net change in agricultural soil carbon is the change in the amount of carbon stored in soils over time (ICF 2020b). In the past, the SIT did not include the ability to calculate emissions from soil carbon flux from tillage practices, but EPA recently updated the SIT to calculate agricultural soil carbon flux using the same methodologies as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2018* (EPA 2020).

Adjustments

The DNR used the updated SIT methodologies to recalculate forest carbon flux for 2010 – 2018 as described above under "Method". The recalculated emissions are shown in Table 26 below.

Table 26: Recalculated Forest Carbon Flux ($MMtCO_2e$)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Value Published Dec. 2019	-2.68	-0.14	-0.47	-1.02	+3.04	+2.87	+1.29	-0.61	-0.61
Updated Value	-2.60	-2.59	-2.58	-2.57	-2.56	-2.59	-2.61	-2.63	-2.66

This year the DNR recalculated urban tree flux using the total urban area and percent of urban area with tree cover provided in the SIT module (ICF 2020) as shown in Table 27. The SIT extrapolates the 2011 – 2018 values from urban tree coverage measures in 1990, 2000, and 2010. In previous years, DNR used the 2010 Iowa total urban area urban percent tree cover from a DNR data set that is a mix of land cover/remote sensing data with about a one-meter resolution. The 2010 values were then used as a proxy for 2011 – 2018.

Table 27: Recalculated Urban Tree Flux ($MMtCO_2e$)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Value Published Dec. 2019	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74	-0.74	+0.59	+0.59
Updated Value	-0.31	-0.31	-0.31	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34

2018 emissions from urea fertilization were recalculated using fertilizer data from the 2019 Iowa Agricultural Statistics Bulletin (USDA 2019) as shown in Table 28. Previously 2017 fertilizer usage was used as a proxy for 2018.

Table 28: Recalculated Emissions from Urea Fertilization ($MMtCO_2e$)

Pollutant	2018 Value (Published Dec. 2019)	2018 Updated Value
CO_2	+0.18	+0.13

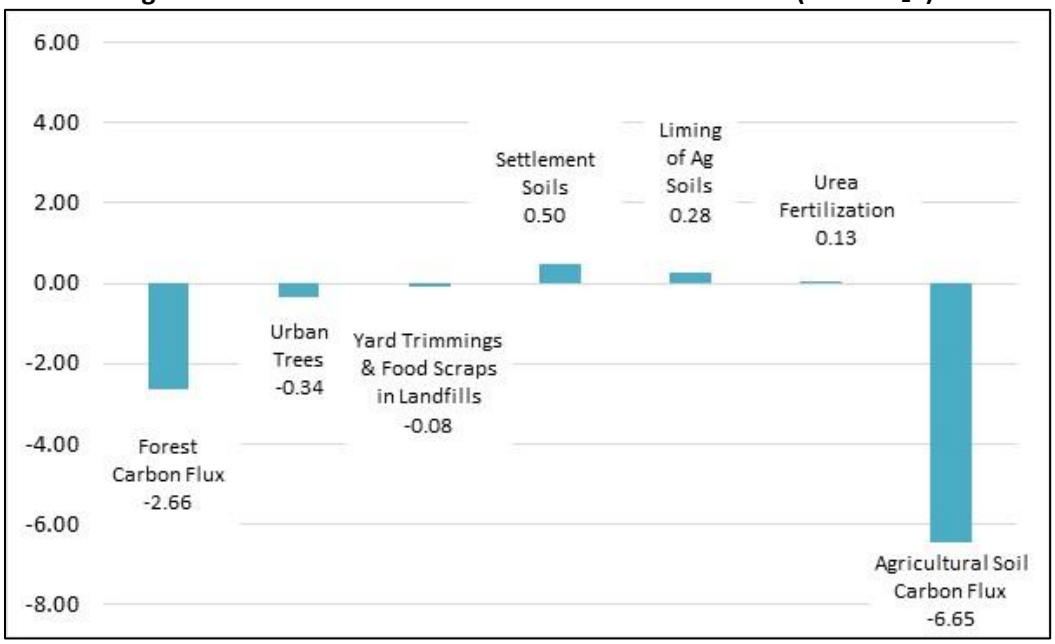
Results

Overall, sources in the LULUCF sector stored more carbon than they stored in 2019, storing 8.82 $MMtCO_2e$ as shown in Table 29 and Figure 12. This is an increase of 1.15% from 2018 and decrease of 2.89% from 2009. Emissions of CO_2 are shown above the x-axis in Figure 12 and carbon sinks are shown below the x-axis.

Table 29: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[24]

Sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Forest Carbon Flux	-2.60	-2.59	-2.58	-2.57	-2.56	-2.59	-2.61	-2.63	-2.66	-2.66
Liming of Ag Soils	+0.47	+0.51	+0.65	+0.47	+0.41	+0.34	+0.46	+0.45	+0.40	+0.28
Urea Fertilization	+0.11	+0.12	+0.13	+0.11	+0.15	+0.15	+0.19	+0.18	+0.13	+0.13
Urban Trees	-0.31	-0.31	-0.31	-0.32	-0.32	-0.33	-0.33	-0.34	-0.34	-0.34
Yard Trimmings & Food Scraps Stored in Landfills	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08
N_2O from Settlement Soils	+0.48	+0.57	+0.57	+0.57	+0.52	+0.49	+0.51	+0.53	+0.48	+0.50
Agricultural Soil Carbon Flux	-7.13	-9.96	-10.98	-6.62	-4.53	-5.21	-7.88	-7.59	-6.65	-6.65
Total	**-9.08**	**-11.78**	**-12.64**	**-8.46**	**-6.44**	**-7.26**	**-9.77**	**-9.49**	**-8.72**	**-8.82**

Figure 12: 2019 GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)



Uncertainty

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

- Using growing year synthetic fertilizer data for settlement soils instead of calendar year data,
- Assuming the ratio of limestone to dolomite in Iowa is 50%, 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.

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

Chapter 10 – Electricity Consumption

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

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

2019 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) 2020 with Projections to 2050* (EIA 2020a) to Iowa's 2018 electricity consumption data from EIA (EIA 2020b).

Transportation

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the Iowa Legislative Services Agency (LSA 2020), 4,599 electric vehicles were registered in Iowa as of December 30, 2019. This is an increase of 42% from 2018, but is 0.10% of the total number of vehicles, 4.53 million, registered in the state in 2019 (IDOT 2020). Emissions were calculated assuming that each electric vehicle consumes 4,250 kWh of electricity per year (IEDA 2016). This does not include emissions from electric propulsion, other electric batteries, or non-highway electric vehicles such as golf carts.

Adjustments

2018 emissions have been recalculated since the DNR's 2018 GHG Inventory Report was published in December 2019. The DNR previously forecasted 2018 emissions due to a lack of Iowa-specific energy consumption data. However, the 2018 energy data was released by EIA in June 2020 (EIA 2020b), so the DNR used the data to recalculate 2018 emissions as shown in Table 30 and Table 31.

Table 30: Updated 2018 Activity Data

Category	2018 Value Published Dec. 2019	2018 Updated Value
Electricity Consumption (kWh)		
Residential	13,731,884,370	14,841,108,884
Commercial	12,137,951,352	12,421,569,951
Industrial	23,065,780,822	23,953,975,079
Total	**48,935,616,544**	**51,230,428,164**

Table 31: Recalculated Electricity Emissions ($MMtCO_2e$)

Category	2018 Value Published Dec. 2019	2018 Updated Value
Residential	6.55	7.08
Commercial	5.79	5.92
Industrial	11.00	11.42
Total	**23.16**	**24.42**

Results

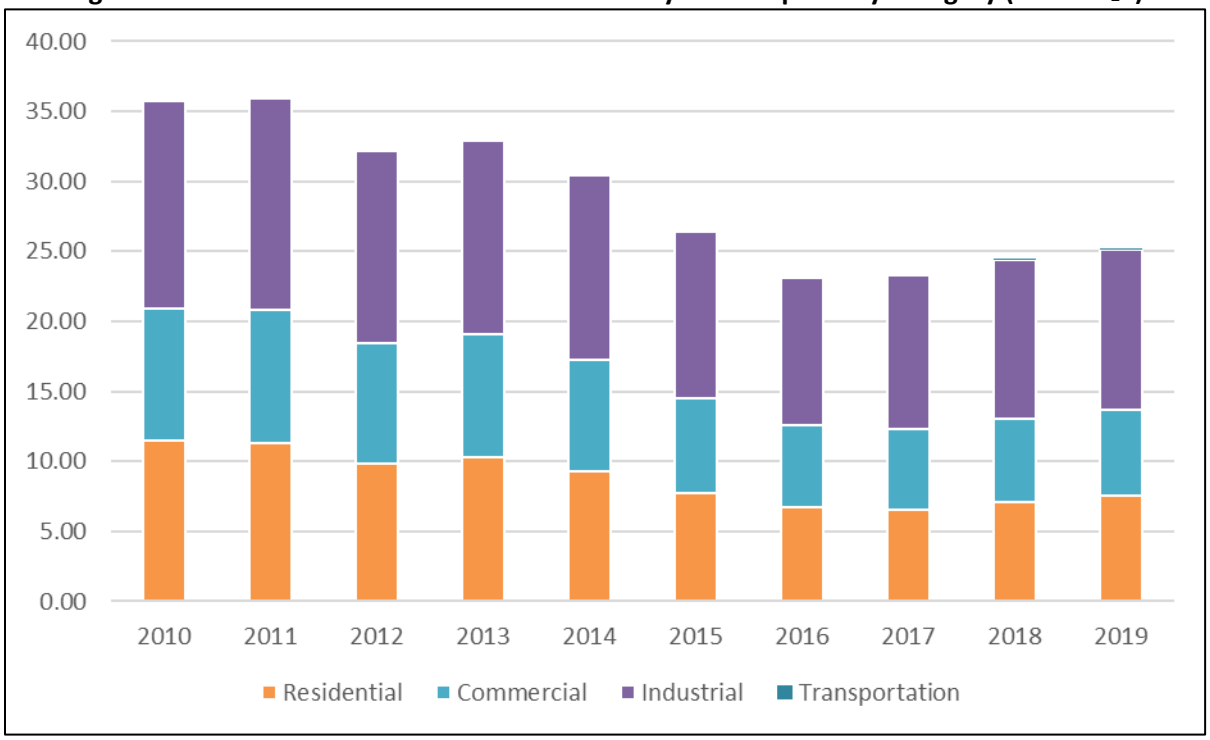
Indirect GHG emissions from electricity consumption were 25.12 $MMtCO_2e$ in 2019, increasing 4.75% since 2018, due to projected increases in electricity consumption in all four categories (EIA 2019a) as shown in Table 32 and Figure 13. Industrial users consumed the largest percentage of electricity, 45.62%, as shown in Figure 14.

Table 32: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[25]

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Residential	11.45	11.27	9.85	10.30	9.29	7.72	6.72	6.54	7.08	7.58
Commercial	9.46	9.51	8.60	8.77	7.64	6.76	5.86	5.79	5.92	6.07
Industrial	14.84	15.14	13.74	13.83	13.16	11.92	10.51	11.00	11.42	11.46
Transportation	*not calculated**					0.00	0.00	0.00	0.01	0.01
Total	**35.76**	**35.92**	**32.19**	**32.90**	**30.39**	**26.41**	**23.09**	**23.32**	**24.43**	**25.12**

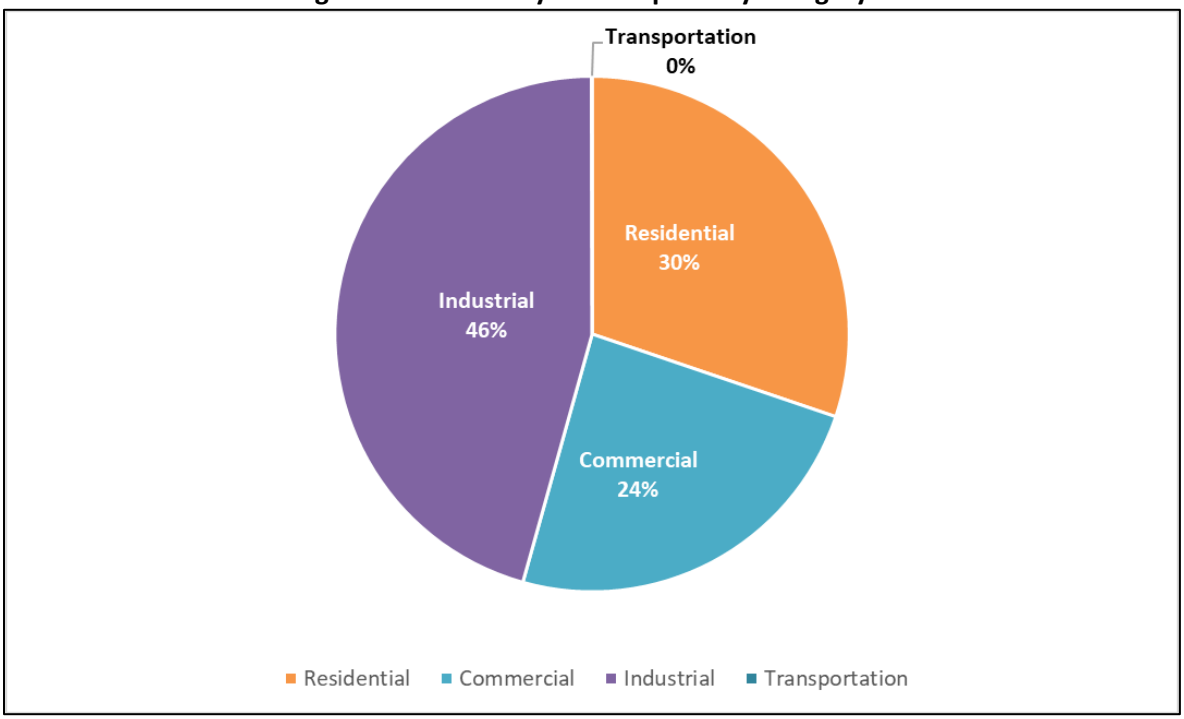
* 2015 was the first time that DNR calculated indirect emissions from electricity consumption.

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



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

Figure 14: Electricity Consumption by Category[26]



[26] Emissions from transportation round to 0%.

Forecasting

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

Method

The DNR projected emissions out to 2030 using the SIT Projection Tool (ICF 2020 and 2019). The Projection Tool predicts that Iowa's population decreases every year from 2020 – 2030. This is contrary to the most recent population projections available from the U.S. Census. Consequently, the DNR replaced the Projection Tool default populations with the actual Iowa population for 2007 -2019 (U.S. Census 2020) 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 – 2018, using a combination of data sources and national projections for activity data. The Projection Tool would ideally include data through 2019 to be consistent with the DNR's 2019 calculated GHG inventory, but this discrepancy is unavoidable. It would be preferable to forecast emissions using the DNR's 2019 calculated GHG inventory as the baseline, but it is not reasonable to fully update the data in the SIT Projection Tool to eliminate all such inconsistencies.

Results

The DNR's calculated 2019 GHG inventory and projected emissions from the SIT Projection Tool for 2019, 2020, 2025, and 2030 for each category are shown in Table 33 (intervening year forecasts are available from the DNR upon request). The 2019 "forecast" was produced to help gauge the reasonableness of the projections. Only the Power Plant, Waste, and Natural Gas T & D sectors yielded a 2019 forecast within 1 $MMtCO_2e$ of its calculated value.

Table 33: Projected Gross GHG Emissions 2018 – 2030 ($MMtCO_2e$)

	Calculated	Projected			
Sector	**2019**	**2019**	**2020**	**2025**	**2030**
Agriculture	37.82	43.35	44.48	50.16	55.84
Power Plants	24.57	25.56	22.78	21.91	22.21
RCI Fossil Fuel Use	36.58	33.25	32.77	33.12	33.43
Industrial Processes	7.37	5.93	6.48	7.90	8.99
Natural Gas T & D	1.42	1.35	1.54	1.64	1.65
Transportation	20.15	22.20	22.23	20.91	19.93
Waste	2.16	3.11	3.14	3.27	3.41
Total	**130.07**	**134.74**	**133.41**	**138.92**	**145.46**

Factors that May Affect Future Emissions

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

1. *Global Pandemic*

   The global pandemic has affected the way Americans use energy. The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* on December 9, 2020, predicting that US CO_2 emissions will "fall by 19% for coal, by 13% for petroleum, and by 2% for natural gas. Many of this year's changes in energy-related CO2 emission are attributable to the economic and behavioral effects

the COVID-19 pandemic has had on energy consumption" (EIA 2020). It should be noted that the STEO addresses national emissions, not Iowa-specific emissions. In addition, a November article in The Gazette reports that during the pandemic (from March 13 – November 19) the vehicle miles traveled by Iowans decreased almost 20% compared to the same period in 2019. However, the article notes that travel was expected to decrease at a lesser rate during the holidays despite the pandemic (Murphy 2020).

2. *Derecho*

   On August 10th, a derecho swept across portions of central and eastern Iowa and left behind widespread destruction and huge holes in the tree canopy above a number of Iowa towns and cities. The DNR estimates that 724,480 acres of forest and trees were lost across the 27 counties most directly impacted (Hanigan 2020). This will likely reduce the amount of carbon sequestered in by forests in 2020, and may continue to decrease in future years as damaged trees are affected by pests and disease.

   GHG emissions from crop production and agricultural soils will likely also be affected. According to data provided to the Washington Post by Iowa state climatologist Justin Glisan, about 20% of Iowa's total cropland was damaged by the derecho, affecting yields (Henson 2020). Emissions from the fossil fuel combustion sector may also be affected as approximately 500,000 Iowans lost electricity. In some areas, such as Cedar Rapids, it was not restored for up to fourteen days (Sahouri 2020).

3. *Emissions from Power Plants*

   Emissions from power plants will likely decrease as Iowa utilities shift away from burning coal to burning natural gas and installing renewable generation. Two Iowa electric utilities have publicly announced plans to retire their coal-fired electric generating units.

   Alliant Energy plans to eliminate all coal from its power generating system by 2040. Their sustainability plan includes goals to reduce CO_2 emissions by 50% in the next 10 years and reach net-zero CO_2 emissions by 2050. This plan includes shutting down the 275 megawatt (MW) coal-fired generating station in Lansing by 2022 (Eller 2020).

   Muscatine Power and Water (MP&W) is planning to retire three coal-fired electric generating units and replace them with a natural-gas fired plant. Unit 7 (25.0 megawatts) and Unit 8A (75 megawatts) will retire at the end of 2022, Unit 9 (175.5 megawatts) – will retire by the end of 2030. The new natural-gas fired plant will start operating in 2028. MP&W will also install 30 megawatts of photovoltaic solar generation in 2023 (Potter 2020).

   However, emissions from power plants may also be affected by the economy, weather, future environmental regulations, demand by customers, how electricity generation is dispatched by the grid operator electricity, and other market forces.

<u>Other Uncertainty</u>

As with many forecasts, numerous factors affect the significant level of uncertainty associated with emissions projections. As noted above, these factors include the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, and other

variables. Although the SIT Projection Tool provides a useful first look at projected future emissions, it has several specific areas of uncertainty:

1. Agricultural emissions are highly dependent on the weather and crop and livestock prices, which are not addressed by the Projection Tool.
2. Emissions from electric power plants and RCI fuel combustion are also highly dependent on weather and the number of heating and cooling days per year.
3. Emissions from electric power plants also may fluctuate due to differences in how electricity generation is dispatched by MISO, electricity demand by customers, and other market forces.
4. In sectors where the Projection Tool predicts future emissions based on historical emissions (industrial processes, agriculture, and waste), it only uses emissions from 1990 – 2018 and does not consider 2019 data.

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Appendix A – Iowa GHG Emissions 2010 - 2019 by Sector[27]

Emissions ($MMtCO_2e$)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	36.38	37.91	36.78	35.77	**36.39**	39.00	39.49	41.71	**38.60**	37.82
Enteric Fermentation	8.39	8.41	8.40	8.38	**8.19**	8.36	8.43	8.40	**8.69**	8.66
Manure Management	8.83	9.53	10.86	10.85	**11.06**	11.07	10.96	11.75	**8.20**	8.19
Agricultural Soil Management	19.16	19.98	17.53	16.55	18.14	19.58	20.09	21.56	**21.70**	20.97
Fossil Fuel Combustion	73.56	70.42	65.72	65.88	66.26	61.00	54.78	58.67	62.94	61.15
Electric Generating Facilities	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57
Residential, Commercial, Industrial	31.23	31.44	29.96	32.82	32.82	31.54	29.45	32.05	**32.07**	36.58
Industrial Processes	4.79	4.50	5.18	5.07	**5.12**	**5.09**	**5.34**	**7.10**	**7.40**	7.37
Ammonia & Urea Production	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60	3.26	3.14
Cement Manufacture	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66	1.30	1.21
Electric Power Transmission and Distribution Systems	0.07	0.07	0.06	0.06	**0.06**	**0.05**	**0.06**	**0.06**	**0.06**	0.05
Iron and Steel Production	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20	0.19	0.18
Lime Manufacture	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18	0.16	0.17
Limestone and Dolomite Use	0.39	0.16	0.15	0.18	0.21	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78
ODS Substitutes	1.39	1.43	1.47	1.39	**1.42**	**1.45**	**1.47**	**1.47**	**1.47**	1.61
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF[28]	**-9.08**	**-11.78**	**-12.64**	**-8.46**	**-6.44**	**-7.26**	**-9.77**	**-9.49**	**-8.72**	-8.82
Forest Carbon Flux	**-2.60**	**-2.59**	**-2.58**	**-2.57**	**-2.56**	**-2.59**	**-2.61**	**-2.63**	**-2.66**	-2.66
Liming of Agricultural Soils	0.47	0.51	0.65	0.47	0.41	0.34	0.46	0.45	0.40	0.28
Urea Fertilization	0.11	0.12	0.13	0.11	0.15	0.15	0.19	0.18	**0.13**	0.13
Urban Trees	**-0.31**	**-0.31**	**-0.31**	**-0.32**	**-0.32**	**-0.33**	**-0.33**	**-0.34**	**-0.34**	-0.34
Yard Trimmings and Food Scraps Stored in Landfills	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	-0.09	-0.08	-0.08
Fertilization of Settlement Soils	0.48	0.57	0.57	0.57	0.52	0.49	0.51	0.53	0.48	0.50

[27] 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.

[28] 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 ($MMtCO_2e$)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Natural Gas Transmission & Distribution	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42
Transmission	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.78
Distribution	0.60	0.61	0.62	0.61	0.62	0.61	0.62	0.48	0.62	0.63
Transportation	19.41	19.58	19.59	19.46	19.55	20.02	20.12	20.42	**19.92**	20.15
Waste	2.01	1.94	2.15	1.96	1.93	2.14	2.16	**2.15**	**2.15**	2.16
Solid Waste	1.47	1.47	1.68	1.49	1.48	1.69	1.71	**1.68**	**1.67**	1.68
Wastewater	0.53	0.47	0.47	0.47	0.45	0.45	0.45	0.48	0.48	0.48
Gross Emissions	137.54	**135.74**	**130.82**	129.55	**131.67**	**128.65**	**123.30**	**131.32**	**132.42**	130.07
Sinks	**-9.08**	**-11.78**	**-12.64**	**-8.46**	**-6.44**	**-7.26**	**-9.77**	**-9.49**	**-8.72**	-8.82
Net Emissions	**128.45**	**123.96**	**118.18**	**121.09**	**125.23**	**121.39**	**113.53**	**121.83**	**123.70**	121.25
% Change from Previous Year (Gross)		-1.31%	-3.62%	-0.98%	**+1.64%**	**-2.29%**	**-4.16%**	**+6.51%**	**+0.83%**	-1.77%
% Change from 2010 (Gross)		**-1.31%**	**-4.88%**	**-5.81%**	**-4.27%**	**-6.46%**	**-10.35%**	**-4.52%**	**-3.72%**	**-5.43%**

Appendix B – Iowa GHG Emissions 2010 - 2019 by Pollutant[29]

Emissions ($MMtCO_2e$)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gross CO_2	**94.54**	**91.34**	**87.32**	**87.53**	**88.02**	**83.31**	**77.52**	**83.48**	**87.47**	85.75
Net CO_2	**84.98**	**78.99**	**74.10**	**78.49**	**81.05**	**75.55**	**67.24**	**73.46**	**78.28**	76.43
Stationary Fossil Fuel Combustion	73.09	69.96	65.30	65.47	65.85	60.64	54.51	**58.35**	62.58	60.84
Transportation	19.04	19.27	19.31	19.21	19.32	19.81	19.93	**20.25**	**19.74**	19.97
Industrial Processes	2.38	2.09	2.69	2.83	2.83	2.84	3.07	4.87	**5.14**	4.93
Solid Waste	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
LULUCF[30]	**-9.56**	**-12.35**	**-13.22**	**-9.03**	**-6.96**	**-7.76**	**-10.28**	**-10.02**	**-9.20**	-9.32
CH_4	20.17	20.21	21.72	21.50	**20.93**	21.88	**21.80**	**22.45**	**19.36**	19.31
Stationary Fossil Fuel Combustion	0.19	0.19	0.17	0.17	0.17	0.14	0.09	0.13	**0.15**	0.14
Transportation	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	**0.03**	0.03
Natural Gas and Oil Transmission and Distribution	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42
Enteric Fermentation	8.39	8.41	8.40	8.38	8.19	8.36	8.43	8.40	**8.69**	8.66
Manure Management	8.26	8.36	9.67	9.67	**9.31**	9.91	9.79	10.58	**7.02**	7.00
Solid Waste	1.45	1.45	1.66	1.48	1.46	1.68	1.70	**1.66**	**1.66**	1.67
Wastewater	0.44	0.38	0.38	0.38	0.36	0.35	0.36	0.38	0.39	0.39
N_2O	21.85	23.25	20.83	19.65	21.20	22.46	22.98	24.39	**24.53**	23.85
Stationary Fossil Fuel Combustion	0.28	0.27	0.25	0.24	0.24	0.21	0.19	0.18	**0.20**	0.17
Transportation	0.33	0.27	0.24	0.21	0.19	0.18	0.16	0.14	**0.14**	0.15
Industrial Processes	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73	0.78
Manure Management	0.57	1.17	1.19	1.18	**1.75**	1.16	1.17	1.17	**1.18**	1.19
Agricultural Soil Management	19.16	19.98	17.53	16.55	18.14	19.58	20.09	21.56	**21.70**	20.97
N_2O from Settlement Soils	0.48	0.57	0.57	0.57	0.52	0.49	0.51	0.53	0.48	0.50
Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
HFC, PFC, and SF_6	1.46	1.50	1.53	1.44	**1.47**	**1.50**	**1.53**	**1.53**	**1.53**	1.66
Industrial Processes	1.46	1.50	1.53	1.44	**1.47**	**1.50**	**1.53**	**1.53**	**1.53**	1.6
Gross Emissions	138.02	**136.31**	131.40	130.12	**132.19**	**129.15**	**123.81**	**131.85**	**132.90**	130.56
Sinks	**-9.56**	**-12.35**	**-13.22**	**-9.03**	**-6.96**	**-7.76**	**-10.28**	**-10.02**	**-9.20**	-9.32
Net Emissions (Sources and Sinks)	**128.45**	**123.96**	**118.18**	**121.09**	**125.23**	**121.39**	**113.53**	**121.83**	**123.70**	**121.25**

[29] 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.

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