IOWA DEPARTMENT OF
NATURAL RESOURCES

2013 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

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

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AFOLU	agriculture, forestry, and land use
BOD	biochemical oxygen demand
BOF	blast oven furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CH_4	methane
CO_2	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CRP	Conservation Reserve Program
DNR	Iowa Department of Natural Resources
DOE	United States Department of Energy
DOT	United States Department of Transportation
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Agency
FIA	Forest Inventory Analysis
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
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
ILPA	Iowa Limestone Producers Association
IPCC	Intergovernmental Panel on Climate Change
LDC	local distribution company
LDDT	light duty diesel truck
LDDV	light duty diesel vehicle
LDGT	light duty gasoline truck
LDGV	light duty gasoline vehicle
LFGTE	landfill gas to energy
LULUCF	land use, land use change, and forestry

Acronyms and Key Terms (Continued)

MC	motorcycle
MMtC	million metric tons carbon
$MMtCO_2e$	million metric tons carbon dioxide equivalent
MODIS	Moderate Resolution Imaging Spectroradiometer
MSW	municipal solid waste
N	nitrogen
NRCS	Natural Resources and Conservation Service
NO_3-	nitrates
NO_2-	nitrites
N_2O	nitrous oxide
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
SIT	State Inventory Tool
Tg	teragram
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 *2013 Iowa Statewide Greenhouse Gas Emissions Inventory* Report, which is available at http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx. Total Iowa GHG emissions from 2005 – 2013 are provided in Appendices A and B of this document.

This is a "top-down" inventory 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).

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 – 2012, 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 Technical Support Document are listed in Table 1 on the next page. The coal module was not used as there are no coal mines currently operating in Iowa.

Benefits of reports like this include the evaluation of emissions trends and development of a baseline to track progress in reducing emissions. A state-specific inventory also provides a more in-depth analysis and more accurate inventory of emissions compared to national emissions.

[1] The SIT may be requested at http://www.epa.gov/statelocalclimate/resources/tool.html.

Table 1: TSD Chapters and Corresponding SIT Modules

TSD Chapter	SIT Module	Release Date	Pollutants Addressed
Agriculture	Ag	01/01/14 (draft)	CH_4, N_2O
Energy	CO_2FFC	08/01/14	CO_2
	Stationary Combustion	08/01/14	CH_4, N_2O
Industrial Processes	IP	01/01/14 (draft)	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission and Distribution	Natural Gas and Oil	01/01/14	CH_4
Transportation	CO_2FFC	08/01/14	CO_2
	Mobile Combustion	08/01/14	CH_4, N_2O
Waste	Solid Waste	01/01/14	CO_2, CH_4
	Wastewater	01/01/14	CH_4, N_2O
Land Use, Land Use Change, and Forestry (LULUCF)	LULUCF	01/01/14 (draft)	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	01/01/14	CO_2
Future Emissions	Projection Tool	08/01/14	CO_2, CH_4, N_2O, HFC, PFC, SF_6

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 2 below 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 2014d).

Table 2: Sources of Agricultural GHG Emissions in Iowa

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

<u>Method</u>

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated January 1, 2014 (ICF 2014a and 2014b).

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 3 on the next page. 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). For consistency, the same dairy cattle, beef cattle, sheep, goat, swine, and horse populations were used as for the enteric fermentation sector. Several other animal types were added as shown in Table 3.

Table 3: Animal Populations

Animal Type	Year	Data Source
Dairy cattle	2013	USDA Quick Stats (USDA 2014d)
Beef cattle		
Sheep		
Goats	2012 used as proxy for 2013	2012 Census of Agriculture (USDA 2014a)
Horses		
Breeding swine	2013	2014 Iowa Agricultural Statistics Bulletin (USDA 2014c)
Market swine under 60 lbs.[2]		
Market swine 60 – 119 lbs.[3]		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Hens	2012 used as proxy for 2013	2012 Census of Agriculture (USDA 2014a)
Pullets		
Chickens		
Broilers		
Turkeys	2012 used as proxy for 2013	USDA Quick Stats (USDA 2014d)

In addition, the number of "Sheep on Feed" and "Sheep Off Feed" were derived by applying a 6.5/93.5 on feed/off feed ratio to the total number of sheep.

Agricultural Residue Burning

The SIT assumes that 3% of Iowa corn, soybean, and wheat field residue are burned annually. However, burning of cropland is not a typical agricultural practice in Iowa. Previous Iowa greenhouse gas inventories (Ney et al. 1996 and Strait et al. 2008) have noted that the SIT over-estimates emissions from agricultural residue burning in Iowa, but did not include Iowa-specific data to refine the SIT estimate. The *Year 2000 Iowa Greenhouse Gas Emissions Inventory* notes that **"**According to expert opinion, even this lower estimate [3%] is thought to be too large in Iowa because burning is mostly a maintenance tool for conservation plantings, which are not extensive" (Wollin and Stigliani 2005).

Noting this overestimation, beginning with the 2010 inventory, the DNR chose to calculate GHG emissions from burning of agricultural residues using a more refined method used in EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009 (EPA 2011). This method used data on the area burned in each state by crop type from a study by McCarty (2010) in which remote sensing data from a

[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.

Moderate Resolution Imaging Spectroradiometer (MODIS) was used to approximate the area burned by crop. The method combined changes in surface reflection with locations of ongoing burning from active fire discoveries (McCarty 2011). The study also used improved combustion efficiencies, emission factors, and fuel loads to calculate emissions. The state-level area burned was then divided by state-level crop area harvested data from USDA to estimate the percent of crop area burned by crop.

During the development of the state's nonpoint inventory in 2014, the DNR learned from EPA and other states that the MODIS was identifying recently tilled fields with dark soils as burned fields. This caused the percentage of crop lands burned to be over-estimated. DNR was able to improve the percentage of crop lands burned by using actual fire data that is reported to the DNR by local Iowa fire departments (Kantak 2014). In 2013, fire departments reported that 115.5 acres of corn fields were burned. This was 0.00085% of the total acres of corn harvested (USDA 2014d), and all of the fires were started accidentally during harvest season, either from harvesting equipment sparks or trash fires that spread to dry cornfields. The resulting emissions were much lower than using the SIT method as shown in Table 4.

Table 4: Emissions from Ag Residue Burning (MMtCO$_2$e)

Year	SIT Method	DNR Method
2013	0.10	2.49×10^{-5}

Agricultural Soils

N_2O emissions in the agricultural soils sector occur 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 (NO_2-) and then nitrates (NO_3-). It is carried out by specialized bacterial and naturally occurs 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 2011).

<u>Plant Residues and Legumes</u>

2013 crop production data for alfalfa, corn for grain, oats, soybeans, and wheat (USDA 2014d) was used to calculate N_2O from nitrogen-fixing crops, including alfalfa and soybeans, and nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans.

<u>Soil Cultivation - Nitrous Oxide (N_2O)</u>

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently available (Bedmarek 2012), so the DNR estimated the number of cultivated histosol acres by multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2014d) and by the average percentage of each crop that is tilled (USDA 2014d). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, "…all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a Histosol would require some type of artificial drainage in order to be consistently row cropped" (Sucik 2011a).

Soil Tillage Practices

Carbon may be emitted when soils are tilled. However, carbon may also be sequestered when soil conservation practices are used (no-till or reduced tillage), are converted to the Conservation Reserve Program, or are converted grass, trees or wetlands. This balance between emissions and sequestration is called the soil carbon flux. The SIT does not include the ability to calculate emissions from soil carbon flux from tillage practices.

Practicing no-till for many consecutive years produces the greatest carbon sequestration. When soil is tilled the soil becomes oxygenated, increasing microbial activity and releasing stored carbon. However, there is uncertainty in the amount of carbon stored and released. Scientific studies and literature reviews such as those by Baker et al. (2007) and Blanco-Canqui and Lal (2008) have created uncertainty in this area, while other studies such as those by Franzluebbers (2009) and Boddey et al (2009) dispute them. According to the USDA's "*'No-Till" Farming is a Growing Practice",* there is much uncertainty in the interaction between tillage practices, carbon, and other greenhouse gases" (USDA 2010). A 2007 study by West and Six explains that, "*The extent to which soil C accumulation occurs after a reduction in tillage intensity is determined by the history of land management, soil attributes, regional climate, and current carbon stocks"* (West and Six 2007). The relationship between tillage and nitrogen oxides (N_2O) is also not completely certain. Several studies have observed increases, decreases, and no change in N_2O when soil is tilled (USDA 2013).

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

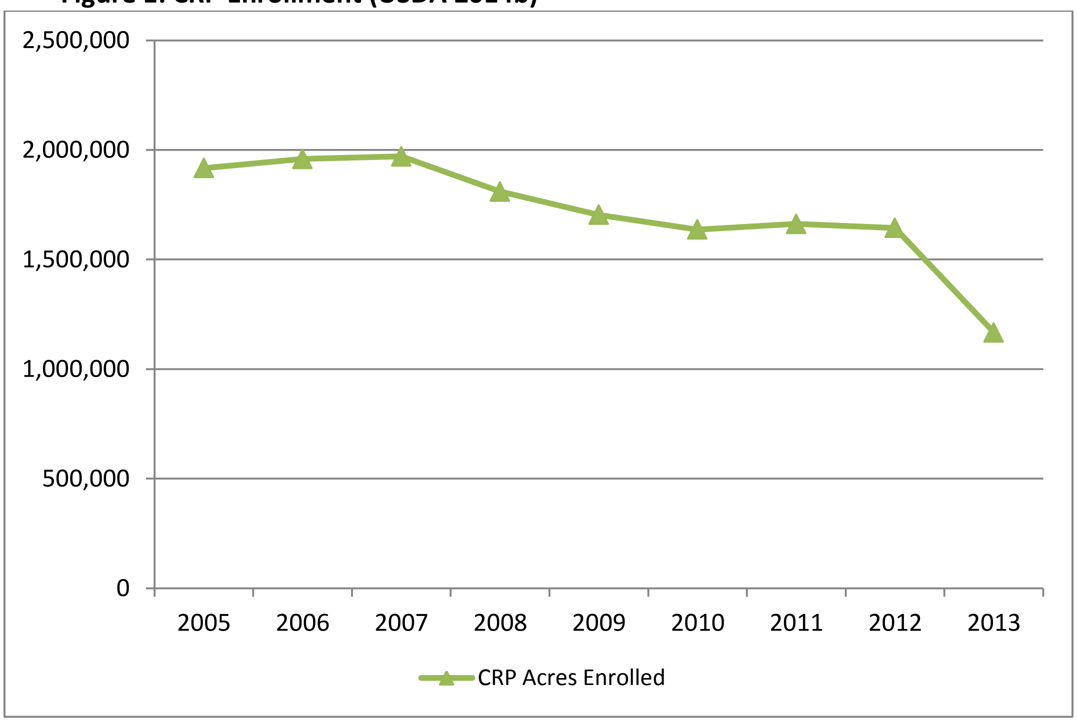
The USDA has also established seven regional climate change offices, offering climate hazard and adaptation data and services to farmers, ranchers, and forest landowners. The NRCS, a department within the USDA, has also launched a program called Carbon Management and Evaluation Online Tool (COMET-FARM)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

The tool guides you through describing your farm and ranch management practices including alternative future management scenarios. Once complete, a report is generated comparing the carbon changes and greenhouse gas emissions between your current management practices and future scenarios (NRCS 2014).

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

While the DNR is unable to quantify agricultural soil carbon flux at this time, it is known that cumulative Iowa acres in the CRP program are decreasing as shown in Figure 1 below. This indicates that the amount of carbon stored in agricultural soils *may* be decreasing as more soil is tilled each year. However, any effects from cover crops were not considered. This may be a future inventory improvement.

Figure 1: CRP Enrollment (USDA 2014b)



Fertilizer Utilization

The DNR calculated fertilizer emissions for 2013 using fertilizer tonnages from the Iowa Department of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* report (IDALS 2014). The IDALS fertilizer data is provided per the 2013 growing season, which is from July 2012 – June 2013. The 2013 growing season was then used as a proxy for the 2014 growing season (July 2013 – June 2014).

Adjustments

As shown in Table 5, 2012 emissions from enteric fermentation, manure management, agricultural soils, and agricultural residue burning have been updated since the DNR's 2012 GHG Inventory Report was published in December 2013.

Table 5: Recalculated Fossil Fuel Emissions (MMtCO_2e)

Sector	2012 value published Dec 2013	2012 updated value
Enteric Fermentation	6.95	6.95
Manure Management	8.54	8.40
Agricultural Soils	20.04	19.56
Agricultural Residue Burning	0.01	0.00
Total	**35.53**	**34.90**

Enteric Fermentation and Manure Management

Several animal populations were updated with more recent values as shown in Table 6. In addition, emissions changed because the enteric fermentation emission factors and manure management volatile solids vary by year.

Table 6: Updated Animal Populations

Animal Type	2012 Value used in 2012 Inventory Published Dec. 2013		Updated 2012 Value	
	Population	Data Source	Population	Data Source
Dairy replacement heifers	140,000	2012 Iowa Agricultural Statistics Bulletin (USDA 2012)	160,000	2014 Iowa Agricultural Statistics Bulletin (USDA 2014c)
Heifer stockers	640,000		620,000	
Goats	56,000		56,239	
Hens (layers)	52,544,000[4]		52,218,870	2012 Census of Agriculture (USDA 2014a)
Pullets	13,765,000[4]		12,565,630	
Chickens	66,319,000[4]		64,784,500	
Broilers	13,284,300	SIT default value	1,948,950	
Horses	71,994	USDA Quick Stats (USDA 2013)	62,206	
Turkeys	9,000,000; 2008 turkey production – measured in head		4,383,172; 2012 turkey inventory – total	USDA Quick Stats (USDA 2014d)

Agricultural Soils

The agricultural soils emissions were recalculated using actual fertilizer usage data for the 2013 growing season from IDALS (IDALS 2014) instead of the proxy data that was previously used.

[4] 2011 value was used as a surrogate for 2012.

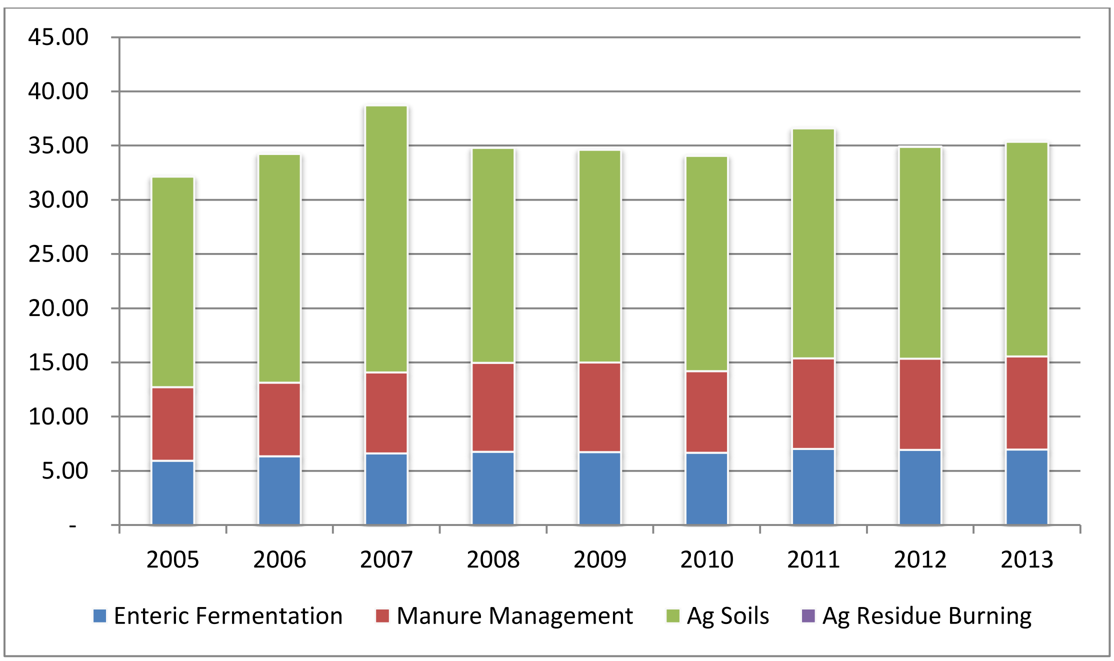
Agricultural Residue Burning
Emissions from agricultural residue burning were recalculated using fire data reported to the DNR (Kantak 2014) as discussed earlier in this chapter.

Results
GHG emissions from agriculture increased 1.36% from 2012 – 2013 and increased 10.21% from 2005 – 2013. Gross GHG emissions from agriculture were 35.38 $MMtCO_2e$ in 2013, or 27.17% of Iowa's total gross GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. The majority of emissions (56.01%) are from agricultural soils as shown in Table 7 and Figure 2.

Table 7: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[5]

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	6.95	6.98
Manure Management	6.77	6.80	7.48	8.19	8.25	7.53	8.34	8.40	8.59
Agricultural Soils	19.42	21.10	24.63	19.85	19.63	19.86	21.22	19.56	19.82
Ag. Residue Burning	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Total	**32.14**	**34.25**	**38.73**	**34.81**	**34.63**	**34.07**	**36.61**	**34.90**	**35.38**

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



Enteric Fermentation
CH_4 emissions from enteric fermentation were 6.98 $MMtCO_2e$ in 2013, increasing 0.36% from 2012. This can be attributed to a 0.46% increase in the beef cattle population and a 3% increase in the swine

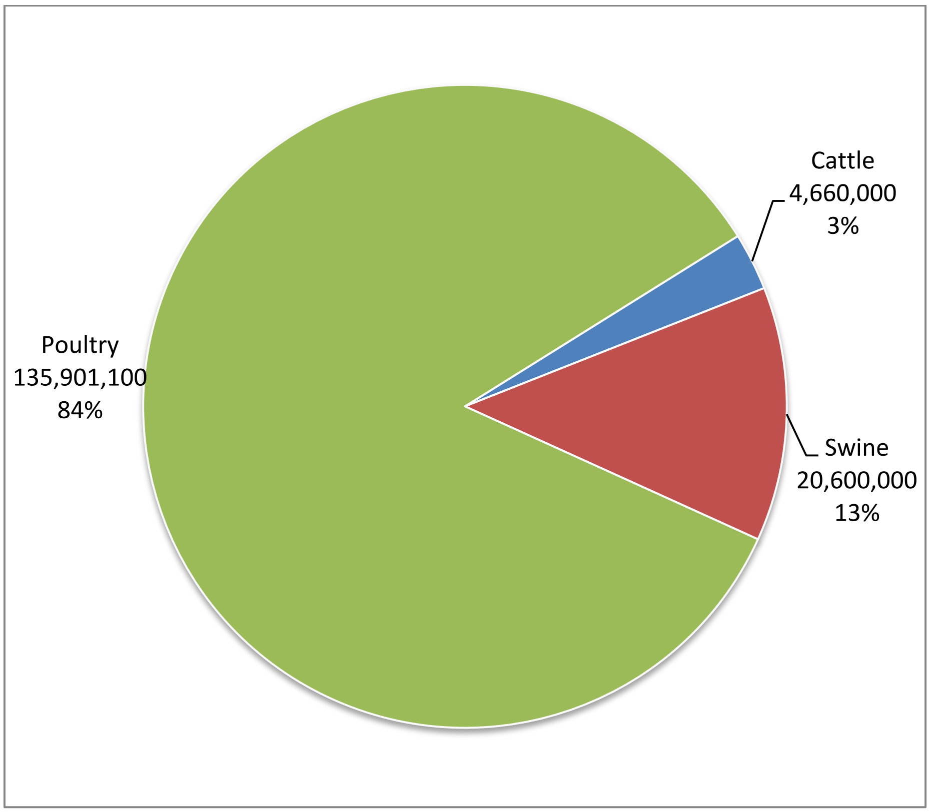
[5] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

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 the cattle population. This is because cattle emit more CH_4 than other ruminant animals due to their unique stomachs. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 8.

Table 8: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2013a)
Beef Cattle	42.0 – 92.0
Dairy Cattle	43.5 – 132.4
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Figure 3: 2013 Animal Populations (USDA 2014a, 2014c, 2014d)[6]



Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 2.30%

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

from 2012 and accounted for 24.27% of agricultural GHG emissions in 2013. The increase in emissions in 2013 can be linked to an increase of 600,000 head in the swine population. It was offset slightly by a 0.43% decrease in the cattle (beef and dairy) population and a 10.26% decrease in the sheep population. As mentioned earlier, the poultry population was assumed to be the same as 2012.

Agricultural Soils

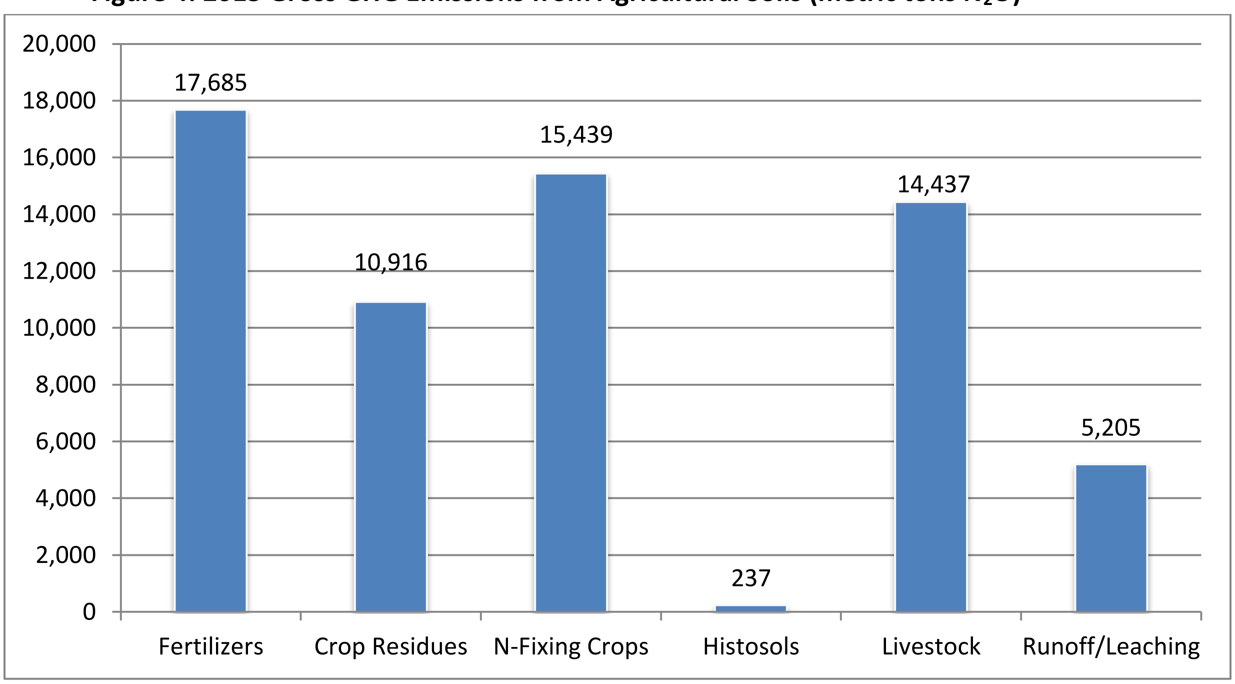
N_2O emissions from agricultural soils increased 1.31% from the previous year. At the same time, field crop production (corn, soybeans, oats, and wheat) increased 12.71% from 2012-2013 as shown in Table 9. Crop production in 2012 was low due to drought conditions.

Table 9: Iowa Crop Production 2012 - 2013

Crop	2012 (1000 Bushels)	2013 (1000 Bushels)
Corn for Grain	1,876,900	2,161,500
Soybeans	414,295	420,875
Wheat	689	1,092
Oats	3,770	3,960
Total	**2,295,654**	**2,587,427**

N_2O emissions from agricultural soils accounted for 56.01% of all agricultural GHG emissions and 15.22% of total statewide GHG emissions in 2013. 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.

Figure 4: 2013 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)



Agricultural Residue Burning
While the estimation of GHG emissions from agricultural residue has been improved, it had little impact on total GHG emissions, accounting for 0.0001% of Iowa agricultural GHG emissions and less than 0.00002% of total Iowa GHG emissions in 2013.

Uncertainty
Excerpted from SIT Agriculture Module (ICF 2014a):

Enteric Fermentation
The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the estimates of animal populations and the emission factors used for each animal type. Therefore, the uncertainty associated with the emission estimate stems from those two variables. Uncertainty is also introduced as animal populations vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. Emission factors vary in each animal, depending on its production and diet characteristics, as well as genetics (ICF 2014a).

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 is the lack of Iowa-specific data describing manure management systems in the SIT 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 amount of N_2O emission 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 (ICF 2014a).

Agricultural Residue Burning

The quantity of emissions is dependent on the number of crop acres burned, and the emission factor, fuel load, and combustion efficiency used for each crop type. Therefore, the uncertainty associated with the emission estimate stems from those four variables. In many cases, the emission factors, fuel load, and combustion efficiencies were derived from expert knowledge and laboratory studies using limited samples. Emission factors also do not provide for seasonal differences in crop burning (McCarty 2011).

Chapter 3 – Fossil Fuel Consumption

This chapter includes GHG emissions from fossil fuel consumption in four categories: electric power generation, residential, industrial, and commercial. The residential, industrial, and commercial categories are often combined into one category called RCI. Together, these four categories accounted for nearly half (49.08%) of Iowa's total 2013 GHG emissions. Fossil fuels combusted by mobile sources are included in the transportation sector and discussed later in this report in *Chapter 6 – Transportation*. Emissions from the electric power 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 2014a-d). These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 10:

Table 10: Fuel Types Included in Fossil Fuel Consumption

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

Iowa-specific 2013 energy consumption data will not be published by the U.S. Energy Information Administration until June 2015, so the DNR projected 2013 energy for the RCI categories. This was done by using the EIA's *Annual Energy Outlook (AEO) 2014 with Projections to 2040* (EIA 2014a) and 2012 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2014b). The AEO2014 includes thirty different projection cases, which each address different uncertainties. The DNR used the AEO2014 "Reference Case", which assumes that the laws and regulations in effect as of the end of October 2013 remain unchanged throughout the projections. It does not include future reductions resulting from EPA's proposed Clean Power Plan. The projections in the Reference Case are done at the regional level, and Iowa is in the West North Central U.S. Census Region. The 2013 energy consumption was estimated for each fuel type using one of three methods as described below and shown in Table 11:

Fuel Method 1

The ratio of 2012 Iowa fuel consumption from SEDS to the 2012 regional fuel consumption from the AEO2014 was calculated. This ratio was then applied to the predicted 2013 regional fuel consumption in the AEO2014. Some accuracy is lost because fuel consumption data in SEDS is in units of billion British thermal units (Btu) while the fuel consumption data in the AEO2014 is in units of quadrillion Btu rounded to just two decimal places. This method was used for the fuel types listed in Table 11 below.

Fuel Method 2

These sectors were not included in the AEO Reference Case, so it was assumed that 2013 fuel consumption was equal to the 2012 fuel consumption. This method was used for the fuel types listed in Table 11 below.

Table 11 – Method Used to Estimate 2013 Fuel Consumption

Fuel Type	Estimation Method
Commercial Coal	Method 1
Commercial Distillate Fuel Oil	Method 1
Commercial Kerosene	Method 1
Commercial Motor Gasoline	Method 1
Commercial Natural Gas	Method 1
Commercial Residual Fuel	Method 1
Industrial Coal	Method 1
Industrial Distillate Fuel Oil	Method 1
Industrial Natural Gas	Method 1
Industrial Motor Gasoline	Method 1
Industrial Other Coal	Method 1
Residential Coal	Method 1
Residential Distillate Fuel	Method 1
Residential Kerosene	Method 1
Residential Natural Gas	Method 1
Commercial LPG	Method 2
Commercial Wood	Method 2
Commercial Other	Method 2

Table 11 (continued)

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

Electric Power Generation

Emissions from the electric power category were not calculated using fuel consumption data. Instead, the total reported CO_2, CH_4, and N_2O emissions from the federal GHG reporting program (40 CFR 98, EPA 2014) were used. This data is more accurate than the values from EIA because the CO_2 emissions reported by facilities to EPA are actual measured emissions values from continuous emission monitors (CEMS) located on electric generating units, and 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 was consistent with the CO_2 emissions reported by the same facilities to EPA as required by the Acid Rain Program (CAMD 2014).

Adjustments

The DNR previously forecasted 2012 emissions due to a lack of Iowa-specific bulk energy consumption data. However, the 2012 energy data was released by EIA in June 2014 (EIA 2014b), so the DNR used the data to recalculate 2012 emissions as shown in Table 12 below.

Table 12: Recalculated Fossil Fuel Emissions ($MMtCO_2e$)

Category	2012 Value Published Dec. 2013	2012 Updated Value
Residential	4.46	4.00
Commercial	4.36	4.16
Industrial	21.41	21.49
Electric Power	35.76	35.76
Total	**65.99**	**65.40**

Results

Total GHG emissions from energy consumption in 2013 were 63.90 $MMtCO_2e$, a decrease of 2.29% from 2012 but 4.92% above 2005 levels as shown in Table 13 below and Figure 5 on the next page.

Of the four fossil fuel categories, the electric power generation category had the highest emissions, accounting for 51.83% emissions from the fossil fuel combustion sector. However, emissions from the electric power generation category decreased 7.37% from the previous year and 21.76% from their peak in 2010.

In contrast, emissions from the other three categories increased because more fossil fuels were consumed by these categories in 2013:

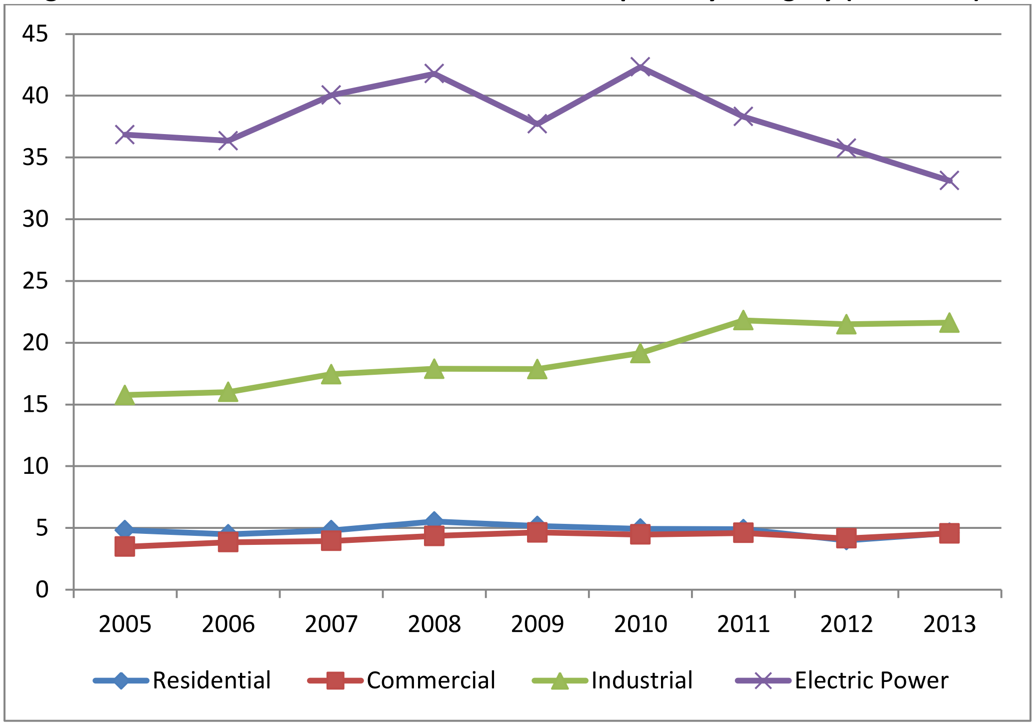
- residential fuel use emissions increased 15.07%
- commercial fuel use emissions increased 9.64%
- industrial fuel use emissions increased 0.62%

Table 13: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)[7]

Category/Fuel Type	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	4.82	4.48	4.81	5.52	5.16	4.94	4.89	4.00	4.60
Commercial	3.48	3.84	3.95	4.35	4.64	4.47	4.60	4.16	4.56
Industrial	15.76	16.00	17.45	17.88	17.86	19.15	21.82	21.49	21.62
Electric Power Generation	36.84	36.35	40.04	41.78	37.71	42.33	38.98	35.76	33.12
Total	**60.90**	**60.68**	**66.26**	**69.53**	**65.38**	**70.89**	**70.29**	**65.40**	**63.90**

[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.

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



<u>Uncertainty -</u>

CO_2 Emissions - Excerpted from SIT CO_2FFC Module (ICF 2014a):

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

National total energy consumption data is fairly accurate, but there is more uncertainty in the state-level 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 (ICF 2014a).

CH_4 and N_2O Emissions - Excerpted from SIT Stationary Combustion Module (ICF 2014b):
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, the more detailed information available on the combustion activity, the lower the uncertainty. 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 data sets 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 (ICF 2014b).

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

Table 14: Industrial Processes and GHG Emissions

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

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.

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.

Soda Ash Use
Soda ash is currently only produced in three states – Wyoming, Colorado, and California (ICF 2014b). 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, paper, textiles, and food (EPA 2014b). In Iowa it is commonly used by corn wet millers for pH control, in ion exchange regeneration, and in other operations (DNR 2010).

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 2010). 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 also from the consumption of supplemental materials used to augment the melting process (EPA 2010).

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 fairly complicated, 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.

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 2014b).

Electric Power Transmission and Distribution
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 2014b).

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

Method

2013 emissions from industrial processes were calculated using either the SIT (ICF 2014a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (40 CFR 98, EPA 2014a) as shown in Table 15. In past years, emissions were calculated using either the SIT or the World Resource *Institute's The GHG Protocol* in conjunction with facility-specific activity data. The DNR has transitioned to using the federal GHG reporting data because it is more accurate and undergoes quality assurance checks. For some categories, such as cement production, the federal GHG reporting program requires GHG emission readings from continuous emissions monitors (CEMS) (40 CFR 98 Subpart H).

Categories Calculated using the SIT

Emissions from use of limestone and dolomite in industrial processes were calculated by multiplying Iowa's annual consumption by the ratio of national consumption for industrial uses to total national consumption. Emissions from ODS substitutes and soda ash consumption categories were calculated by assuming that Iowa emissions were 0.98% of national emissions because Iowa's population is 0.98% of the total U.S. Population (U.S. Census 2014). Emissions from electric power transmission distribution were calculated by determining the ratio between 2012 Iowa retail sales vs. 2012 national retail sales, and applying that ratio to 2012 national emissions.

Table 15: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2013	40 CFR 98 Subpart G	(EPA 2014a)
Cement Production		40 CFR 98 Subpart H	(EPA 2014a)
Iron and Steel Production		40 CFR 98 Subpart Q	(EPA 2014a)
Lime Manufacture		40 CFR 98 Subpart S	(EPA 2014a)
Nitric Acid Production		40 CFR 98 Subpart V	(EPA 2014a)
Electric Power Transmission and Distribution	2012 as proxy for 2013	SIT	(EIA 2013), (EPA 2014b)
Limestone and Dolomite Use		SIT	(USGS 2014a)
ODS Substitutes		SIT	SIT default value
Soda Ash Use	2013	SIT	(USGS 2014b)

Adjustments

As discussed above, emissions from electric power transmission distribution were calculated by multiplying national emissions by the ratio of Iowa retail sales to national retail sales (EIA 2014). Emissions for 2005 -2012 were recalculated using updated emissions from the national GHG emissions inventory (EPA 2014b) as shown in Table 16.

Table 16: SF_6 Emissions from Electric Power Systems ($MMtCO_2e$) [8]

Year	Emissions Using EPA 2013		Revised Emissions Using EPA 2014b	
	National	Iowa	National	Iowa
2005	10.3	0.12	10.2	0.12
2006	NA	0.12	-	0.12
2007	8.2	0.10	-	0.10
2008	7.5	0.09	7.2	0.09
2009	7.5	0.09	6.9	0.08
2010	7.0	0.08	6.4	0.08
2011	6.3	0.08	5.9	0.07
2012	NA	0.08	4.8	0.06

Limestone and Dolomite Use

2005, 2006, and 2010 emissions from use of limestone and dolomite were recalculated using data the default consumption values in the SIT. The difference in the emissions was negligible, ranging from 29-6,307 metric tons as shown in Table 17.

Table 17: Emissions from Limestone and Dolomite Use ($mtCO_2e$)

	2005	2006	2010
2013 Version of SIT	187,386	305,217	389,819
2014 Version of SIT	181,078	294,487	389,791
Difference	-6,307	-10,730	-29

Substitutes for Ozone Depleting Substances (ODS)

2008-2012 emissions were recalculated using updated national emissions (EPA 2014b) adjusted for Iowa population. EPA revised national emissions for 2008 – 2012 using a new "Vintaging Model" to calculate emissions from refrigerants in vehicles:

> "*…A detailed Vintaging Model of ODS-containing equipment and products was used to estimate the actual—versus potential—emissions of various ODS substitutes, including HFCs and PFCs. The name of the model refers to the fact that it tracks the use and emissions of various compounds for the annual "vintages" of new equipment that enter service in each end-use. The Vintaging Model predicts ODS and ODS substitute use in the United States based on modeled estimates of the quantity of equipment or products sold each year containing these chemicals and the amount of the chemical required to manufacture and/or maintain equipment and products over time. Emissions for each end-use were estimated by applying annual leak rates and release profiles, which account for the lag in emissions from equipment as they leak over time. By aggregating the data for 60 different end-uses, the model produces estimates of annual use and emissions of each compound…*
>
> *…A review of the MVAC light-duty vehicle (LDV) and light-duty truck (LDT) end-uses led to revisions in the assumed transition scenarios, stock and growth rate assumptions, and equipment lifetime. Updated annual sales and registration data was used to update the installed base, annual growth rate, and lifetime*

[8] NA= not available. If national emissions were not published for a specific year, the previous year's emissions were used as a proxy.

for the MVAC end-uses. In addition, although HFC-134a has been the dominant refrigerant in MVACs since the 1990s, an additional transition to HFO-1234yf was added to the Vintaging Model beginning in 2012 to reflect a recent shift in new vehicles to HFO-1234yf…" (EPA 2014b).

The new Vintaging Model results in national emissions that are approximately 7% higher than previously calculated.

Results

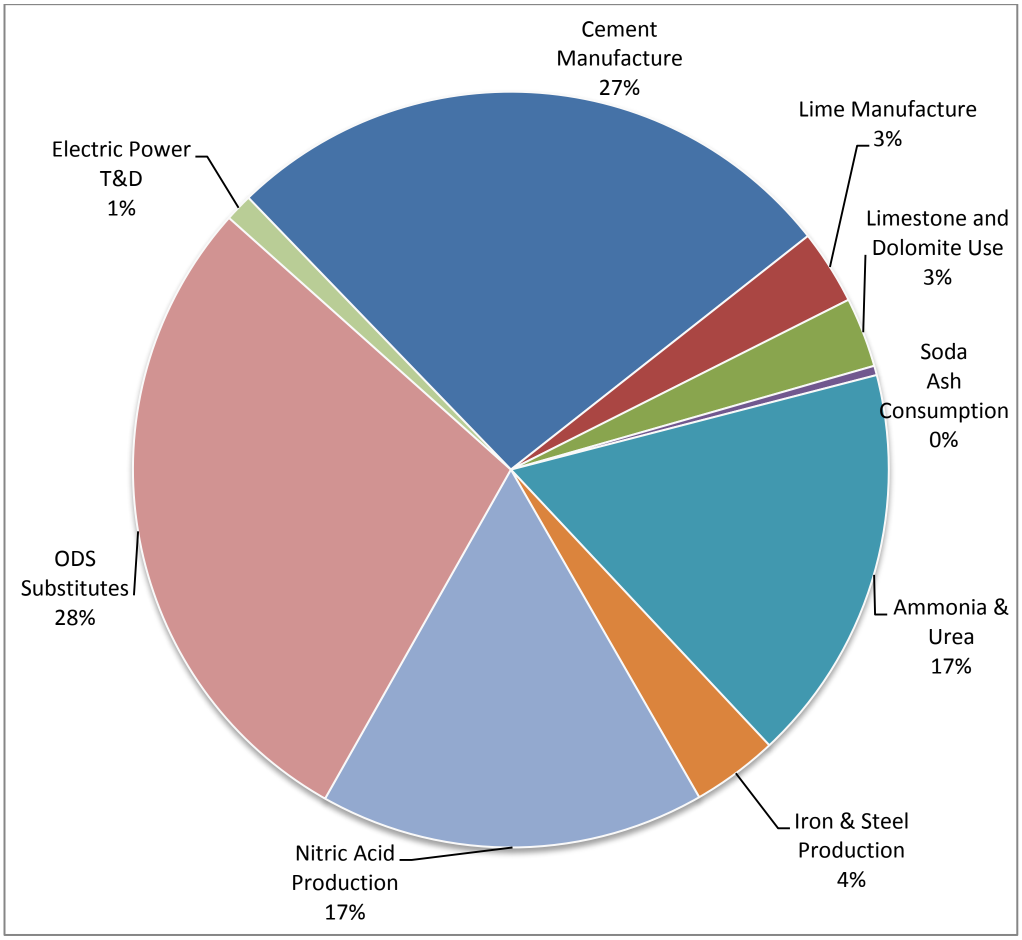
GHG emissions from industrial processes in 2013 were 5.05 $MMtCO_2e$, or 3.88% of total statewide GHG emissions. Emissions from this sector decreased 2.56% from 2012 and increased 10.21% from 2005 – 2013 as shown in Table 18. Ammonia and urea production, ODS substitutes, nitric acid production, and cement manufacture were the highest contributors to industrial process emissions in 2013 as shown in Figure 6 on the next page. All other categories individually contributed less than 5% each.

Table 18: GHG Emissions from Industrial Processes ($MMtCO_2e$)[9,10]

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013
Ammonia & Urea[11]	1.01	0.91	0.95	0.87	0.60	0.84	0.75	0.85	0.86
Cement Manufacture	1.27	1.29	1.27	1.31	0.84	0.72	0.79[12]	1.27	1.34
Electric Power T&D	0.12	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.06
Iron & Steel Production	0.13	0.13	0.13	0.12	0.09	0.23	0.20	0.23	0.19
Lime Manufacture	0.18	0.17	0.16	0.17	0.13	0.18	0.18	0.18	0.16
Limestone & Dolomite Use	0.18	0.29	0.24	0.25	0.29	0.39	0.16	0.15	0.15
Nitric Acid Production	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.83
ODS Substitutes	0.99	1.01	1.01	1.20	1.27	1.36	1.39	1.44	1.44
Soda Ash Consumption	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	**4.58**	**4.71**	**4.70**	**4.93**	**4.23**	**4.80**	**4.49**	**5.18**	**5.05**

[9] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[10] Values for Electric Power T & D 2008 – 2012; Limestone and Dolomite Use 2005, 2006, 2010; and Total Emissions 2005 – 2012 have been updated.
[11] 2005 – 2007 values may be overestimates as they do not account for CO_2 that was recovered for urea or carbon sequestration and storage.
[12] Total includes emissions from fossil fuel combustion that were measured by the Continuous Emission Monitor on the kiln(s). This may be double-counted in the Fossil Fuel Combustion sector.

Figure 6: 2013 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 (*Excerpted from SIT Agriculture Module (ICF 2014a).*

- The estimation of emissions for limestone and dolomite use contains some inherent uncertainty based on limestone's variable composition.
- Although the model used to generate national emission estimates from the consumption of ozone depleting substances substitutes is comprehensive, significant uncertainties exist and are exacerbated by the use of population to disaggregate national emissions.
- Uncertainties in emission estimates for electric power transmissions and distribution can be attributed to apportioning national emissions based on electricity sales because this method incorporates a low probability assumption that various industry emission reduction practices occur evenly throughout the country.

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) may also be emitted from venting and flaring, but was not calculated due to lack of data. GHG emissions from coal mining, natural gas production, oil production, oil transmission, and oil transportation are not included as those industries are currently not active in Iowa.

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2014b).

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 2014). The Iowa Utilities Board confirmed that the number of natural gas compressor and gas storage stations did not change from the previous year (Stursma 2014).

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 2014b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2014). Data entered included miles of steel and cast iron distribution pipeline, unprotected and protected; number of services; and number of steel services, unprotected and protected.

Natural Gas Venting and Flaring

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

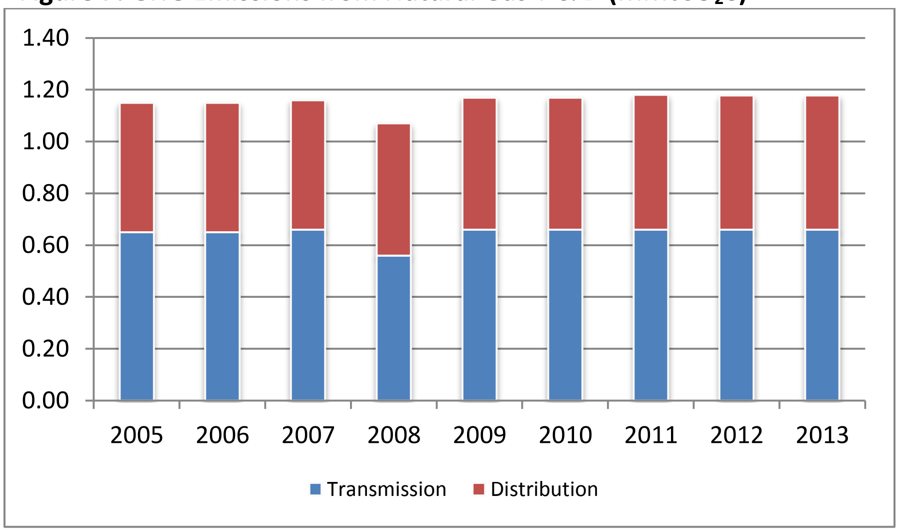
Results

Total GHG emissions from natural gas transmission and distribution were 1.1760 $MMtCO_2e$[13] in 2013, a decrease of 0.14% from 2012 and an increase of 2.33% from 2005 as shown in Table 19 and Figure 7. Emissions decreased in 2013 due to decreases in miles of distribution pipeline and number of steel services (e.g. gas meters). GHG emissions from this sector account for 0.90% of 2013 statewide GHG emissions.

Table 19: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013
Transmission	0.6474	0.6487	0.6589	0.6600	0.6609	0.6611	0.6601	0.6604	0.6606
Distribution	0.5018	0.5026	0.5046	0.5120	0.5110	0.5066	0.5151	0.5173	0.5154
Total	**1.1492**	**1.1513**	**1.1635**	**1.1720**	**1.1720**	**1.1677**	**1.1752**	**1.1777**	**1.1760**

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



Uncertainty

Excerpted from SIT Natural Gas and Oil Systems Module (ICF 2014a):

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 2014a).

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

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

An important distinction to make in the transportation category is that carbon dioxide (CO_2) emissions from all vehicle categories are calculated based on fossil fuel consumption, as are methane (CH_4) and nitrous oxide (N_2O) emissions from non-highway vehicles. However, CH_4 and N_2O emissions from highway vehicles are calculated based on vehicle miles traveled (VMT).

GHG emissions from transportation were calculated using two SIT modules – the CO_2FFC module for CO_2 emissions and the Mobile Combustion module for CH_4 and N_2O emissions. The CO_2FFC SIT module also calculates emissions from the residential, commercial, industrial, and electric power sectors, but in this report those emissions are discussed in *Chapter 3 – Fossil Fuel Combustion*. Emissions from international bunker fuels were not calculated due to a lack of state-level data. Bunker fuels are fuels used in international aviation and marine transportation that originates in the United States. It is a standard inventory practice to subtract emissions from bunker fuels if they are included in state energy consumption totals because the pollutants may not be emitted within the state (IFC 2014a).

CO_2 Emissions

Iowa-specific 2013 energy consumption data will not be published by the U.S. Energy Information Administration until June 2015, so the DNR projected 2013 energy consumption. This was done by using the EIA's *Annual Energy Outlook (AEO) 2014 with Projections to 2040* (EIA 2014b) and 2012 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2014c). The AEO2014 includes thirty different projection cases, which each address different uncertainties. The DNR used the AEO2014 "Reference Case", which assumes that the laws and regulations in effect as of the end of October 2013 remain unchanged throughout the projections. It does not include future reductions resulting from EPA's proposed Clean Power Plan. The projections in the Reference Case are done at the regional level, and Iowa is in the West North Central U.S. Census Region. The 2013 fuel consumption was estimated for each fuel type using one of three methods as described below and shown in Table 20:

> Fuel Method 1
>
> The ratio of 2012 Iowa fuel consumption from SEDS to the 2012 regional fuel consumption from the AEO2014 was calculated. This ratio was then applied to the predicted 2013 regional fuel consumption in the AEO2014. Some accuracy is lost because fuel consumption data in SEDS is in units of billion British thermal units (Btu) while the fuel consumption data in the AEO2014 is in units of quadrillion Btu rounded to just two decimal places. This method was used for the fuel types listed in Table 20.

Fuel Method 2

These sectors were not included in the AEO Reference Case, so it was assumed that 2013 fuel consumption was equal to the 2012 fuel consumption. This method was used for the fuel types listed in Table 20 below.

Table 20 – Method Used to Estimate 2013 Fuel Consumption

Fuel Type	Estimation Method
Transportation Distillate Fuel	Method 1
Transportation Jet Fuel, Kerosene	Method 1
Transportation Motor Gasoline	Method 1
Transportation Natural Gas	Method 1
Transportation Residual Fuel	Method 1
Transportation Aviation Gasoline	Method 2
Transportation Ethanol	Method 2
Transportation LPG	Method 2
Transportation Lubricants	Method 2

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 annual VMT of 31,542 million miles (IDOT 2014). Neither the IDOT nor FHWA track state-level VMT by the seven classes used in the SIT, so the VMT was then distributed among seven vehicle/fuel classes using the national distribution percentages from the Tables A-93 and A-94 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012* (EPA 2014). The classes and the national distribution percentages are shown in Table 21.

Table 21: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2012 (EPA 2014)	2013 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.41%	2,654
Heavy duty gas vehicle	HDGV	1.01%	319
Light duty diesel truck	LDDT	0.81%	257
Light duty diesel vehicle	LDDV	0.34%	108
Light duty gasoline truck	LDGT	19.38%	6,112
Light duty gasoline vehicle	LDGV	69.32%	21,866
Motorcycle	MC	0.72%	227
Total		100.00%	31,542

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 matched that in of Table A-97 in the most recent national inventory (EPA 2014), so it was not updated.
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. Except for the values for Tier 2 Heavy Duty Vehicles and Low Emission Vehicles, the “Percentage of Each Vehicles with Each Control Technology” tables in the SIT matched the Table A-103 in Annex 3 of the most recent national inventory (EPA 2014). The values for those two vehicle types were updated in the SIT.

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 22. Although 30,305 snowmobiles were registered in Iowa in 2013 (Downing 2013), emissions from snowmobiles were not calculated because fuel use data was not available.

Table 22: Iowa-specific Non-highway Activity Data Used

Vehicle Type/Fuel	Year	Data Source
Aviation Jet Fuel, Kerosene	2011 used as proxy for 2012	EIA SEDS (EIA 2014c)
Aviation Gasoline		EIA SEDS (EIA 2014c)
Boats Gasoline		FHWA 2012
Locomotives Distillate Fuel		EIA Adjusted Sales (EIA 2014a)
Tractor Gasoline		FHWA 2012
Tractor Distillate Fuel		EIA Adjusted Sales (EIA 2014a)
Construction Gasoline		FHWA 2013
Construction Distillate Fuel	2010 used as proxy for 2012	SIT default value
Diesel HD Utility		

Alternative Fuel Vehicles (CH_4 and N_2O)

Alternative fuel vehicles include vehicles that combust methanol, ethanol, compressed natural gas, liquefied natural gas, and liquefied petroleum gas. Iowa-specific VMT for alternative fuel vehicles were not available, so the 2011 value was used as a surrogate for 2012 and 2013.

<u>Adjustments</u>

2012 emissions have been updated since the DNR’s 2012 GHG Inventory Report was published in December 2013. The DNR previously forecasted 2012 emissions for some fuel types due to a lack of Iowa-specific bulk energy consumption data. However, the 2012 energy data was released by EIA in June 2014 (EIA 2014c), so the DNR used the data to recalculate 2012 emissions as shown in Table 23.

Table 23: Recalculated Transportation Emissions ($MMtCO_2e$)

Pollutant	2012 Value Published Dec. 2013	2012 Updated Value
CO_2	22.17	20.79
CH_4	0.03	0.03
N_2O	0.25	0.25
Total	**22.45**	**21.07**

Results

Total GHG emissions from transportation were 21.71 $MMtCO_2e$ in 2013 as shown in Table 24 below. This was an increase of 3.03% from 2012 but a decrease of 0.77% from 2005. GHG emissions from this sector account for 16.68% of 2013 statewide GHG emissions. CO_2 is the most prevalent GHG, accounting for 98.83% of GHG emissions from the transportation sector.

Table 24: GHG Emissions from Transportation ($MMtCO_2e$)[14]

Pollutant	2005	2006	2007	2008	2009	2010	2011	2012	2013
CO_2	21.25	21.82	22.31	21.54	21.03	21.72	22.37	20.79	21.46
CH_4	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
N_2O	0.59	0.52	0.46	0.40	0.36	0.33	0.28	0.25	0.22
Total	**21.88**	**22.38**	**22.81**	**21.97**	**21.42**	**22.07**	**22.68**	**21.07**	**21.71**

The CO_2 method in SIT calculates emissions based only on total fuel consumption by fuel; it does not account for vehicle type, vehicle age, control technologies, or vehicle miles traveled. However, the SIT method for calculating CH_4 and N_2O emissions accounts for all of those factors for highway vehicles.

The SIT shows that while CO_2 emissions vary from year to year, emissions of CH_4 and N_2O have steadily decreased as shown in Figure 8, Table 24, and Table 25. The decrease in CH_4 and N_2O emissions can be attributed to changes in vehicle distribution and improvements in vehicle fuel-efficiency (EPA 2014). A future improvement to this inventory may be to calculate transportation emissions using the same method for each pollutant. However, CH_4 and N_2O account for such a small portion of little emissions that decreases in these pollutants have little effect in total emissions as shown in Figure 9.

Table 25: Total CH_4 and N_2O Emissions from Mobile Sources ($MMtCO_2e$)[15]

Fuel /Vehicle Type	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gasoline Highway	0.57	0.51	0.44	0.38	0.34	0.31	0.25	0.23	0.20
Diesel Highway	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.004
Non-Highway	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05
Alternative Fuels	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004
Total	**0.63**	**0.56**	**0.50**	**0.43**	**0.39**	**0.35**	**0.31**	**0.28**	**0.25**

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

Figure 8: CH_4 and N_2O Emissions by Fuel and Vehicle Type ($MMtCO_2e$)

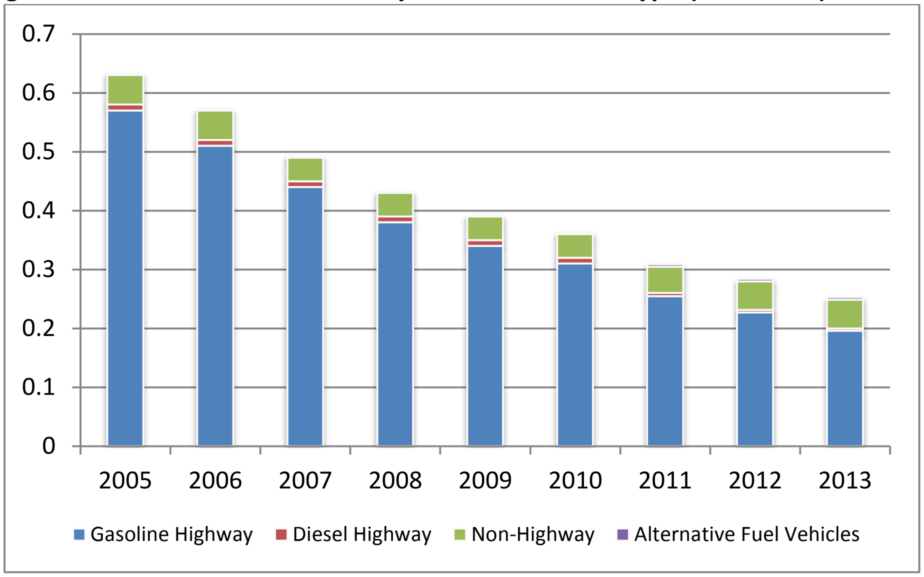
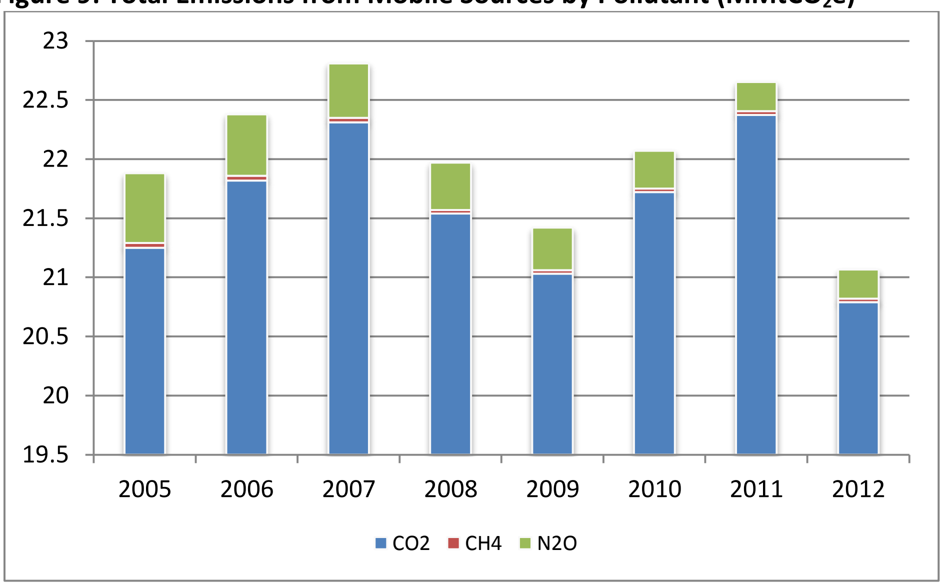


Figure 9: Total Emissions from Mobile Sources by Pollutant ($MMtCO_2e$)



Uncertainty

CO_2 Emissions - Excerpted from SIT CO_2FFC Module (ICF 2014a):

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

National total energy consumption data is fairly accurate, but there is more uncertainty in the state-level data, especially when allocating consumption to the transportation end-use sector. 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. Uncertainty is also introduced by not subtracting emissions from international bunker fuel (ICF 2014a).

The uncertainty in carbon content and oxidation is 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 and these coefficients are also provided in the SIT.

CH_4 and N_2O Emissions:

Uncertainty in CH_4 and N_2O emissions 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. The annual VMT value used also has some uncertainty because the values provided by the federal DOT differed from the value provided by the state DOT. There is also some uncertainty in the method EPA used to develop the national vehicle/fuel type distributions and to develop emission factors (EPA 2014). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable locate Iowa-specific VMT data. Since CH_4 and N_2O emissions from non-highway vehicles are calculated in a fairly straightforward calculation by multiplying fuel consumption data by an emission factor, 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 2014b).

Aviation CH_4 and N_2O emissions have a higher level of uncertainty because the jet fuel and aviation gasoline fuel data used is the total quantity of those fuels purchased in Iowa and includes fuel that may be consumed during interstate or international flights (Strait et al. 2008).

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. It also accounts for CH_4 that is flared or captured for energy production. 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, climate; the quantity of CH_4 that is recovered and either flared or combusted in landfill-gas-to-energy (LFGTE) projects; 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).

<u>Method</u>

Municipal Solid Waste (MSW) Landfills

CO_2 and CH_4 are produced in landfills from anaerobic decomposition of organic matter. The resulting GHG emissions are approximately 50% CO_2 and 50% CH_4. Some landfills collect and flare landfill gas, and there are also landfills that collect and burn landfill gas for landfill-gas-to-energy (LFGTE) projects. CH_4 emissions were determined by estimating the amount of CH_4 generated by landfills and subtracting any CH_4 that was flared or combusted in LFGTE projects.

- The amount of CH_4 generated at landfills was calculated using the total amount of municipal solid waste (2,632,604 tons) sent to Iowa landfills in 2013. These amounts are reported annually by individual landfills to the DNR's Land Quality Bureau by (DNR 2014a and Jolly 2014).
- The amount of CH_4 emissions avoided from flaring and LFGTE projects was calculated using data reported annually by individual facilities to the DNR's Air Quality Bureau on their annual air emissions inventories. Facilities reported flaring 14,222 tons of CH_4 and recovering 17,479 tons of CH_4 for LFGTE projects in 2013 (DNR 2014b).

The DNR was unable to obtain Iowa-specific waste composition and oxidation rates, so the following SIT defaults were used to calculate emissions:

- CH_4 generation from industrial landfills in the U.S. is assumed to be 7% of generation from municipal solid waste landfills.
- 10% of landfill CH_4 that is not flared or recovered is oxidized in the top layer of the soil over the landfill.
- The fraction oxidized for plastics, synthetic rubbers, and synthetic fibers is 98%.

Combustion of Municipal Solid Waste

The amount of CH_4 emitted from power plants burning municipal solid waste 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 (DNR 2014b). One facility reported burning a total of 28,222 tons of municipal solid waste in 2013.

The inventory was also refined by using state-specific proportions of discards that are plastics, synthetic rubbers, and synthetic instead of SIT default values to calculate CO_2 emissions from municipal solid waste combustion. These state-specific proportion values are from the *2011 Iowa Statewide Waste Characterization Study (*MSW 2011). The state-specific proportions of discards used are shown in Table 26 below.

Table 26: Proportions of Discards used in the Solid Waste Module

Material	SIT Default Value[16]	2011 Iowa Study
Plastics	17.0 – 18.0%	16.7%
Synthetic Rubber[17]	2.3 – 2.6%	1.0%
Synthetic Fibers[18]	5.6 – 6.3%	4.1%

Plastics and synthetic rubber materials may be further divided in the SIT into subcategories of plastics and rubber (e.g. polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), etc.), but the subcategories in the SIT do not match the subcategories in the waste characterization study. Therefore, the DNR did subcategorize the proportion of municipal solid waste discards.

<u>Results</u>

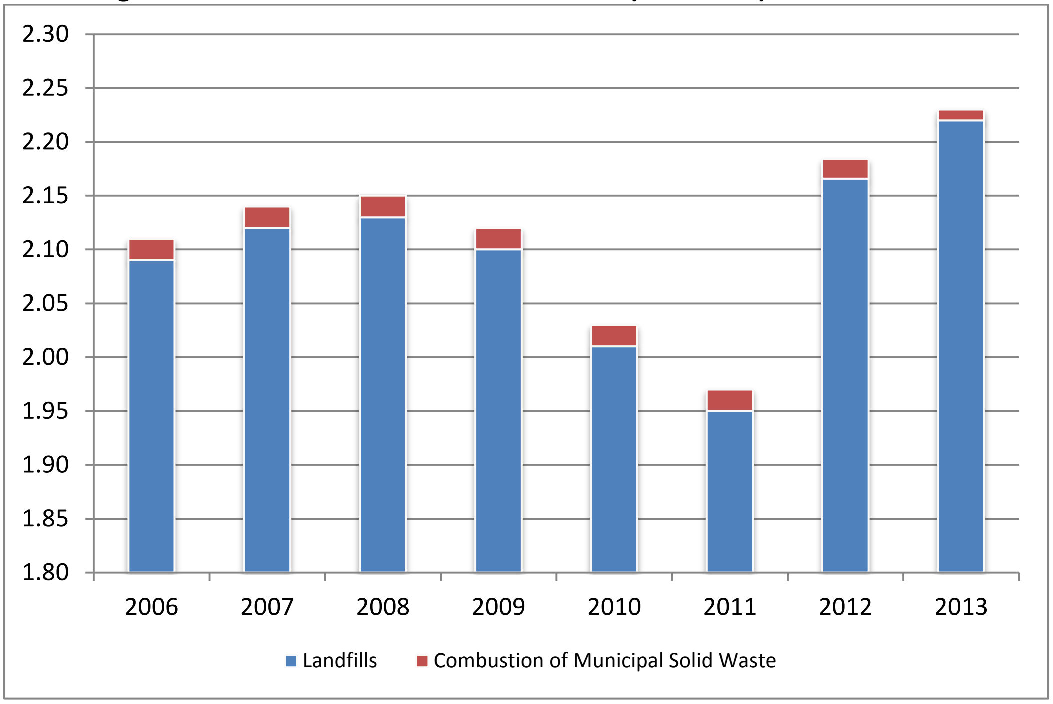
Total GHG emissions from the solid waste category were 2.23 $MMtCO_2e$ in 2013, an increase of 2.03% from 2012 and an increase of 2.83% from 2005 as shown in Table 27 and Figure 10 on the next page. Emissions from municipal solid waste increased in 2013 for two reasons: First, the cumulative amount of waste in landfills increases every year, but the calculation method assumes that the waste composition if each landfill is the same. Second, more methane was emitted because less landfill gas was flared off than in the previous year as shown in Table 28.

Table 27: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$) [19]

Pollutant	2005	2006	2007	2008	2009	2010	2011	2012	2013
Landfills	2.14	2.09	2.12	2.13	2.10	2.01	1.95	2.17	2.22
MSW Combustion	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Total	**2.17**	**2.11**	**2.14**	**2.15**	**2.12**	**2.03**	**1.97**	**2.18**	**2.23**

[16] Default values for 2005 – 2008.
[17] The 2011 Iowa waste characterization studies identify this material as “rubber”.
[18] The 2011 Iowa waste characterization studies identify this material as “textiles and leather”.
[19] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

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



Approximately 0.60 $MMtCO_2e$ of CH_4 emissions were avoided in 2013 by combusting CH_4 in flares or converting it in LFGTE projects as shown in Table 28. This is a 3.96% decrease from the previous year but a 49.20% increase from 2005.

Table 28: CH_4 Emissions from Landfills ($MMtCO_2e$)[20,21]

Category	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Potential CH_4	2.78	2.81	2.86	2.90	2.94	2.97	3.00	3.04	3.07
MSW Generation	*2.60*	*2.63*	*2.67*	*2.71*	*2.74*	*2.77*	*2.80*	*2.84*	*2.87*
Industrial Generation	*0.18*	*0.18*	*0.19*	*0.19*	*0.19*	*0.19*	*0.20*	*0.20*	*0.20*
CH_4 Avoided	(0.40)	(0.49)	(0.50)	(0.53)	(0.60)	(0.74)	(0.83)	(0.63)	(0.60)
Flare	*(0.26)*	*(0.19)*	*(0.16)*	*(0.19)*	*(0.35)*	*(0.37)*	*(0.49)*	*(0.30)*	*(0.27)*
Landfill Gas-to-Energy	*(0.15)*	*(0.30)*	*(0.34)*	*(0.34)*	*(0.25)*	*(0.37)*	*(0.34)*	*(0.33)*	*(0.33)*
Oxidation at MSW Landfills	0.22	0.21	0.22	0.22	0.21	0.20	0.20	0.22	0.23
Oxidation at Industrial Landfills	0.18	0.18	0.19	0.19	0.19	0.02	0.02	0.02	0.02
Total	**2.14**	**2.09**	**2.12**	**2.13**	**2.10**	**2.01**	**1.95**	**2.17**	**2.22**

[20] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[21] Numbers in parentheses are negative numbers.

Uncertainty

Excerpted from SIT Solid Waste Module (ICF 2014a):

MSW Landfills

The methodology does not account for characteristics of individual landfills that impact CH_4 emissions such as temperature, rainfall, landfill design, and the time period that the landfill collects waste. The methodology also assumes that the waste composition of each landfill is the same. The SIT also assumes that 10% of CH_4 is oxidized during diffusion through the soil cover over landfills. This assumption is based on limited information. The methodology also does not account for the presence of landfill gas collection systems that may affect activity in the anaerobic zones of landfills since active pumping may draw more air into the fill (ICF 2014a).

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 2014a).

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 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 emission 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 2014b).

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 2013 (U.S. Census 2014). 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 from Table 8-15 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012* (EPA 2014b). Because the 2013 protein value was not available at the time of publication, the 2012 value was used as a surrogate for 2013.

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

The SIT calculates industrial wastewater treatment emissions from the pulp and paper industry and from food processors of fruits, vegetables, red meat and poultry. The DNR calculated emissions from red meat processing using red meat production numbers from the USDA (USDA 2014). The DNR was unable to find production data for fruits, vegetables, poultry, and pulp and paper in the units required by the SIT, so emissions from these sources were not calculated.

Several source categories including food processors are required to report annual emissions from industrial wastewater to the federal greenhouse gas reporting program (GHGRP). However, not all food processors are required to report; only sources that emit 25,000 metric tons CO_2e or more are required to report. Because the GHGRP data does not include emissions from all processors of red meat, it was not used in this inventory. In 2013, six food processors reported emissions of 0.09 MMtCO_2e. Sixteen ethanol producers also reported 0.03 MMtCO_2e of emissions from industrial wastewater treatment (EPA 2014a).

Adjustments

Municipal wastewater emissions for 2005 – 2012 were recalculated using updated available protein values from Table 8-15 in the most recent national GHG inventory (EPA 2014b). In that inventory, EPA updated the protein values by extrapolating 2007 – 2012 values from 1990 – 2006 data from the USDA Economic Research Service. The previous and revised values are shown in Table 29 below. The difference in emissions negligible - approximately was 0.00 – 0.01 MMtCO_2e - depending on the year.

Table 29: Available Protein (kg/person-year)

Year	EPA 2013	EPA 2014
2005	41.7	39.8
2007	42.1	40.7
2008	42.2	40.8
2009	42.4	40.9
2010	42.6	41.0
2011	42.8	41.1
2012	-	41.2

Results

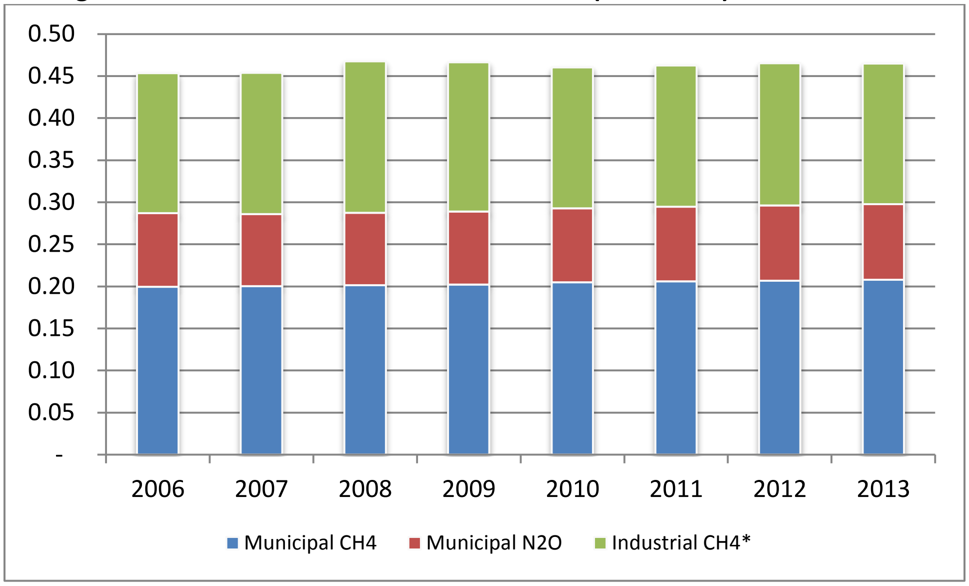
Wastewater emissions account for 0.36% of total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.47 MMtCO_2e in 2013, a 0.03% decrease from 2012 and a 4.14% increase from 2005 as shown in Table 30. CH_4 and N_2O from municipal wastewater treatment accounted for 63.92% (0.30 MMtCO_2e) of total wastewater treatment GHG emissions as shown in Figure 11.

Table 30: GHG Emissions from Wastewater (MMtCO_2e)[22]

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal CH_4	0.1985	0.1994	0.2003	0.2014	0.2023	0.2049	0.2060	0.2068	0.2079
Municipal N_2O	0.0829	0.0875	0.0855	0.0861	0.0867	0.0880	0.0887	0.0893	0.0897
Industrial CH_4	0.1650	0.1665	0.1679	0.1799	0.1773	0.1672	0.1678	0.1690	0.1673
Total	**0.4464**	**0.4533**	**0.4538**	**0.4674**	**0.4663**	**0.4602**	**0.4625**	**0.4650**	**0.4649**

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

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



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

<u>Uncertainty</u>

Excerpted from SIT Wastewater Module (ICF 2014a):

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the Iowa-specific percentage of the population without septic systems was used to calculate emissions, the value is from 1990. There can also be variation in the per-capita BOD production association with food consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors that can be attributed to differences in wastewater treatment facilities (ICF 2014a).

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 fairly 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 2014a).

Industrial Wastewater

GHG emissions from industrial wastewater are underestimated because they do not include emissions from the treatment of wastewater from the production of fruits and vegetables, pulp and paper, or turkeys. While Iowa-specific red meat production data was used to calculate GHG emissions from the treatment of industrial wastewater from red meat, there can be large uncertainties associated with using default emission factors. For example, wastewater outflows and organics loadings can vary considerably for different plants and different sub-sectors, and there can also be variation in the per-capita BOD production associated with industrial processes, and disposal characteristics for organic matter. Furthermore, there is variation in these factors that can be attributed to characteristics of industrial pre-treatment systems as well as eventual treatment at municipal facilities (ICF 2014a).

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, as well as carbon sequestered by forests, urban trees, and yard waste and food scraps that are sent to the landfill.

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). CO_2 is emitted by live tree respiration, decay of dead material, fires, and biomass that is harvested and used for energy (Strait et al. 2008). This balance between the emission of carbon and the uptake of carbon is known as carbon flux (ICF 2014b).

The annual forest carbon flux was calculated using carbon storage statistics from the USDA Forest Service's *Forest Inventory Data Online (FIDO) (*USFS 2014). FIDO data used to calculate sequestration/emission included 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

Because 2014 carbon storage statistics were not available to calculate the 2013 carbon storage flux (2014 storage minus 2013 storage), the 2013 flux was assumed to be the same as the previous year.

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 2014). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (DOT) tracks general information for active aggregate sources used for construction, including whether the material is limestone or dolomite. They do not track that information for limestone produced for agricultural purposes. The DOT 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.

Urea Fertilization

The amount of urea fertilizer applied in the in last six months of 2013 was not available; so 2012 was used as a surrogate for 2013.

Urban Tree Flux

The amount of carbon stored in urban trees was calculated using the most recent Iowa urban forest data, 13.7% of urban area with tree cover, from the U.S. Forest Service (Nowak 2010 and 2013) and the total annual urban area provided in the *2010 Census Urban and Rural Classification and Urban Area Criteria* (U.S. Census 2014). It was assumed that 2012 carbon storage equaled 2013 carbon storage.

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 2014b). N_2O emissions from settlement soils were calculated using 10% of the total annual synthetic fertilizer value from the SIT Agriculture module. For more information on how the 2013 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[23] of wildfires and prescribed burns in Iowa are 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 waste and food waste in municipal solid waste from the *2011 Iowa Statewide Waste Characterization Study* (MSW 2011) to the total amount of municipal solid waste sent to landfills in 2013 (Jolly 2014). While the DNR was able to use more accurate Iowa values for the annual amounts of yard waste 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.

[23] Of those that specified the vegetation type burned on their fire report to the Department. The Department tracks the date, location, and total acres of wildfires and prescribed burns reported to the Department, but the type of vegetation burned is not required to be reported for each fire.

Adjustments

Forest Carbon Flux

The 2012 forest carbon flux value was recalculated using data from the USDA Forest Service's *Forest Inventory Data Online* (USFS 2014 and Barnett 2014). In the previous inventory, the 2011 carbon flux value was used as a surrogate for 2012. The previous reported value was -0.14 $MMtCO_2e$. The revised value is -0.47 $MMtCO_2e$. This changed the total emissions from the LULUCF sector in 2012 from 0.80 $MMtCO_2e$ to 0.48 $MMtCO_2e$.

Urea Fertilization

The 2012 emissions from urea fertilization were recalculated using 2012 urea application data (USDA 2013, 2014). The previous reported value was 0.12 $MMtCO_2e$. The revised value is 0.13 $MMtCO_2e$.

Results

Overall, sources in the LULUCF sector released more carbon than they stored in 2012, emitting a total of 0.20 $MMtCO_2e$ as shown in Table 31 and Figure 12. This is a decrease of 40.31% from 2012. and an increase of 101.39% from 2005. Emissions of CO_2 are shown above the x-axis in Figure 12 and carbon sinks are shown below the x-axis.

Table 31: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[24]

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013
Forest Carbon Flux	-21.24	-6.53	+2.70	-4.48	-5.47	-2.68	-0.14	-0.47	-0.47
Liming of Ag Soils	+0.42	+0.45	+0.37	+0.28	+0.27	+0.47	+0.51	+0.65	+0.47
Urea Fertilization	+0.15	+0.15	+0.15	+0.15	+0.12	+0.11	+0.12	+0.13	+0.13
Urban Trees	-0.25	-0.25	-0.25	-0.26	-0.26	-0.28	-0.28	-0.28	-0.28
Yard Trimmings & Food Scraps Stored in Landfills	-0.09	-0.09	-0.08	-0.09	-0.10	-0.10	-0.13	-0.12	-0.11
N_2O from Settlement Soils	+0.46	+0.48	+0.53	+0.49	+0.44	+0.48	+0.56	+0.57	+0.55
Total	**-20.54**	**-5.79**	**+3.41**	**-3.91**	**-5.00**	**-2.00**	**+0.66**	**0.48**	**+0.28**

The decrease in forest carbon flux can be attributed to a decrease in total forested area. The total amount of forested land in Iowa has decreased 87,830 acres (2.88%) from 2007 – 2012 (USFS 2014). The majority of forest carbon is stored in above ground living trees (37%) and in the forest soil (42%) as shown in Figure 13 on the next page.

[24] Updated values. Positive numbers show carbon emissions. Negative numbers show carbon sequestration, also known as carbon sinks.

Figure 12: 2013 GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[25]

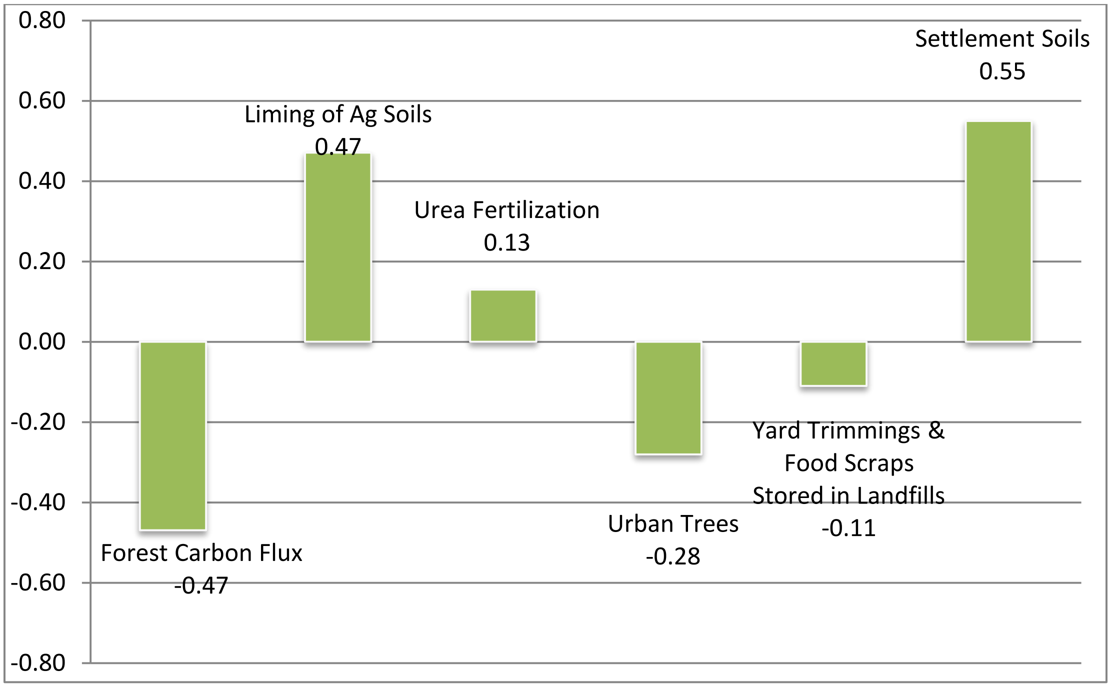
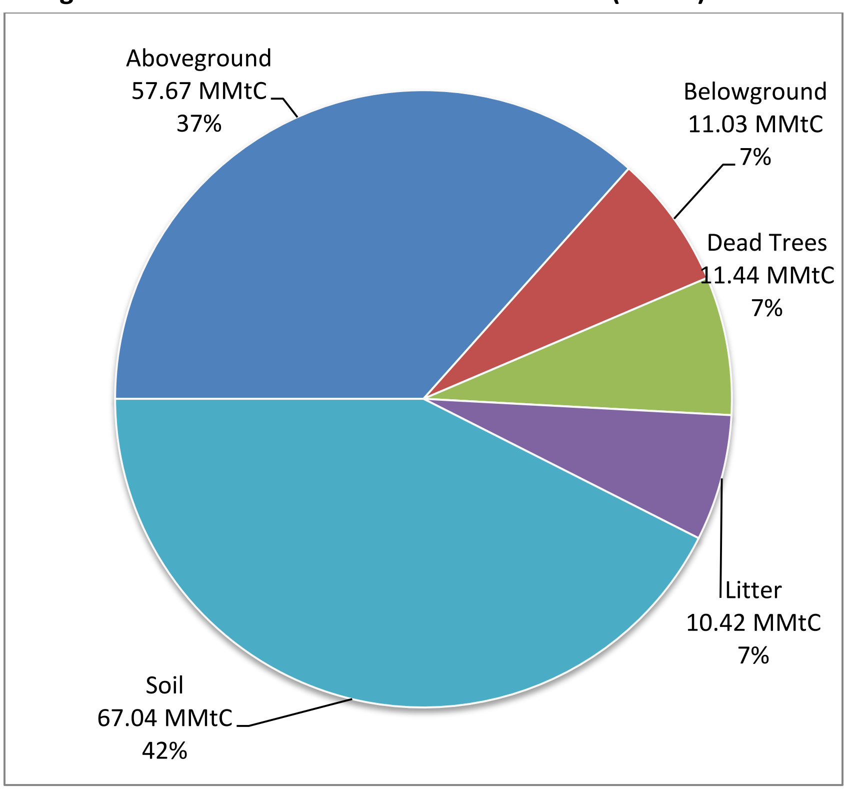


Figure 13: 2013 Where Forest Carbon is Stored (MMtC)



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[25] Positive numbers show carbon emissions. Negative numbers show carbon sequestration, also known as carbon sinks.

Uncertainty

One of the largest sources of uncertainty in the LULUCF sector is 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 waste and food scraps stored in landfills are more certain because Iowa-specific activity data was used, but uncertainty was also introduced by using surrogate data fertilizer data for the last six months of 2013, assuming the ration of limestone to dolomite in Iowa is 50%, and using 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. In addition, due to the high uncertainty in soil carbon flux from tillage practices, it was not included in the DNR's calculations. Refer to *Chapter 2 – Agriculture* for more information.

Future Improvements

The DNR has recently obtained more accurate data for urban forest canopies. The new data set is a mix of land cover/remote sensing analysis that has about a one-meter resolution. However, the forest canopy data is per incorporated area, not urban area. Next year the DNR plans to break the data down to urban area and use it in the 2014 Statewide GHG Inventory.

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 2014b). 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

2013 emissions were calculated using state-specific 2013 electricity consumption data from EIA (EIA 2014b). A grid loss factor of 6.471% in 2007 was used as a surrogate for 2013.

Transportation

Electricity consumption from electric vehicles in Iowa was not calculated due to a lack of consumption data. According to the Iowa Department of Transportation, as of August 2013, 104 electric-only and 18,900 hybrid vehicles were registered in Iowa (Lewis 2013). Many low-speed, non-highway electric vehicles, such as golf carts, also operate in Iowa. However, the Iowa DOT does not have electricity consumption data for these vehicles (Carroll 2011). In addition, the Federal Transit Administration's National Transit Database shows no data from electric propulsion or electric batteries (FTA 2014).

Adjustments

2012 emissions have been updated since the DNR's 2012 GHG Inventory Report was published in December 2013. The DNR previously forecasted 2012 emissions due to a lack of Iowa-specific bulk energy consumption data. However, the 2012 energy data was released by EIA in June 2014 (EIA 2014a), so the DNR used the data to recalculate 2012 emissions as shown in Table 32.

Table 32: Recalculated Electricity Emissions (MMtCO$_2$e)

Category	2012 Value Published Dec. 2013	2012 Updated Value
Residential	11.85	11.75
Commercial	10.32	10.26
Industrial	16.51	16.39
Total	**38.68**	**38.41**

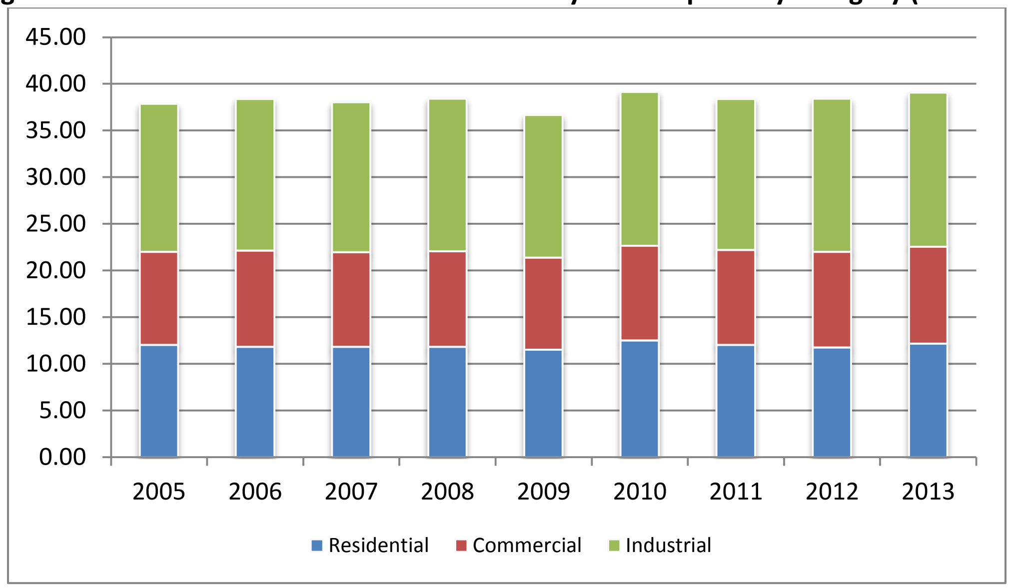
Results

Indirect GHG emissions from electricity consumption were 39.06 $MMtCO_2e$ in 2013, increasing 1.69% since 2012 and 3.16% from 2005. Industrial users consumed 42.27% of electricity in the state, while residential users consumed 31.13% and commercial users consumed 26.63% as shown in Table 33 and Figure 14.

Table 33: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[26]

Sector/Fuel Type	2005	2006	2007	2008	2009	2010	2011	2012[27]	2013
Residential	12.02	11.82	11.81	11.83	11.53	12.52	12.04	11.75	12.16
Commercial	9.98	10.33	10.15	10.23	9.84	10.13	10.16	10.26	10.40
Industrial	15.86	16.23	16.07	16.33	15.30	16.48	16.17	16.39	16.51
Total	**37.86**	**38.38**	**38.04**	**38.39**	**36.67**	**39.13**	**38.36**	**38.41**	**39.06**

Figure 14: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)



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

[27] Updated value.

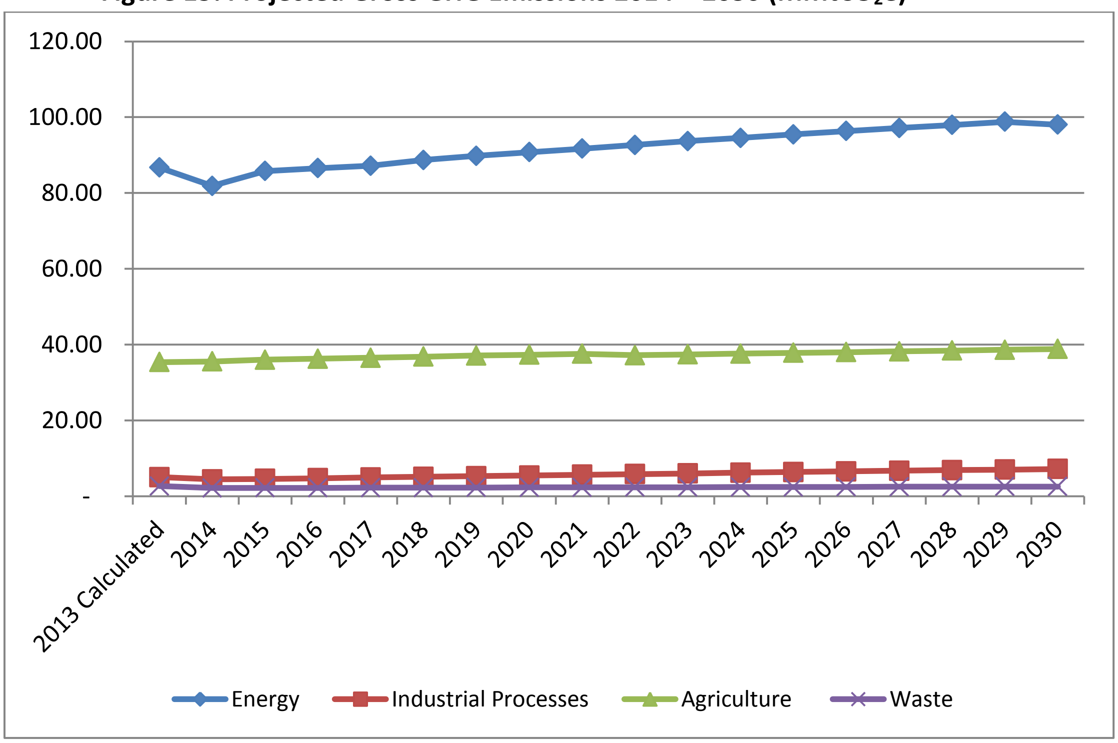
Forecasting

Iowa Code 455B.104 requires that the DNR forecast trends in GHG emissions. The DNR projected emissions from to 2030 using the SIT Projection Tool. As with many forecasts, there are numerous factors that affect the significant level of uncertainty with future emissions. These factors may include among other things - the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, etc.

The SIT projects that Iowa's population decreases every year from 2011 – 2030. This is contrary to the most recent population projections available from the State Data Center (Woods & Poole, 2009). Consequently, the DNR replaced the SIT default populations with the 2015, 2020, 2025, and 2030 projections from Woods & Poole Economics. The data points for the intervening years were calculated using a linear interpretation.

The projected emissions for 2014 – 2030 for each category are shown in Figure 15 below. The SIT Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2012, using a combination of data sources and national projections for activity data.

Figure 15: Projected Gross GHG Emissions 2014 – 2030 ($MMtCO_2e$)

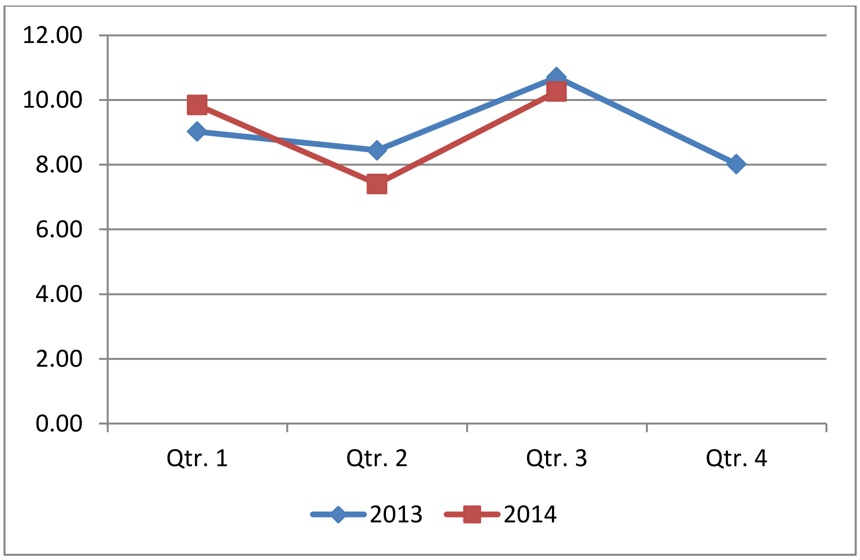


The energy forecast is based on projected energy consumption values from the EIA's *Annual Energy Outlook (2014) with Projections to 2040.* The AEO2014 includes thirty different projection cases, which each address different uncertainties. The DNR used the AEO2014 "Reference Case", which assumes that the laws and regulations in effect as of the end of October 2013 remain unchanged throughout the projections (EIA 2014). More information on the key findings in the AEO2014 is available in *Chapter 3 – Fossil Fuel Consumption*.

Short-term Projections for the Electric Power Sector

CO_2 emissions from the electric power sector are likely to decrease slightly in 2014 based on CO_2 data submitted by electric generating stations to EPA's Clean Air Markets Division (CAMD) for the first three quarters of 2014. However, if temperatures are unusually cold during October – December this year, demand for electricity could increase, resulting in an increase in emissions. So far this year, total CO_2 emissions are 2.36% lower than during the first three quarters of 2013 as shown in Figure 16 below. Total coal usage in the first three quarters of 2014 was 2.03% lower than the previous year, and total natural gas usage in the first three quarters was 21.10% lower than in same time period in 2013.

Figure 16: Electric Power Sector CO_2 Emissions 2013 vs. 2014 ($MMtCO_2$)



Uncertainty

Because the Projection Tool's energy projections are done at the regional level, the emissions predicted for future years have a significant level of uncertainty. Iowa is currently a net exporter of electricity, which may cause Iowa energy emissions to be higher than projected for the West Central region overall. In addition, the projections do not include any reductions resulting from future regulations such as EPA's planned carbon reduction standards for power plants. A high level of uncertainty also exists in the agriculture sector, as emissions from agricultural soils are highly dependent on the weather.

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Appendix A – Iowa GHG Emissions 2005 – 2013 by Sector[28]

Emissions ($MMtCO_2e$)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Agriculture	32.14	34.25	38.73	34.81	34.63	34.07	36.61	**34.90**	35.38
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	**6.95**	6.98
Manure Management	6.77	6.80	7.48	8.19	8.25	7.53	8.34	**8.40**	8.59
Agricultural Soil Management	19.42	21.10	24.63	19.85	19.63	19.86	21.22	**19.56**	19.82
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Fossil Fuel Combustion	60.90	60.68	66.26	69.53	65.38	70.89	70.29	**65.40**	63.90
Electric Power Generation	36.84	36.35	40.04	41.78	37.71	42.33	38.38	35.76	33.12
Residential, Commercial, Industrial	24.07	24.32	26.21	27.75	27.66	28.56	31.31	**29.65**	30.78
Industrial Processes	**4.58**	**4.71**	**4.70**	**4.93**	**4.23**	**4.80**	**4.49**	**5.18**	5.05
Ammonia & Urea Production	1.01	0.91	0.95	0.87	0.60	0.84	0.75	0.85	0.86
Cement Manufacture	1.27	1.29	1.27	1.31	0.84	0.72	0.79	1.27	1.34
Electric Power Transmission & Distribution Systems	0.12	0.12	0.10	**0.09**	**0.08**	**0.08**	**0.07**	**0.06**	0.06
Iron and Steel Production	0.13	0.13	0.13	0.12	0.09	0.23	0.20	0.23	0.19
Lime Manufacture	0.18	0.17	0.16	0.17	0.13	0.18	0.18	0.18	0.16
Limestone and Dolomite Use	0.18	**0.29**	0.24	0.25	0.29	**0.39**	**0.16**	**0.15**	0.15
Nitric Acid Production	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.83
ODS Substitutes	**0.99**	**1.01**	**1.01**	**1.20**	**1.27**	**1.36**	**1.39**	**1.44**	1.44
Soda Ash Consumption	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF	-20.54	-5.79	3.41	-3.91	-5.00	-2.00	0.66	**0.48**	0.28
Forest Carbon Flux	-21.24	-6.53	2.70	-4.48	-5.47	-2.68	-0.14	**-0.47**	-0.47
Liming of Agricultural Soils	0.42	0.45	0.37	0.28	0.27	0.47	0.51	0.65	0.47
Urea Fertilization	0.15	0.15	0.15	0.15	0.12	0.11	0.12	0.13	0.13
Urban Trees	-0.25	-0.25	-0.25	-0.26	-0.26	-0.28	-0.28	-0.28	-0.28
Yard Trimmings and Food Scraps Stored in Landfills	-0.09	-0.09	-0.08	-0.09	-0.10	-0.10	-0.13	-0.12	-0.12
Fertilization of Settlement Soils	0.46	0.48	0.53	0.49	0.44	0.48	0.56	0.57	0.55

[28] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that are bolded have been adjusted since the previous 2012 inventory published by the Department in December 2013. The adjustments are described in detail in this document.

Emissions ($MMtCO_2e$)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Natural Gas Transmission & Distribution	1.15	1.15	1.16	1.17	1.17	1.17	1.18	1.18	1.18
Transmission	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Distribution	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52
Transportation	21.88	22.38	22.81	21.97	21.42	22.07	22.68	21.07	21.71
Waste	2.62	2.56	2.60	2.62	2.58	2.49	2.43	2.65	2.69
Municipal Solid Waste	2.17	2.11	2.14	2.15	2.12	2.03	1.97	2.18	2.23
Wastewater	0.45	0.45	0.45	0.47	0.47	0.46	0.46	0.47	0.47
Gross Emissions	**123.27**	**125.73**	**139.67**	**135.04**	**129.42**	**135.49**	**138.34**	**130.87**	130.20
Sinks	-20.54	-5.79	0	-3.91	-5.00	-2.00	0	0	0
Net Emissions	**102.73**	**119.93**	**139.67**	**131.13**	**124.42**	**133.49**	**138.34**	**130.87**	130.20
% Change from Previous Year		+1.99%	+11.09%	-3.31%	-4.16%	+4.69%	+2.10%	-5.40%	-0.51%
% Change from 2005		+1.99%	+13.30%	+9.54%	+4.98%	+9.91%	+12.22%	+6.16%	+5.32%

Appendix B – Iowa GHG Emissions 2005 – 2013 by Pollutant[29]

Emissions ($MMtCO_2e$)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gross CO_2	84.68	85.03	**93.93**	**93.50**	**88.07**	**94.57**	**94.42**	**88.50**	87.72
Net CO_2	63.68	78.75	**93.93**	**89.10**	**82.64**	**92.08**	**94.42**	**88.41**	87.46
Fossil Fuel Combustion	60.60	60.37	65.93	69.19	65.06	70.45	69.85	**65.00**	63.53
Transportation	21.25	21.82	22.31	21.54	21.03	21.72	22.37	**20.79**	21.46
Industrial Processes	2.80	2.82	**2.78**	**2.75**	**1.97**	**2.38**	**2.09**	**2.69**	2.72
Waste	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
LULUCF	-21.00	-6.28	2.89	-4.40	-5.43	-2.49	0.09	**-0.09**	-0.26
CH_4	15.62	15.94	16.90	17.75	17.74	17.36	17.79	**18.11**	18.37
Fossil Fuel Combustion	0.08	0.08	0.08	0.08	0.08	0.17	0.17	0.16	0.14
Transportation	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Natural Gas and Oil Transmission and Distribution	1.15	1.15	1.16	1.17	1.17	1.17	1.18	1.18	1.18
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	**6.95**	6.98
Manure Management	5.89	5.86	6.50	7.18	7.23	6.94	7.04	**7.26**	7.47
Burning of Agricultural Crop Waste	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Municipal Solid Waste	2.14	2.09	2.12	2.13	2.10	2.01	1.95	2.17	2.22
Wastewater	0.36	0.37	0.37	0.38	0.38	0.37	0.37	0.38	0.38
N_2O	22.33	24.11	27.73	22.98	22.68	22.60	24.65	**22.86**	22.87
Fossil Fuel Combustion	0.23	0.23	0.25	0.26	0.24	0.27	0.27	0.25	0.24
Transportation	0.59	0.52	0.46	0.40	0.36	0.32	0.28	0.25	0.22
Industrial Processes	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.83
Manure Management	0.88	0.94	0.97	1.01	1.02	0.59	1.30	**1.14**	1.12
Agricultural Soil Management	19.41	21.09	24.63	19.84	19.63	19.86	21.22	**19.56**	19.82
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O from Settlement Soils	0.46	0.48	0.53	0.49	0.44	0.48	0.56	0.57	0.55
Municipal Solid Waste (MSW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	**0.08**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	**0.09**	0.09

[29] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that are bolded have been adjusted since the previous 2012 inventory published by the Department in December 2013. The adjustments are described in detail in this document.

Emissions ($MMtCO_2e$)	2005	2006	2007	2008	2009	2010	2011	2012	2013
HFC, PFC, and SF_6	**1.11**	**1.13**	**1.11**	**1.29**	**1.35**	**1.44**	**1.46**	1.50	1.49
Industrial Processes	**1.11**	**1.13**	**1.11**	**1.29**	**1.35**	**1.44**	**1.46**	1.50	1.49
Gross Emissions	**123.73**	**126.21**	**139.68**	**135.53**	**129.85**	**135.97**	**138.33**	**130.97**	130.46
Sinks	-21.00	-6.28	0	-4.40	-5.43	-2.49	0	**-0.09**	-0.26
Net Emissions (Sources and Sinks)	**102.73**	**119.93**	**139.68**	**131.13**	**124.42**	**133.48**	**138.33**	**130.88**	130.20