IOWA DEPARTMENT OF NATURAL RESOURCES

2021 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Required by Iowa Code 455B.104

December 27, 2022

Iowa Department of Natural Resources
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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 2021 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.

2021 Statewide GHG Emissions

In 2021, total gross Iowa greenhouse gas emissions were 126.16 million metric tons carbon dioxide equivalent ($MMtCO_2e$) as shown in Table 1 and Figure 1. This is an increase of 6.51 $MMtCO_2e$ (5.44%) from 2020 and a decrease of 3.56% from 2012. The 6.51 $MMtCO_2e$ increase in emissions is largely attributed to the following combination of increases and partially offsetting reductions:

- A 7.20 $MMtCO_2e$ increase in emissions from power plants, due to increased generation of electricity from fossil fuels,
- A 1.94 $MMtCO_2e$ increase in emissions from mobile combustion due to an increase in vehicle miles traveled,
- A 2.32 $MMtCO_2e$ decrease in emissions from residential, commercial and industrial fuel use,
- A 0.34 $MMtCO_2e$ decrease in emissions from industrial processes.

Emissions fluctuations from other sectors were smaller in magnitude, as shown in Figure 2, and differed by 0.05 $MMtCO_2e$ or less per sector from 2020.

Table 1: GHG Emissions 2012 – 2021 by Sector (Million Metric Tons Carbon Dioxide Equivalents ($MMtCO_2e$))[1]

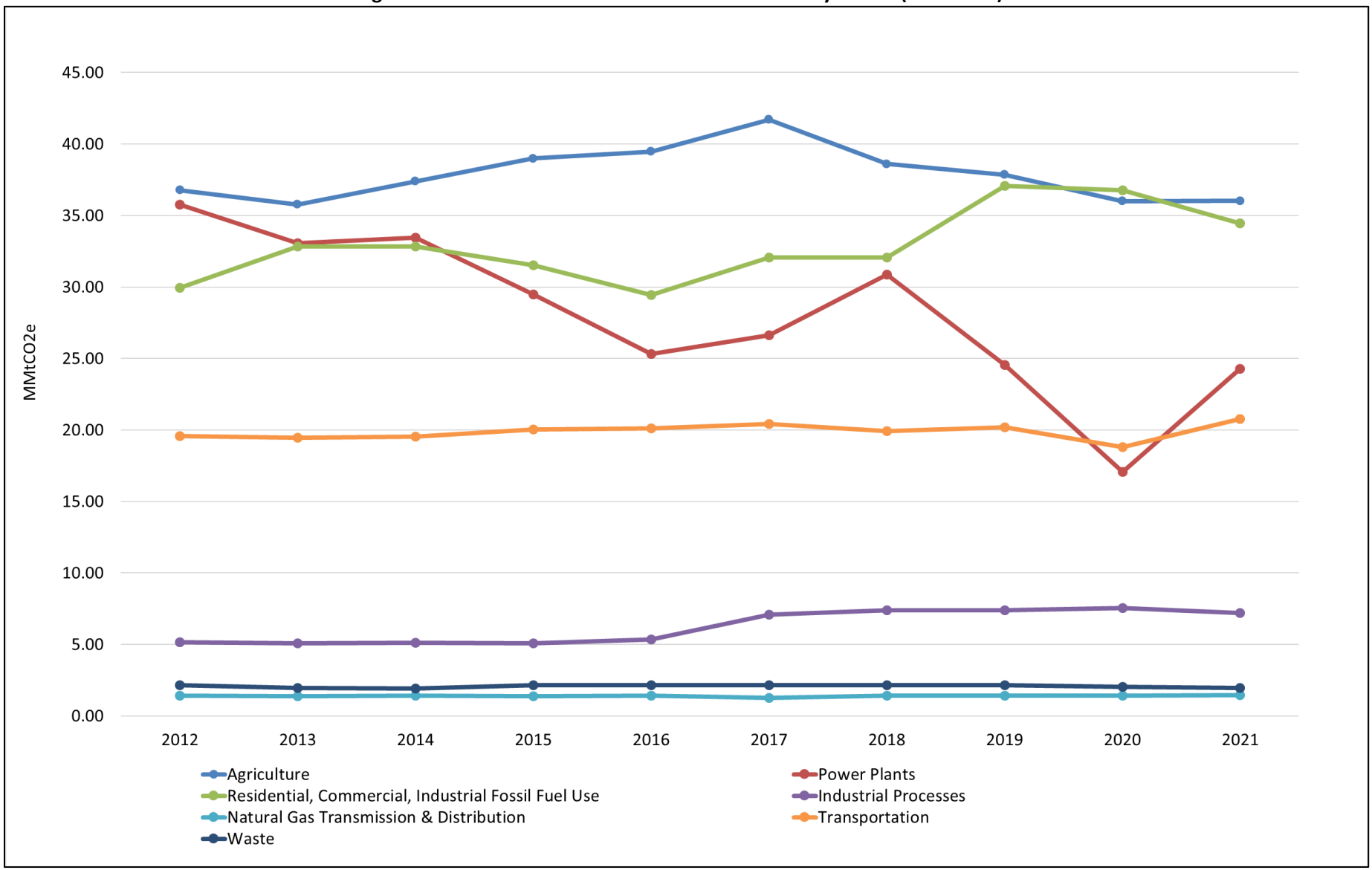
Emissions ($MMtCO_2e$)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change from 2020		
											$MMtCO_2e$	%	Trend
Agriculture	36.78	35.77	37.39	39.00	39.49	41.71	38.60	37.85	36.00	36.03	0.03	0.08%	↑
Power Plants	35.76	33.06	33.44	29.46	25.33	26.62	30.87	24.57	17.07	24.27	7.20	42.16%	↑
Residential, Commercial, and Industrial Fuel Use	29.96	32.82	32.82	31.54	29.45	32.05	32.07	37.07	36.76	34.45	-2.32	-6.30%	↓
Industrial Processes	5.18	5.07	5.12	5.09	5.34	7.10	7.40	7.38	7.55	7.21	-0.34	-4.50%	↓
Natural Gas Transmission and Distribution	1.40	1.40	1.40	1.40	1.41	1.27	1.41	1.42	1.42	1.47	0.05	3.67%	↑
Transportation	19.59	19.46	19.55	20.02	20.12	20.42	19.92	20.20	18.81	20.76	1.94	10.32%	↑
Waste	2.15	1.96	1.93	2.14	2.16	2.15	2.15	2.16	2.03	1.98	-0.05	-2.58%	↓
Total Gross Emissions	**130.82**	**129.55**	**131.67**	**128.65**	**123.30**	**131.32**	**132.42**	**130.64**	**119.65**	**126.16**	**6.51**	**5.44%**	↑
Carbon Stored in LULUCF[2]	-12.64	-8.46	-6.44	-7.26	-9.77	-9.49	-8.72	-8.88	-7.53	-7.39	-0.15	-1.93%	↓
Total Net Emissions	118.18	121.09	125.23	121.39	113.53	121.83	123.70	121.76	112.12	118.77	6.66	5.94%	↑

[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 2021. 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 2012 – 2021 ($MMtCO_2e$)

Figure 2: Iowa Gross[3] GHG Emissions 2012 – 2021 by Sector ($MMtCO_2e$)

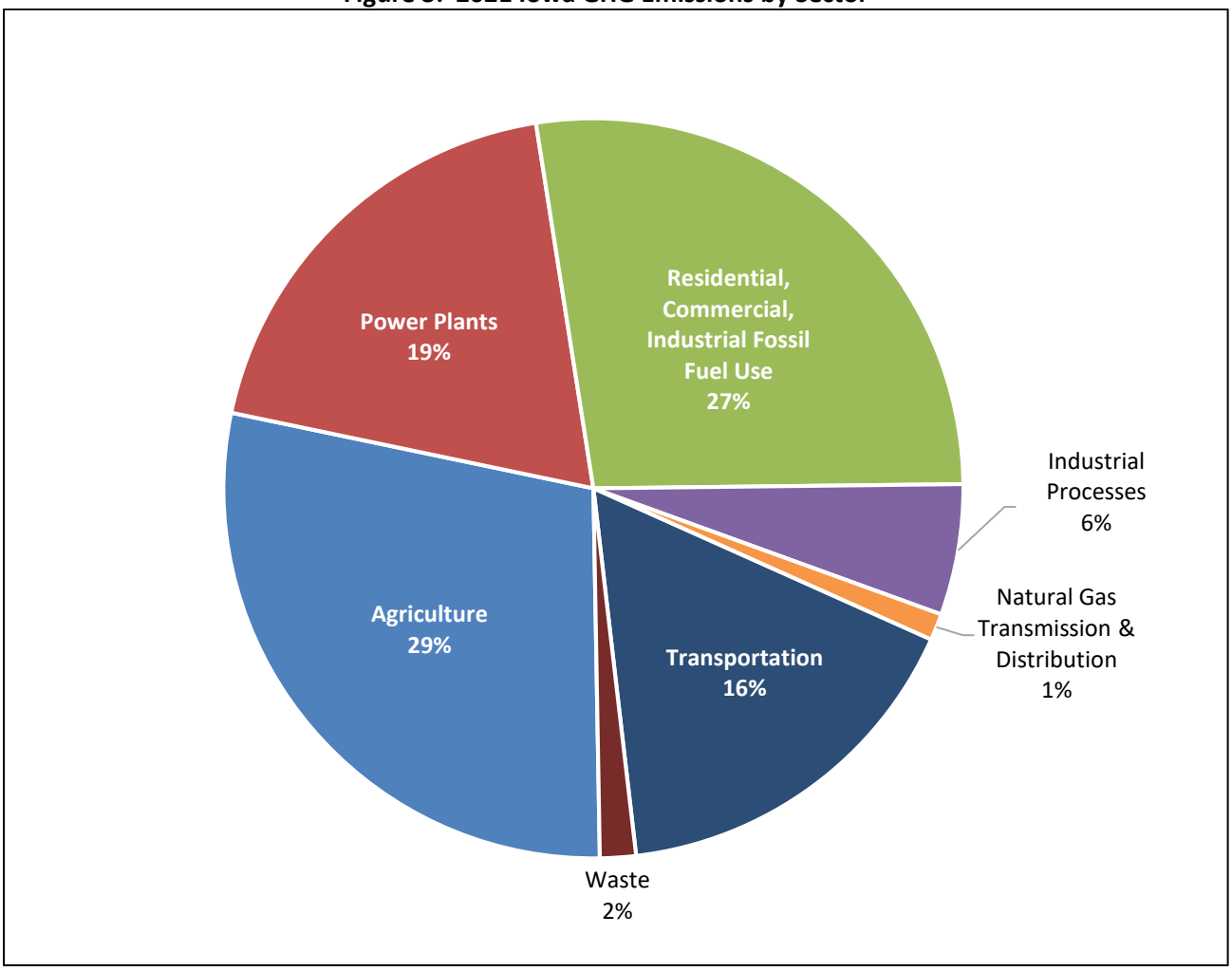


[3] Does not include carbon storage from land use, land use change, and forestry (LULUCF).

GHG Emissions by Sector

The majority of GHG emissions in Iowa in 2021 were from the agriculture sector (29%), followed by emissions from the residential/commercial/industrial (RCI) sector (27%), fossil fuel use by power plants (19%), and transportation (16%), 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 2021 GHG Inventory Technical Support Document for more information on a specific sector, such as sources of input data, calculations, and uncertainty.

Figure 3: 2021 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

[4] Industrial fossil fuel use refers to GHG emissions from fossil fuels combusted by industrial facilities. Industrial processes mean 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 sequestered carbon in 2021.

(such as tractors) are included in the transportation sector. As shown in Table 2, total agriculture emissions increased 0.08% between 2020 and 2021. Emissions from agricultural soil management exhibited the largest change. In 2021, the amount of corn harvested increased 11.23% while the volume of soybeans harvested increased 24.88%. It should be noted that emissions calculations for agricultural soil management have a higher level of uncertainty than those for enteric fermentation and manure management, because the agriculture fertilizer data used to calculate emissions is not as current as the animal population data used.

Decreases in emissions from enteric fermentation and manure management offset the increase in emissions from agriculture soil management. Emissions from enteric fermentation decreased 5.05% due to a decrease in the animal population, particularly the number of cattle. Manure management emission were lower as well due to the decrease in the hog population.

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

Category	2020	2021	% Change
Enteric Fermentation	8.54	8.11	-5.05%
Manure Management	8.55	8.28	-3.17%
Agricultural Soil Management	18.91	19.64	3.87%
Total	**36.00**	**36.03**	**0.08%**

Fossil Fuel Combustion

This sector includes GHG emissions from fossil fuels combusted in four categories: power plants, residential, commercial, and industrial (the residential, commercial, and industrial categories combine into one category called RCI). Together, these four categories account for 44.99% of Iowa's total GHG emissions. Table 3 shows a decrease of 6.30% in emissions from RCI and an increase of 42.16% in power plant emissions between 2020 and 2021.

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

Category	2020	2021	% Change
Residential, Commercial, Industrial (RCI)	36.76	34.45	-6.30%
Residential	5.22	5.16	-1.03%
Commercial	4.05	4.09	0.81%
Industrial	27.49	25.20	-8.35%
Power Plants	17.07	24.27	42.16%
Total	**53.83**	**58.72**	**9.07%**

Residential, Commercial, and Industrial (RCI)

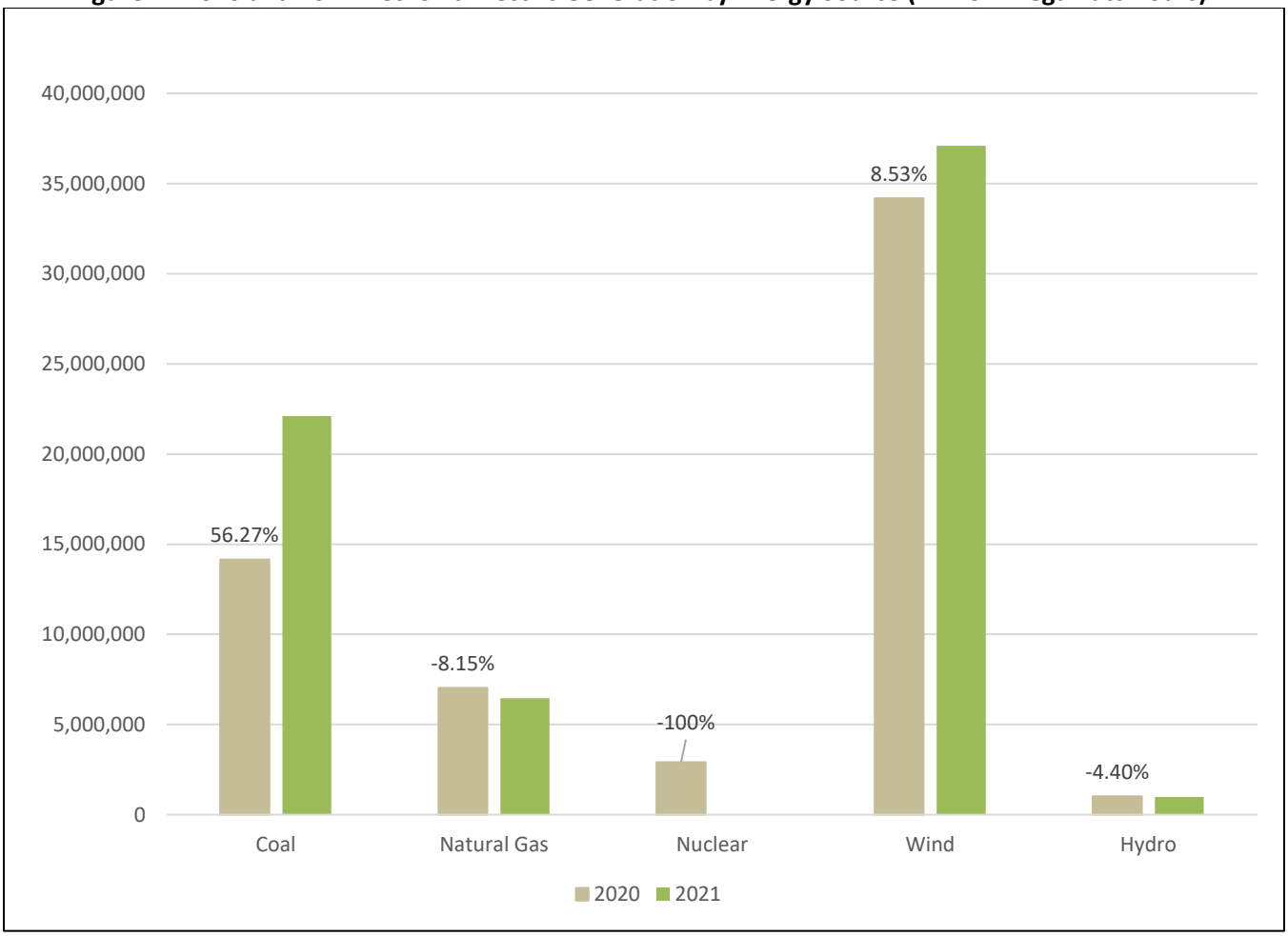
Actual fuel use data for 2021 for the RCI sector was not available from the U.S. Energy Information Administration (EIA), so emissions were calculated based on projected energy consumption values from the EIA's *Annual Energy Outlook 2021 with Projections to 2050.* Emissions predicted for 2020 from the RCI sector in last year's inventory (36.77 $MMtCO_2e$) were replaced with actual 2020 consumption values now available from EIA. The resulting recalculated 2020 emissions were 36.76 $MMtCO_2e$.

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 increased 7.20 $MMtCO_2e$ (42.16%) from the previous year. As shown in Figure 4, from 2020 to 2021 electricity generation from wind increased by 8.53% but electricity generation from nuclear was eliminated due to the closure of Iowa's only nuclear power plant[6]; electricity generated by these sources do not contribute to GHG emissions. Electricity generated from coal increased by 56.27% from 2020 to 2021.

Figure 4: 2020 and 2021 Net Iowa Electric Generation by Energy Source (Million Megawatt Hours)[7]



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 4.50% from 2020 to 2021, 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] Nuclear Engineering International, Early decommissioning for US Duane Arnold following storm damage, August 27, 2020.
[7] U.S. EIA, Net Generation by State by Type of Producer by Energy Source, October 14, 2022.

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

Category	2020	2021	% Change[8]
Ammonia and Urea Production	3.37	2.88	-14.40%
Cement Manufacturing	1.25	1.31	5.20%
Electric Power Transmission & Distribution Systems	0.06	0.06	NA
Iron and Steel Production	0.20	0.14	-29.93%
Lime Manufacturing	0.18	0.16	-7.17%
Limestone and Dolomite Use	0.21	0.21	NA
Nitric Acid Production	0.66	0.81	23.31%
Ozone Depleting Substances Substitutes	1.62	1.62	NA
Soda Ash Consumption	0.02	0.02	NA
Total	**7.55**	**7.21**	**-4.50%**

Natural Gas Transmission and Distribution (T & D)

This sector includes emissions from natural gas transmission and distribution systems in the state. GHG emissions increased 3.67% from 2020 as shown in Table 5, mainly due to an increase in Iowa's number of liquid natural gas storage compressor stations.

Table 5: GHG Emissions from Natural Gas Transmission and Distribution ($MMtCO_2e$)[9]

Category	2020	2021	% Change
Transmission	0.7845	0.8438	7.56%
Distribution	0.6363	0.6292	-1.12%
Total	**1.4208**	**1.4730**	**3.67%**

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. DNR recalculated 2020 emissions from the transportation sector (published as 18.32 $MMTCO_2e$) using updated methane (CH_4) and nitrous oxide (N_2O) emissions factors for both highway and non-highway vehicles. The updated estimated for 2020 increased by 0.49 $MMTCO_2e$ to 18.81 $MMTCO_2e$.

Total vehicle miles traveled by Iowans increased 11.17% between 2020 and 2021, which contributed significantly to the overall 10.32% increase in transportation GHG emissions shown in Table 6.

[8] For categories marked as "NA," the DNR assumed 2021 values equal 2020 values due to a lack of more current data.

[9] 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.

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

Category	2020	2021	% Change[8]
Gasoline Highway	10.11	11.30	11.75%
Diesel Highway	4.08	4.85	18.91%
Non-Highway	4.61	4.59	-0.39%
Alternative Fuel Vehicles	0.01	0.01	NA
Total	**18.81**	**20.76**	**10.32%**

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 decreased 2.58% from 2020 as shown in Table 7. Solid waste emissions decreased because GHG emissions decrease as the waste in place at landfills ages. Emissions from wastewater decreased because fewer facilities were required to report facility-specific emissions data directly to EPA. Facilities are only required to report if they emit more than 25,000 metric tons CO_2e (0.025 $MMTCO_2e$) in the year.

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

Category	2020	2021	% Change
Solid Waste	1.595	1.558	-2.31%
Wastewater	0.435	0.419	-3.56%
Total	**2.030**	**1.978**	**-2.58%**

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, 7.39 $MMtCO_2e$ of carbon was stored in the LULUCF sector in 2021, as shown in Table 8. This is a 1.93% decrease in the amount of CO_2e being stored compared to 2020. This is attributed to an increase in emissions from liming of agricultural soils, urea fertilization, and fertilization of settlement soils.

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

Category	2020	2021	% Change
Forest Carbon Flux	-2.66	-2.66	NA[10]
Liming of Agricultural Soils	0.54	0.56	3.59%
Urea Fertilization	0.12	0.15	21.67%
Urban Trees	-0.34	-0.28	17.65%
Yard Trimmings & Food Scraps in Landfills	-0.10	-0.11	-9.27%
Fertilization of Settlement Soils	0.31	0.36	16.13%
Agricultural Soil Carbon Flux	-5.40	-5.40	NA[11]
Total	**-7.54**	**-7.39**	**1.93%**

The DNR updated the estimated sequestration by urban trees to reflect the loss of urban tree cover from the August 10, 2020 derecho and emerald ash borer. DNR has conservatively estimated that state-wide tree cover of urban areas was reduced from 19% to 15.5% due to these two disruptions. The loss due to emerald ash borer has occurred over the last 10 years and the loss from the 2020 derecho occurred in 2020, but both are only reflected in the sequestration estimate of the 2021 inventory year. More details included in the 2021 GHG Inventory Technical Support Document.

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 66.09% of all greenhouse gas emissions in 2021. 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 18.84 $MMtCO_2e$ or 14.89% of total 2021 GHG emissions. Nitrous oxide emissions in 2021 were 22.40 $MMtCO_2e$ or 17.07% 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 2020, emissions of these three pollutants totaled 1.67 $MMtCO_2e$, or 1.32% of Iowa's 2021 total GHG emissions.

[10] For forest carbon flux, the DNR assumed 2020 and 2021 values equal 2018 values due to a lack of more current data.

[11] For agricultural soil carbon flux, DNR assumes 2021 is equal to 2020 due to a lack of more current data.

Table 9: 2021 GHG Emissions by Pollutant ($MMtCO_2e$)

Pollutant	2021
CO_2	83.61
CH_4	18.84
N_2O	22.40
HFC/PFC/SF_6	1.67
Total	**126.52**[12]

Figure 5: 2021 Carbon Dioxide Emissions by Sector

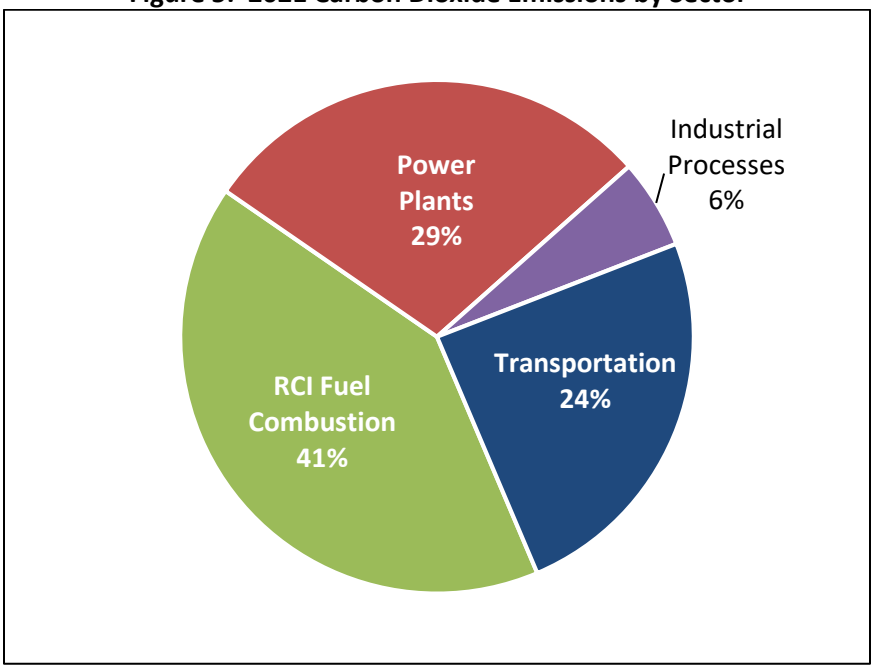


Figure 6: 2021 Methane Emissions by Sector

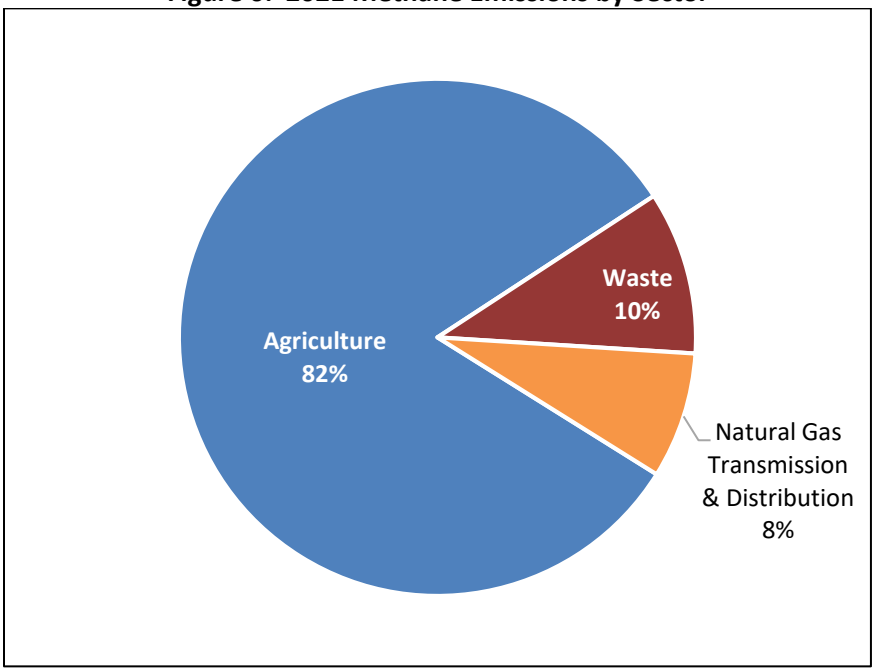


Figure 7: 2021 Nitrous Oxide Emissions by Sector

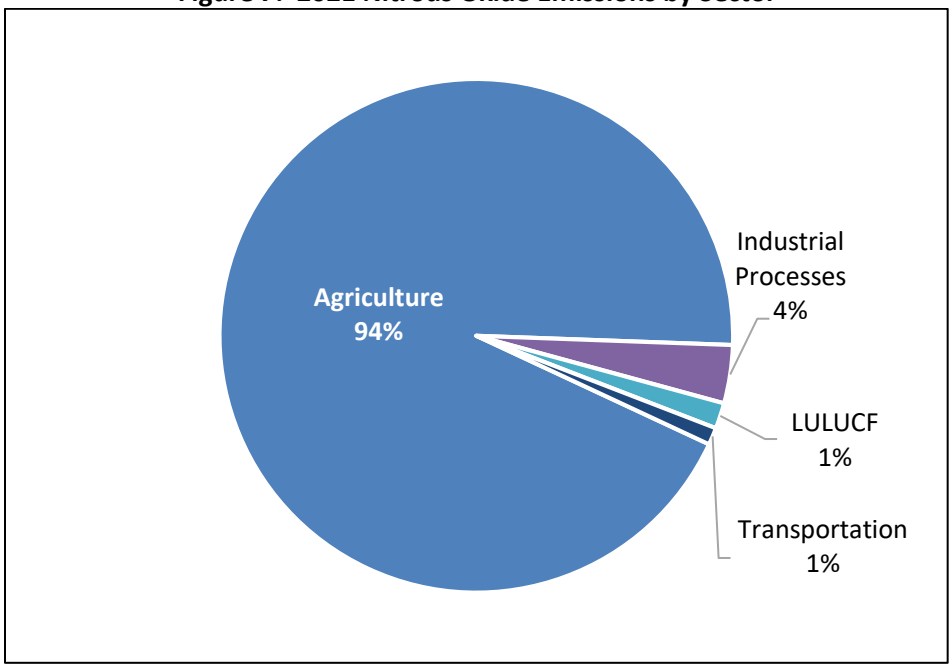
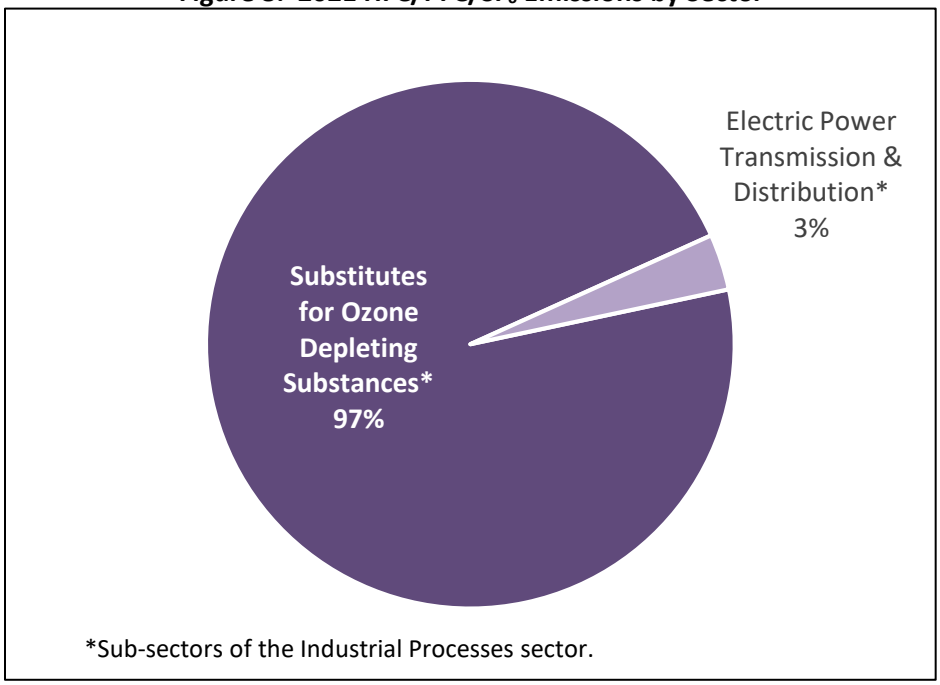


Figure 8: 2021 HFC/PFC/SF_6 Emissions by Sector



Comparison with U.S. Emissions

Comparing Iowa's GHG emissions with U.S. emissions requires the use of 2020 data because the 2021 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

[12] Includes 0.36 $MMtCO_2e$ N_2O from settlement soils that is accounted for in the LULUCF category.

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 2021 were 126.16 $MMtCO_2e$. This represents 2.11% of the total 2020 U.S. gross GHG emissions of 5,981.4 $MMtCO_2e$.

Figure 9: 2020 U.S. GHG Emissions by Sector

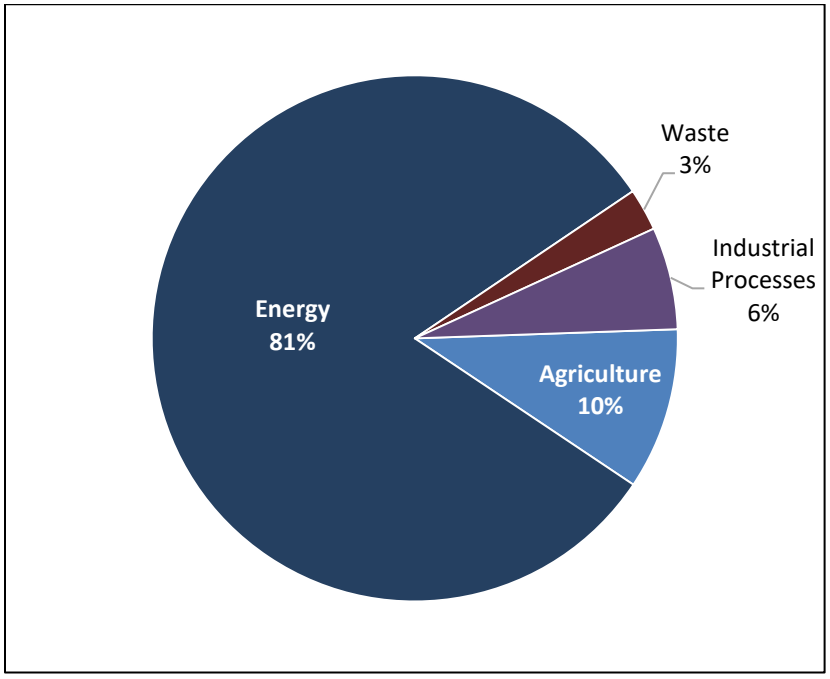
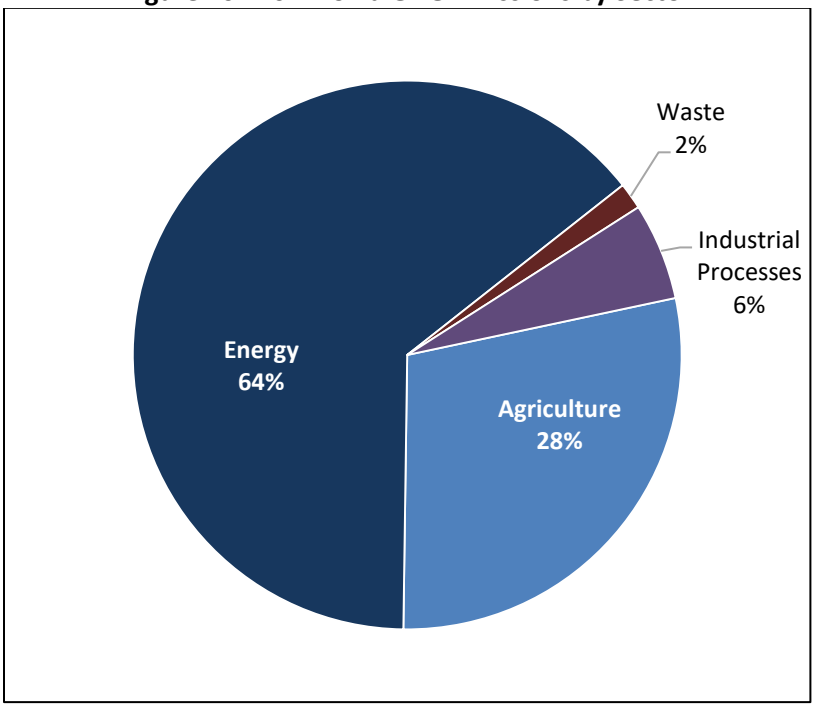


Figure 10: 2021 Iowa GHG Emissions by Sector



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 2025, 2030, 2035, and 2040 as shown in Table 10. The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2019, using a combination of data sources and national projections for activity data. It would be preferable to forecast emissions using the DNR's 2021 calculated GHG inventory as the baseline, but the SIT Projection tool only allows input of emissions up to 2019, and it is not reasonable to fully update the data in the SIT Projection Tool to eliminate all such inconsistencies. A 2021 "forecast" was also produced to help gauge the reasonableness of the projections.

Table 10: Projected Gross GHG Emissions 2021 – 2040 ($MMtCO_2e$)

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

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. Emissions from Power Plants
   Emissions from power plants are difficult to forecast. While emissions may continue to decrease as Iowa utilities shift away from burning coal to burning natural gas and installing renewable generation, the amount and fuel source of electricity generated is influenced by many factors such as:
   - the economy,
   - weather,
   - future environmental regulations,
   - electricity demand by customers,
   - how electricity generation is dispatched by the grid operator, and
   - other market forces.

   Emissions from power plants have increased or decreased by up to 40% from year to year but have shown an overall downward trend, with 2021 emissions the second lowest recorded and 2020 emissions the lowest recorded. The most recent data from EPA's Clean Air Markets Division shows that CO_2 emission from electric power generation during the first nine months of 2022 are 18.5% lower than CO_2 emissions from the first nine months of 2021. However, they are 20.1% higher than the first nine months of 2020 so we can expect 2022 emissions from electric power generation to be between 2020 and 2021.

2. Changes in Agricultural Practices
   29% of Iowa's emissions in 2021 came from agriculture. State-wide fertilizer usage is variable and appears to be trending downward. Fertilizer usage in 2021 was 33.5% lower than 2012 but future fertilizer usage trends are uncertain. More details on emissions from fertilizer are in Chapter 2 - Agriculture of the TSD.
3. Economic Uncertainty
   The U.S. Energy Information Administration (EIA) released its *Short-Term Energy Outlook* (STEO) on November 8, 2022, predicting that "Uncertainty in macroeconomic conditions could significantly affect energy markets in the forecast period. Based on the S&P Global macroeconomic model, we now expect U.S. GDP will fall slightly in 2023, which we forecast will contribute to a drop in total U.S. energy consumption next year. "[13] It should be noted that the STEO addresses national emissions, not Iowa-specific emissions

Uncertainty

As with many forecasts, numerous factors affect the certainty of the predictions. In addition to the factors affecting power plant emissions, GHG emission from other categories may be influenced by energy efficiency and conservation practices, driving practices, use of renewable fuels, and other variables. Discrepancies between the data used to calculate the 2021 GHG inventory and the assumptions within the SIT Projection Tool reduce confidence in the projections as the Tool is not configured to include 2020 or 2021 activity data. For example, the Tool projects that agriculture emissions will continue to increase at the rate they did from 1990 – 2019, when 2018, 2019, and 2020 calculated agriculture emissions actually decreased and 2021 calculated emissions increased only 0.08%. 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 of enhancement are improved forecasting and characterizing the injection of methane from wastewater digesters into natural gas pipelines. Additionally, EPA has planned changes to the SIT to match new disaggregated state-level inventories as a part of the national emissions inventory. This may lead to further improvements in Iowa's inventory.

[13] U.S. EIA, Short-Term Energy Outlook, November 2022.