IOWA DEPARTMENT OF NATURAL RESOURCES

2011 Iowa Statewide Greenhouse Gas Emissions Inventory Report Technical Support Document

Required by Iowa Code 455B.104

December 27, 2012

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

This page is left intentionally blank.

Table of Contents

Acronyms and Key Terms 3

Chapter 1 – General Calculation Method 5

Chapter 2 - Agriculture 7

Chapter 3 – Fossil Fuel Consumption 15

Chapter 4 - Industrial Processes 21

Chapter 5 - Natural Gas Transmission & Distribution 27

Chapter 6 - Transportation 29

Chapter 7 – Waste: Solid Waste 35

Chapter 8 – Waste: Wastewater Treatment 39

Chapter 9 - Land Use, Land Use Change, and Forestry (LULUCF) 42

Chapter 10 –Electricity Consumption 47

Forecasting 49

References 52

Appendix A – Iowa GHG Emissions 2005 – 2011 by Sector 61

Appendix B – Iowa GHG Emissions 2005 – 2011 by Pollutant 62

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
CH_4	methane
CCT	Carbon Control Tool
CO_2	carbon dioxide
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
FHWA	Federal Highway Administration
GHG	greenhouse gas
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
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
MC	motorcycle
MMtC	million metric tons carbon
MMtCE	million metric tons carbon equivalent
$MMtCO_2e$	million metric tons carbon dioxide equivalent

Acronyms and Key Terms (Continued)

MSW	municipal solid waste
N	nitrogen
NIFC	National Interagency Fire Center
NRCS	Natural Resources and Conservation Service
N_2O	nitrous oxide
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
TSD	technical support document
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VMT	vehicle miles traveled

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 *2011 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 – 2011 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 sequestered from land use, land use change, and forestry (LULUCF). A majority of states have recently completed GHG inventories utilizing the SIT methodology. 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.

Emissions were calculated using the most recent version of the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) 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. The individual modules for each sector are Excel workbooks populated with emission factors and default activity data for years 1990 – 2010, 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. The SIT is available by filling out a request form 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	01/03/12	CH_4, N_2O
Energy	CO_2FFC	09/01/12	CO_2
	Stationary Combustion	09/01/12	CH_4, N_2O
Industrial Processes	IP	04/26/12	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission and Distribution	Natural Gas and Oil	01/03/12	CH_4
Transportation	CO_2FFC	09/01/12	CO_2
	Mobile Combustion	09/01/12	CH_4, N_2O
Waste	Solid Waste	01/03/12	CO_2, CH_4
	Wastewater	01/03/12	CO_2, CH_4
Land Use, Land Use Change, and Forestry (LULUCF)	LULUCF	03/21/12	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	01/02/12	CO_2
Future Emissions	Projection Tool	01/03/12	CO_2, CH_4, N_2O, 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 sinks from agriculture are discussed in *Chapter 9 – 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 2011b),

Table 2: Sources of Agricultural GHG Emissions in Iowa

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

Method

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated January 3, 2012 (ICF 2012a and 2012b).

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). Iowa-specific 2011 livestock populations from the United States Department of Agriculture's (USDA*) Quick Stats 2.0 Agricultural Statistics Database* (USDA 2011b), and the *2011 Annual Statistical Bulletin* (USDA 2011a) were used. The number of "Feedlot Heifers" and "Feedlot Steers" was derived by applying a 35/65 heifer/steer ratio to the "Total Number on Feed". Due to a lack of current data, the 2007 population of horses was used for 2011.

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 dairy same 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
Breeding swine	2011	2011 Annual Statistical Bulletin (USDA 2011a)
Market swine under 60 lbs.	2011	
Market swine 60 – 119 lbs.	2011	
Market swine 120 – 179 lbs.	2011	
Market swine over 180 lbs.	2011	
Hens	2010 used as proxy for 2011	
Pullets	2010 used as proxy for 2011	
Chickens	2010 used as proxy for 2011	
Broilers	2009 used as proxy for 2011	No value available from USDA – used 2009 value already in SIT
Turkeys	2008 used as proxy for 2011	USDA Quick Stats (USDA 2011b)

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, the Department 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 uses data on the area burned in each state by crop type from a study by McCarty (2010) in which remote sensing data from 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 and by state for 2003 – 2007 (EPA 2011). EPA provided the Iowa-specific data from McCarty (2010) to the Department (Wirth 2011). For

2011, the Department assumed that the percent area burned was equal to the average percent area burned from 2003 – 2007. This percentage was then applied to the 2011 total acres harvested of corn, wheat, and soybeans (USDA 2011b).

McCarty found that EPA consistently overestimated cropland burned area by a factor of two and national EPA estimates of CH_4 emissions from agricultural residue burning were overestimated by 78% (McCarty 2011). Specifically for Iowa, the average percentage of harvested agricultural areas burned was found to be 0.1% (McCarty 2009) and total GHG emissions were found to be significantly lower than estimated by SIT as shown in Table 4.

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

Year	McCarty Method	SIT Method
2011	0.008	0.188

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).

Plant Residues and Legumes

2011 crop production data for alfalfa, corn for grain, oats, soybeans, and wheat (USDA 2011b) 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.

Soil Cultivation - Nitrous Oxide (N_2O)

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 Soil survey data from the Natural Resources and Conservation Service (NRCS 2011) 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 2011), so the Department 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 2011b) and by the average percentage of each crop that is tilled (USDA 2011b). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, "…all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a Histosol would require some type of artificial drainage in order to be consistently row cropped" (Sucik 2011a).

<u>Soil Tillage - Carbon Dioxide (CO_2)</u>

CO_2 may be emitted when soils are tilled. However, CO_2 may also be sequestered when soils are not tilled or are converted to CRP land, grass, trees or wetlands. This balance between emissions and sequestration is called the soil carbon flux. The SIT does not include a calculation method for agricultural soil carbon flux. Recent 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",* "Many uncertainties remain in scientists' understanding of the relationship between tillage, soil carbon, and other greenhouse gases" (USDA 2010). Therefore, the Department did not include CO_2 sequestration or emissions from agricultural tillage practices in this inventory. The Department plans to quantify the emissions and sequestration in future inventories as more scientific research becomes available.

<u>Fertilizer Utilization</u>

The Department calculated fertilizer emissions for 2011 using fertilizer tonnages from the Iowa Department of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* report (IDALS 2011). The IDALS fertilizer data is provided per the 2011 growing season, which is from July 2010 – June 2011. The 2011 growing season was then used as a proxy for the 2012 growing season (July 2011 – June 2012).

<u>Adjustments</u>

As shown in Table 5, 2010 emissions from enteric fermentation, manure management, and agricultural soils have been updated since the Department's 2010 GHG Inventory Report was published in December 2011. The 2010 values for enteric fermentation and manure management have changed because EPA has updated the enteric fermentation emission factors and some manure management typical animal masses (dairy cows, sheep on feed, sheep not on feed) in the SIT. Manure management volatile solids also vary by year. The agricultural soils emissions were recalculated using actual fertilizer usage data for the 2010 growing season from IDALS (IDALS 2011) instead of the proxy data that was previously used.

Table 5: Recalculated Fossil Fuel Emissions ($MMtCO_2e$)

Sector	**2010 value published Dec 2011**	**2010 updated value**
Enteric Fermentation	6.50	6.67
Manure Management	7.93	7.53
Agricultural Soils	19.45	19.86
Agricultural Residue Burning	0.01	0.01
TOTAL	**33.88**	**34.07**

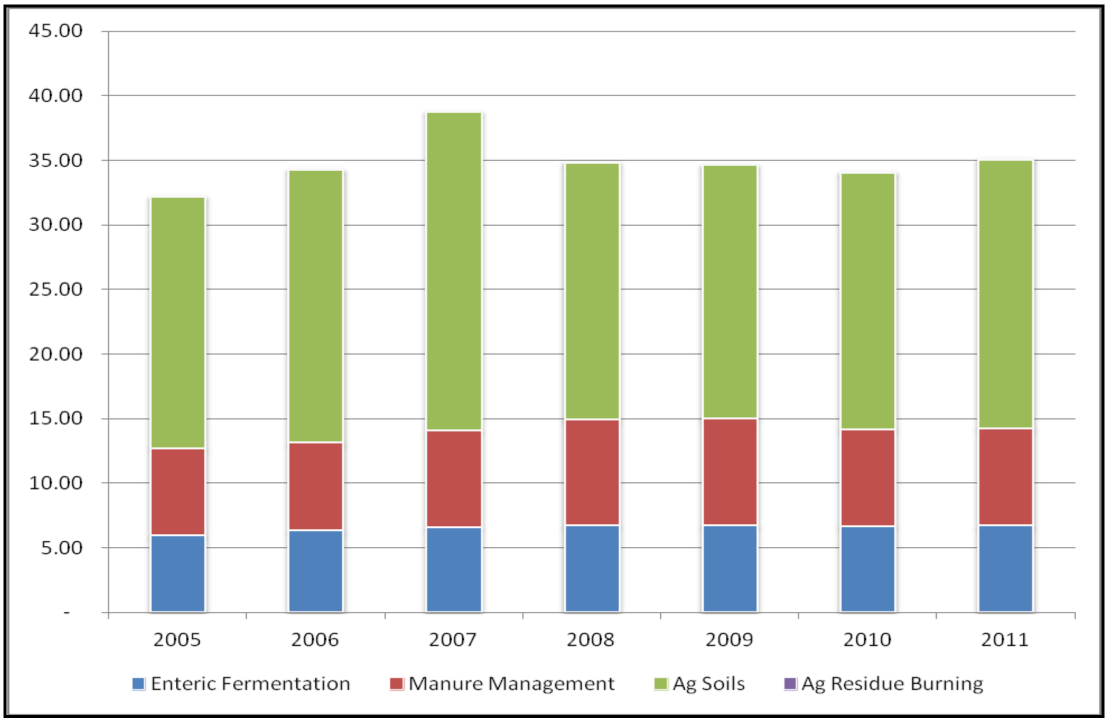
Results

GHG missions from agriculture increased 2.93% from 2010 – 2011 and increased 9.11% from 2005 – 2011. They increased overall in all agricultural categories, except agricultural residue burning, which is a small fraction of agricultural emissions. Total *gross* GHG emissions from agriculture were 35.07 $MMtCO_2e$ in 2011, or 25.91% 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 (59.31%) are from agricultural soils as shown in Table 6 and Figure 1.

Table 6: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[1]

Category	2005	2006	2007	2008	2009	2010[2]	2011
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	6.72
Manure Management	6.77	6.80	7.48	8.19	8.25	7.53	7.54
Agricultural Soils	19.42	21.10	24.63	19.85	19.63	19.86	20.80
Agricultural Residue Burning	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	**32.14**	**34.25**	**38.74**	**34.81**	**34.63**	**34.07**	**35.07**

Figure 1: Gross GHG Emissions from Agriculture ($MMtCO_2e$)



[1] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[2] Updated value.

Enteric Fermentation

CH_4 emissions from enteric fermentation were 6.72 $MMtCO_2e$ in 2011, increasing 0.75% from 2010 and 12.88% from 2005. These increases can be attributed increases in animal population during the same time period(s). While the poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 2 below, 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. The amount of methane emitted from each animal type is shown in Table 7.

Figure 2: 2011 Animal Populations (USDA 2011a and 2011b)

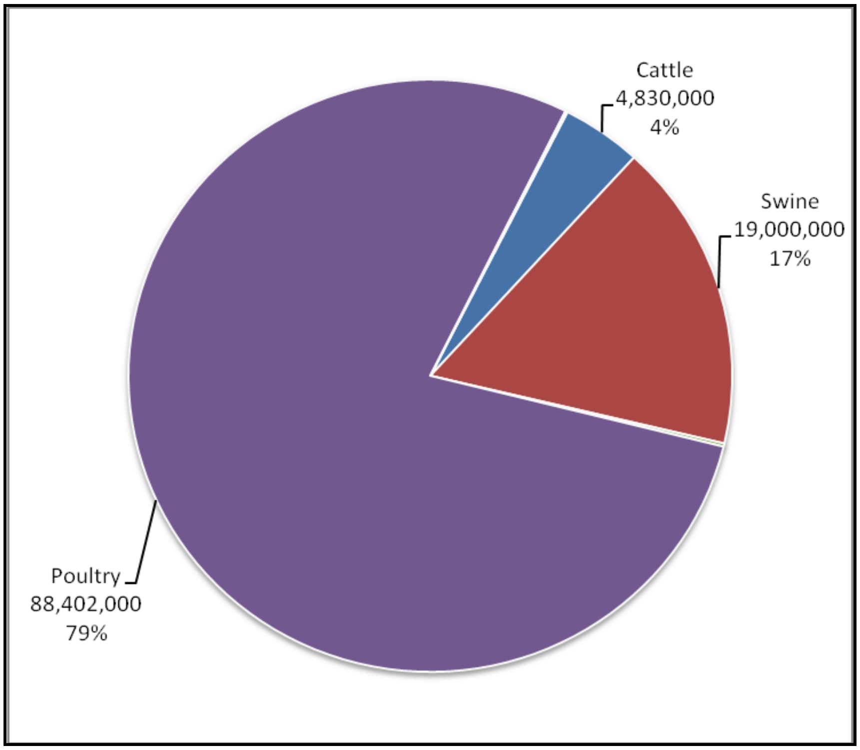


Table 7: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2012a)
Beef Cattle	29.3 – 88.2
Dairy Cattle	52.4 – 131.3
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

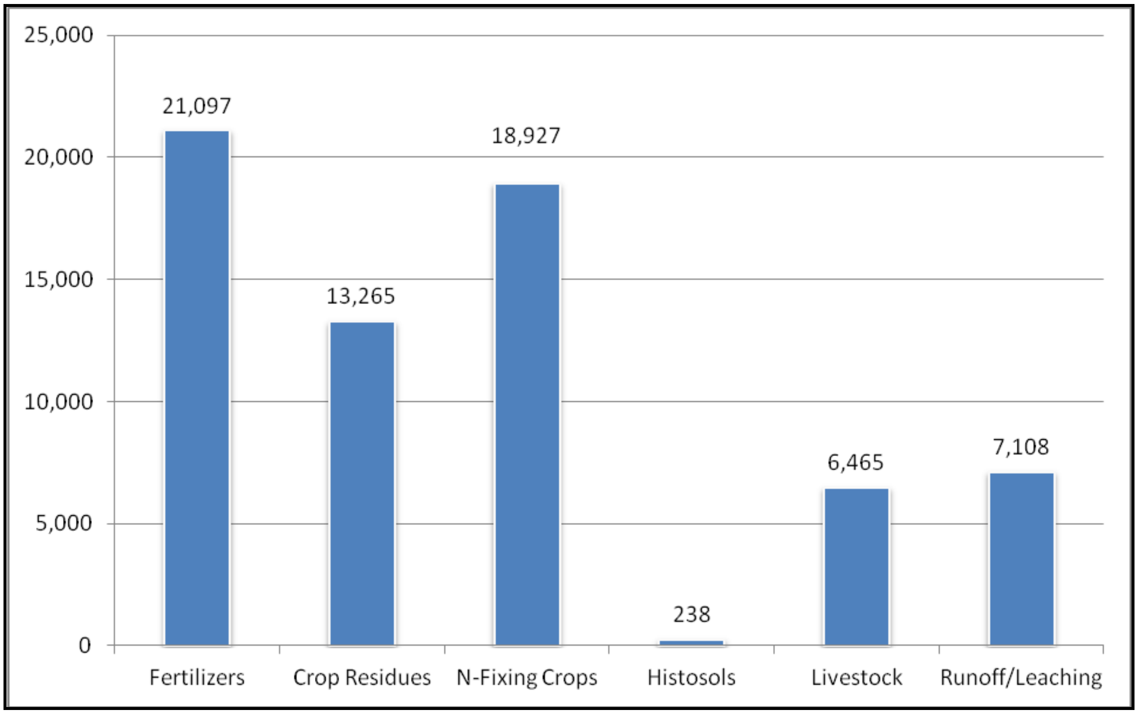
Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 0.12% from 2010 and accounted for 21.50% of agricultural GHG emissions in 2011.

Agricultural Soils

N_2O emissions from agricultural soils accounted for 59.31% of all agricultural GHG emissions and 15.37% of total statewide GHG emissions in 2011. The majority of GHG emissions from agricultural soils can be attributed to crop production (fertilizers, crop residues, and nitrogen fixing) as shown in Figure 3 below.

Figure 3: 2011 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 Iowa statewide GHG emissions, accounting for 0.02% of Iowa agricultural GHG emissions and less than 0.01% of total Iowa GHG emissions in 2011.

<u>Uncertainty</u>

Excerpted from SIT Agriculture Module (ICF 2012a):

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 2012a).

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. Specifically, the N_2O emission factors used are from a limited set of global data (ICF 2012a). 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 2012a).

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 over a half (51.53%) of Iowa's total 2011 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. 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

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. These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 8:

Table 8: Fuel Types Included in Fossil Fuel Consumption

Fuel Types	Residential	Commercial	Industrial	Electric Power
Coal	x	x	x	x
Coking coal, other coal			x	
Natural gas	x	x	x	x
Distillate fuel	x	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	x
Pentanes plus			x	
Still gas			x	
Special naphthas			x	
Unfinished oils			x	
Waxes			x	
Aviation gasoline blending components			x	
Motor gasoline blending components			x	

Iowa-specific 2011 energy consumption data will not be published by the U.S. Energy Information Administration until June 2013, so the Department projected 2011 energy emissions for every category except electric power. This was done by using the EIA's *Annual Energy Outlook (AEO) 2012 with Projections to 2035* (EIA 2012a) and 2010 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2012b). The AEO2012 includes thirty different projection cases, which each address different uncertainties. The Department used the AEO2012 "Reference Case", which assumes that the laws and regulations currently in effect in remain unchanged throughout the projections. 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 2011 fuel consumption was estimated for each fuel type using one of three methods as described below and shown in Table 9:

<u>Fuel Method 1</u>
The ratio of 2010 Iowa fuel consumption from SEDS to the 2010 regional fuel consumption from the AEO2012 was calculated. This ratio was then applied to the predicted 2011 regional fuel consumption in the AEO2012. 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 AEO2012 is in units of quadrillion Btu rounded to just two decimal places. This method was used for the sectors listed in Table 9 below.

<u>Fuel Method 2</u>
The AEO 2012 reference case showed no change in regional emissions from 2010 - 2011 for these sectors, so it was assumed that 2011 fuel consumption was equal to the 2010 fuel consumption.

<u>Fuel Method 3</u>
These sectors were not included in the AEO Reference Case, so it was assumed that 2011 fuel consumption was equal to the 2010 fuel consumption.

<u>Fuel Method 4</u>
The actual 2011 fuel consumption reported to the Department by individual facilities using these fuel types was used instead of estimating fuel consumption. This data was reported to the Department on the facilities' annual air pollution emissions inventories (DNR 2012).

Table 9 – Method Used to Estimate 2010 Fuel Consumption

Fuel Type	Estimation Method
Commercial Coal	Method 1
Commercial Distillate Fuel Oil	Method 1
Commercial LPG	Method 1
Commercial Motor Gasoline	Method 1
Commercial Natural Gas	Method 1
Industrial Distillate Fuel Oil	Method 1
Industrial LPG	Method 1
Industrial Natural Gas	Method 1
Industrial Motor Gasoline	Method 1

Table 9 (continued)

Fuel Type	Estimation Method
Transportation Distillate Fuel	Method 1
Transportation Jet Fuel, Kerosene	Method 1
Transportation LPG	Method 1
Transportation Motor Gasoline	Method 1
Transportation Natural Gas	Method 1
Residential Coal	Method 2
Residential Distillate Fuel	Method 2
Residential Kerosene	Method 2
Residential LPG	Method 2
Commercial Kerosene	Method 2
Commercial Residual Fuel	Method 2
Industrial Residual Fuel	Method 2
Gasoline	Method 2
Transportation Ethanol	Method 2
Transportation Lubricants	Method 2
Residential Wood	Method 3
Commercial Wood	Method 3
Industrial Asphalt and Road Oil	Method 3
Industrial Kerosene	Method 3
Industrial Lubricants	Method 3
Industrial Misc. Petro Products	Method 3
Industrial Special Naphthas	Method 3
Industrial Still Gas	Method 3
Industrial Waxes	Method 3
Industrial Wood	Method 3
Industrial Coal	Method 4
Industrial Coking Coal	Method 4
Industrial Other Coal	Method 4

Emissions from the electric power category were not calculated using fuel consumption data. Instead, Total reported CO_2, CH_4, and N_2O emissions from the federal GHG reporting program (40 CFR 98, Cook 2012) 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 2012).[3]

[3] CO_2 emissions reported to the federal GHG reporting program were 552 metric tons greater than CO_2 emissions reported to the Acid Rain Program. This is a difference of 0.001% and is most likely due to rounding and conversion of metric units (required by the federal GHG reporting program) and short tons (required by the Acid Rain Program).

Adjustments

2010 emissions have been updated since the Department's 2010 GHG Inventory Report was published in December 2011 as shown in Table 10. The Department previously forecasted 2010 emissions due to a lack of Iowa-specific bulk energy consumption data. However, the 2010 energy data was released by EIA in June 2012 (EIA 2012b), so the Department used the data to recalculate 2010 emissions.

Table 10: Recalculated Fossil Fuel Emissions ($MMtCO_2e$)

Category	2010 value published Dec 2011	2010 updated value
Residential	5.01	4.94
Commercial	4.55	4.47
Industrial	21.72	19.15
Electric Power	41.40	41.49
TOTAL	**72.67**	**70.05**

Results

Total GHG emissions from energy consumption in 2011 were 69.74 $MMtCO_2e$, a decrease of 0.45% from 2010, but an increase of 14.50% from 2005 levels as shown in Table 11 below and Figure 4 on the next page. Of the four fossil fuel categories, the electric power category had the highest emissions, accounting for 54.92% emissions from the fossil fuel combustion sector. However, emissions from the electric power category decreased 7.68% from 2010 as facilities in this category, in total, consumed less fossil fuel than in 2010. Also of note, emissions from industrial fuel use increased 14.35% in 2011.

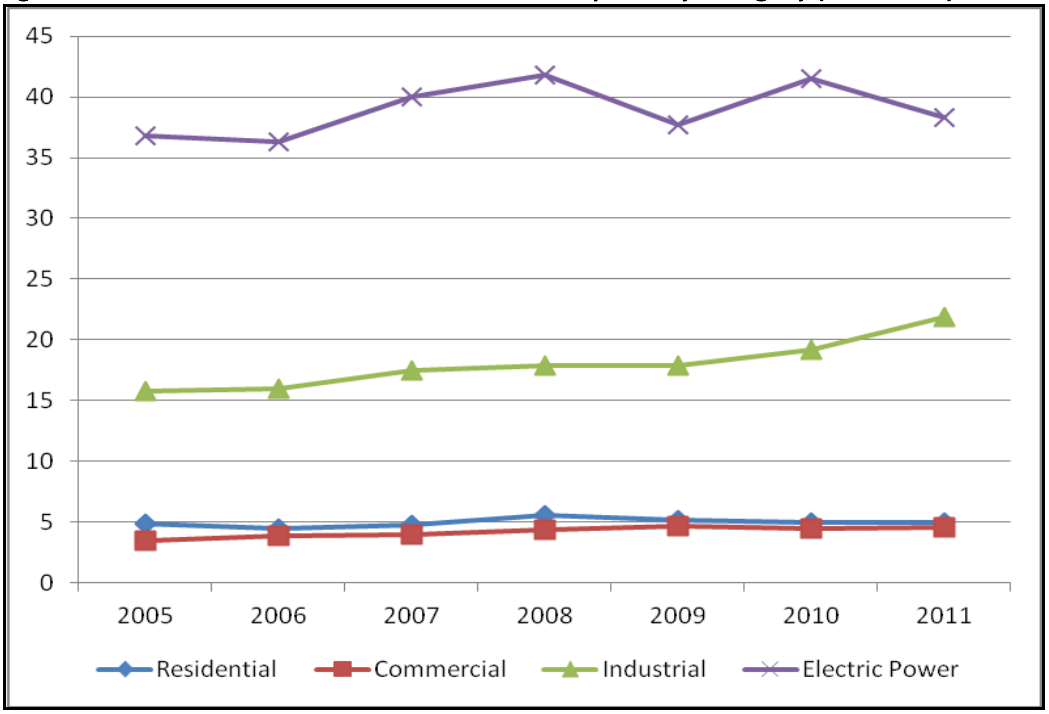
Table 11: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)[4]

Category/Fuel Type	2005	2006	2007	2008	2009	2010[5]	2011
Residential	4.82	4.48	4.81	5.52	5.16	4.94	4.94
Commercial	3.48	3.84	3.95	4.35	4.64	4.47	4.60
Industrial	15.76	16.00	17.45	17.88	17.86	19.15	21.90
Electric Power	36.84	36.35	40.04	41.78	37.71	41.49	38.30
TOTAL	**60.90**	**60.68**	**66.26**	**69.53**	**65.38**	**70.05**	**69.74**

[4] 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.

[5] Updated value.

Figure 4: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)



<u>Uncertainty -</u>

CO_2 Emissions - Excerpted from SIT CO_2FFC Module (ICF 2012a):

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 2012a).

CH_4 and N_2O Emissions - Excerpted from SIT Stationary Combustion Module (ICF 2012b):
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 2012b).

Chapter 4 - Industrial Processes

This chapter includes non-combustion GHG emissions from a variety of industrial processes. The processes and GHG pollutants emitted from each category are shown in Table 12. Emissions from these industries do not include emissions from fossil fuel combustion, which are included in *Chapter 3 – Fossil Fuel Combustion.* Emissions from the production of adipic acid, primary aluminum, HCFC-22, semiconductors, and magnesium were not included as these products are currently not manufactured in Iowa.

Table 12: 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 2012b). 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 2011). 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 is HFCs, but PFCs and SF_6 may also be used (ICF 2012b).

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 2012b).

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 Department is not aware of any of these facilities currently operating in Iowa.

Method

2011 emissions from industrial processes were calculated using either the SIT or using GHG emissions reported to EPA by individual facilities as required by the federal GHG reporting program (40 CFR 98). 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 Department 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).

Cement Production

Because the CEMS measures CO_2 emissions from both the calcining process and fossil fuels combusted in the cement kilns, the fossil fuel emissions were estimated using the actual fossil fuel throughputs in the kiln (Berry and Bertie 2012).[6] These emissions were then subtracted from the CEMS value to avoid double-counting with the fossil fuel combustion emissions in *Chapter 3 – Fossil Fuel Combustion.*

Categories Calculated using the SIT

Emissions from the electric power transmission and distribution, limestone and dolomite use, 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 (State and US Census Bureau 2011). Emissions from electric power transmission distribution were calculated by determining the ratio between Iowa retail sales vs. nation retail sales, and applying that ratio to national emissions.

Table 13: Industrial Processes Calculation Methods and Activity Data

Category	Year	Method and Data Source
Ammonia and Urea Production	2011	40 CFR 98 Subpart G (Cook 2012)
Cement Production	2011	40 CFR 98 Subpart H (Cook 2012)
Iron and Steel Production	2011	40 CFR 98 Subpart Q (Cook 2012)
Lime Manufacture	2011	40 CFR 98 Subpart S (Cook 2012)
Nitric Acid Production	2011	40 CFR 98 Subpart V (Cook 2012)
Electric Power Transmission and Distribution	2010 as proxy for 2011	SIT (EIA 2010)
Limestone and Dolomite Use	2010 as proxy for 2011	SIT (USGS 2010)
ODS Substitutes	2010 as proxy for 2011	SIT default value
Soda Ash Use	2011	SIT (USGS 2012)

[6] Fossil fuel emissions were calculated using the same method as the CO2FCC and Stationary Combustion SIT modules.

Results

GHG emissions from industrial processes in 2011 were 4.50 $MMtCO_2e$, or 3.33% of total statewide GHG emissions. Emissions from this sector decreased 2.57% from 2010 and decreased 3.61% from 2005 – 2010 as shown in Table 14. Ammonia and urea production, ODS substitutes, nitric acid production, and cement manufacture were the highest contributors to industrial process emissions in 2011 as shown in Figure 5 on the next page. All other categories individually contributed less than 10% each. Emissions from the cement production category decreased significantly in 2009 as one of three Iowa cement production facilities shut down in the fall of 2009.

Table 14: GHG Emissions from Industrial Processes ($MMtCO_2e$)[7]

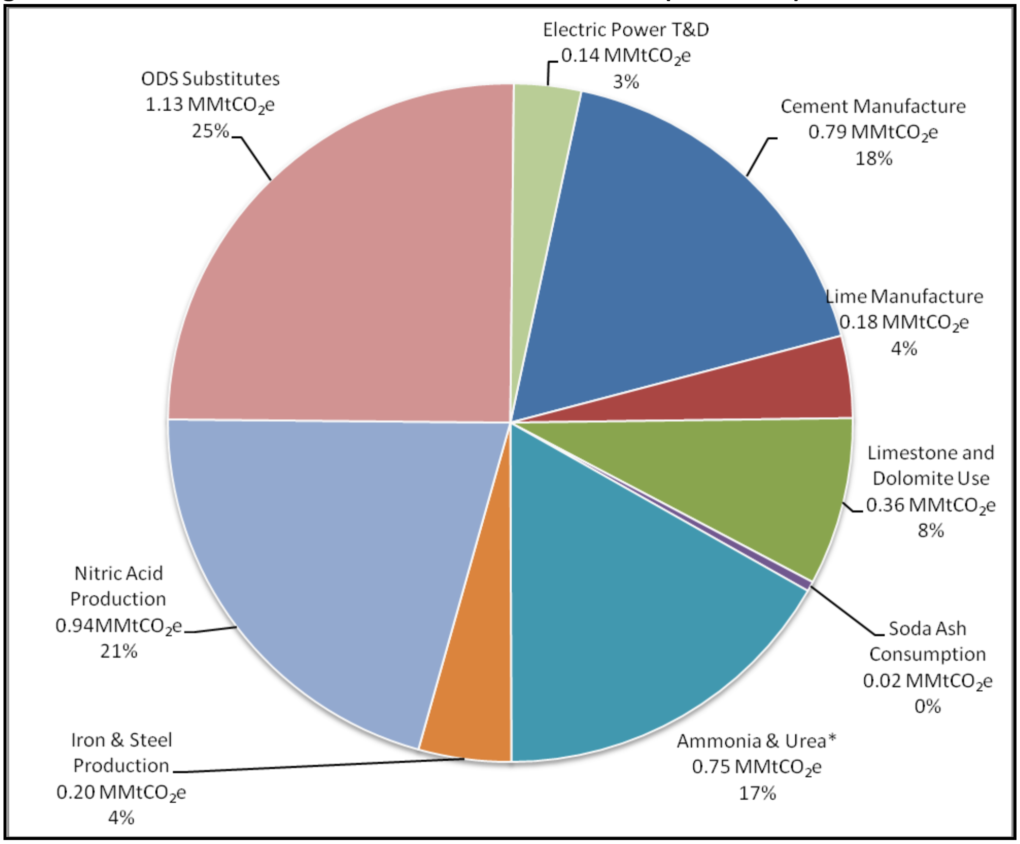
Category	2005	2006	2007	2008	2009	2010	2011
Ammonia & Urea[8]	1.01	0.91	0.95	0.87	0.60	0.84	0.75
Cement Manufacture	1.27	1.29	1.27	1.31	0.84	0.72	0.79[9]
Electric Power T&D	0.16	0.16	0.15	0.16	0.16	0.16	0.14
Iron & Steel Production	0.13	0.13	0.13	0.12	0.09	0.23	0.20
Lime Manufacture	0.18	0.17	0.16	0.17	0.13	0.18	0.18
Limestone & Dolomite Use	0.19	0.31	0.24	0.26	0.31	0.31	0.36
Nitric Acid Production	0.68	0.75	0.81	0.90	0.90	0.99	0.94
ODS Substitutes	1.03	1.07	1.09	1.11	1.18	1.18	1.13
Soda Ash Consumption	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Total Emissions	**4.67**	**4.81**	**4.83**	**4.93**	**4.22**	**4.62**	**4.50**

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

[8] 2005 – 2007 values may be overestimates as they do not account for CO_2 that was recovered for urea or carbon sequestration and storage.

[9] Emissions from fossil fuel combustion that were measured by the Continuous Emission Monitor on the kiln(s) were subtracted from the total as they are already counted in the Fossil Fuel Combustion sector.

Figure 5: 2010 GHG Emissions from Industrial Processes ($MMtCO_2e$)



<u>Uncertainty</u>

Uncertainty occurs in categories where SIT default activity data was used instead of Iowa-specific activity data (limestone and dolomite use, soda ash use, ODS substitutes, and electric power transmission and distribution). Other sources of uncertainty include:

Cement Manufacture:

Certainty has improved because emissions are now measured by continuous emission monitors (CEMS).

Soda Ash Consumption

The main source of uncertainty in soda ash consumption is the lack of Iowa-specific data and variety in possible end-uses (ICF 2012a).

Consumption of ODS Substitutes

As with soda ash consumption, the main source of uncertainty is the lack of Iowa-specific data (ICF 2012a).

Electric Power Transmission and Distribution

Apportioning national emissions based on electricity sales down to the state level is uncertain because it is not based on state-specific data and assumes that SF_6 reduction practices are the same nation-wide (ICF 2012a).

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 2012b).

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 2012). The number of natural gas compressor and gas storage stations was assumed to be unchanged from the previous year.

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 2012b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2012). 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 Department 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 Department 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.

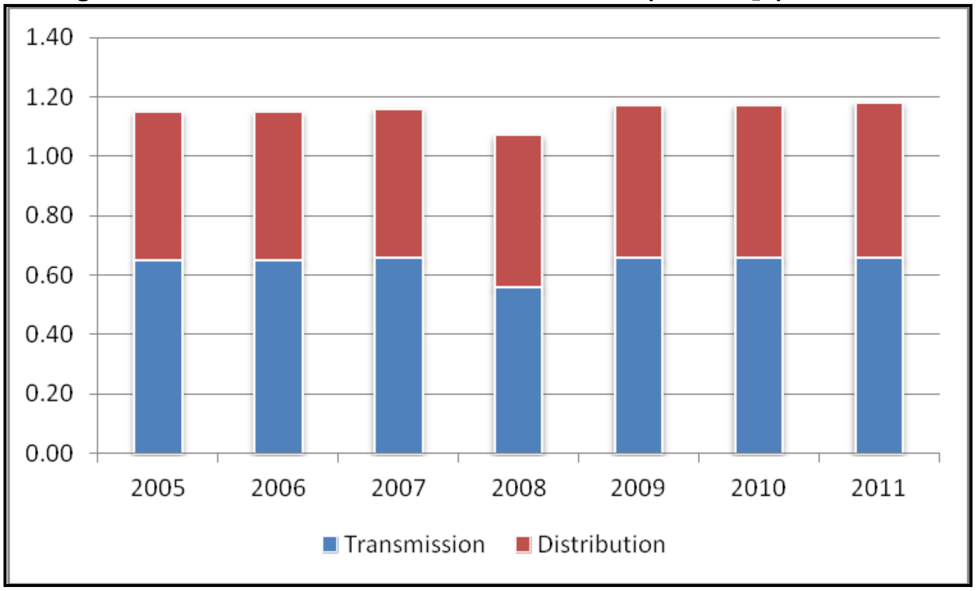
Results

Total GHG emissions from natural gas transmission and distribution were 1.18 $MMtCO_2e$ in 2011, an increase of 0.65% from 2010 and 2.26% from 2005 as shown in Table 15 and Figure 6. Emissions increased in 2011 due to increases in the miles of distribution pipeline and number of services (e.g. gas meters). GHG emissions from this sector account for 0.87% of 2011 statewide GHG emissions.

Table 15: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)

Category	2005	2006	2007	2008	2009	2010	2011
Transmission	0.65	0.65	0.66	0.56	0.66	0.66	0.66
Distribution	0.50	0.50	0.50	0.51	0.51	0.51	0.52
Total Emissions	**1.15**	**1.15**	**1.16**	**1.07**	**1.17**	**1.17**	**1.18**

Figure 6: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)



<u>Uncertainty</u>

Excerpted from SIT Natural Gas and Oil Systems Module (ICF 2012a):

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 2012a).

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 for 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 2012a).

CO_2 Emissions

State-specific 2011 fuel consumption data will not be published by EIA until 2013, so the Department estimated 2011 transportation CO_2 emissions using the Reference Case in EIA's *Annual Energy Outlook 2012 with Projections to 2035* (EIA 2012b). The methods used to estimate 2011 fuel consumption are described in detail earlier in this document in *Chapter 3 – Fossil Fuel Consumption*.

Highway Vehicles (CH_4 and N_2O)

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

1. The vehicle miles traveled (VMT) for each vehicle type was calculated using the total annual VMT of 31,411 million miles (IDOT 2012). 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-89 and A-90 of the the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010* (EPA 2012). The classes and the national distribution percentages are shown in Table 16 on the next page.

Table 16: VMT Vehicle/Fuel Classes and Distribution

Class	Acronym	2010 (EPA 2012)
Heavy duty diesel vehicle	HDDV	8.90%
Heavy duty gas vehicle	HDGV	1.07%
Light duty diesel truck	LDDT	0.84%
Light duty diesel vehicle	LDDV	0.33%
Light duty gasoline truck	LDGT	20.13%
Light duty gasoline vehicle	LDGV	68.09%
Motorcycle	MC	0.63%

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 national on-road age distribution by vehicle/fuel type from Table A-97 the national GHG inventory. The "Annual Vehicle Mileage Accumulation" table in SIT matched that in of Table A-96 in the most recent national inventory, 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. The "Percentage of Each Vehicles with Each Control Technology" tables in the SIT matched the national inventory, so they were not updated.

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 17.

Table 17: Iowa-specific Non-highway Activity Data Used

Vehicle Type/Fuel	Year	Data Source
Aviation Jet Fuel, Kerosene	2010 used as proxy for 2011	EIA SEDS (EIA 2012c)
Aviation Gasoline	2010 used as proxy for 2011	EIA SEDS (EIA 2012c)
Boats Gasoline	2010 used as proxy for 2011	FHWA 2010
Locomotives Distillate Fuel	2010 used as proxy for 2011	EIA Adjusted Sales (EIA 2012a)
Tractor Gasoline	2010 used as proxy for 2011	FHWA 2010
Tractor Distillate Fuel	2010 used as proxy for 2011	EIA Adjusted Sales (EIA 2012a)
Construction Gasoline	2010 used as proxy for 2011	FHWA 2010
Construction Distillate Fuel	2009 used as proxy for 2011	SIT default value
Diesel HD Utility	2009 used as proxy for 2011	SIT default value

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 2009 value was used as a surrogate.

Adjustments

2010 emissions have been updated since the Department's 2010 GHG Inventory Report was published in December 2011. The Department previously forecasted 2010 emissions due to a lack of Iowa-specific bulk energy consumption data. However, the 2010 energy data was released by EIA in June 2012 (EIA 2012c), so the Department used the data to recalculate 2010 emissions as shown in Table 18.

Table 18: Recalculated Transportation Emissions (MMtCO$_2$e)

Pollutant	2010 value published Dec 2011	2010 updated value
CO_2	21.34	21.72
CH_4	0.03	0.03
N_2O	0.32	0.32
TOTAL	**21.70**	**22.07**

Results

Total GHG emissions from transportation were 22.41 MMtCO$_2$e in 2010 as shown in Table 19 below and Figure 7 on the next page. This was an increase of 1.52% from 2010 and an increase of 2.41% from 2005. GHG emissions from this sector account for 16.56% of 2011 statewide GHG emissions. CO_2 is the most prevalent GHG, accounting for 98.66% of GHG emissions from the transportation sector.

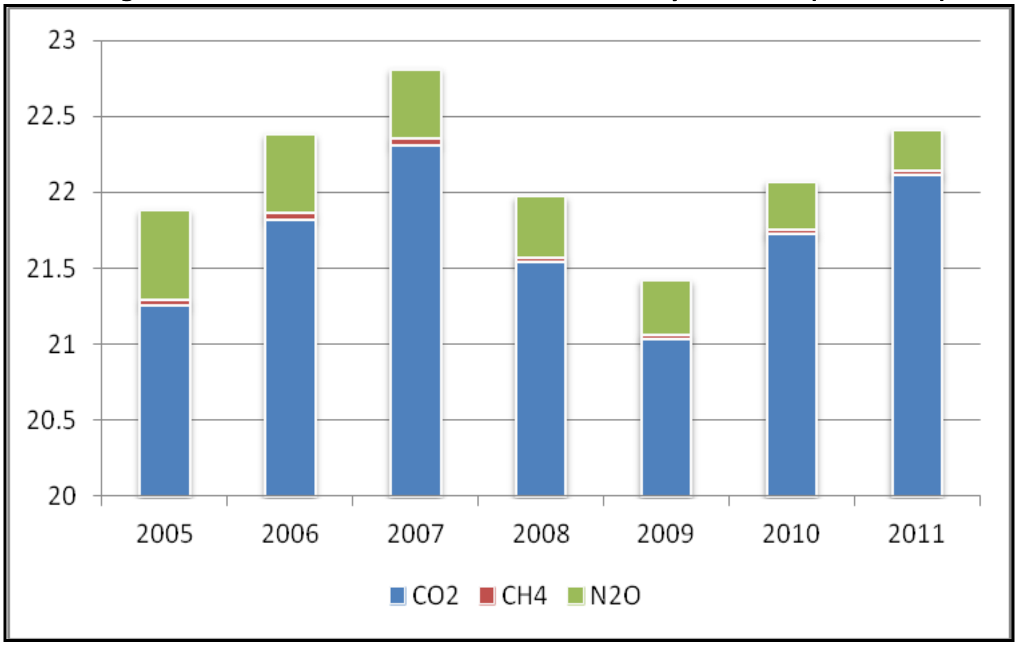
Table 19: GHG Emissions from Transportation (MMtCO$_2$e)[10]

Pollutant	2005	2006	2007	2008	2009	2010[11]	2011
CO_2	21.25	21.82	22.31	21.54	21.03	21.72	22.11
CH_4	0.04	0.04	0.04	0.03	0.03	0.03	0.03
N_2O	0.59	0.52	0.46	0.40	0.36	0.32	0.27
TOTAL	**21.88**	**22.38**	**22.81**	**21.97**	**21.42**	**22.07**	**22.41**

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

[11] Updated value.

Figure7: GHG Emissions from Mobile Sources by Pollutant ($MMtCO_2e$)



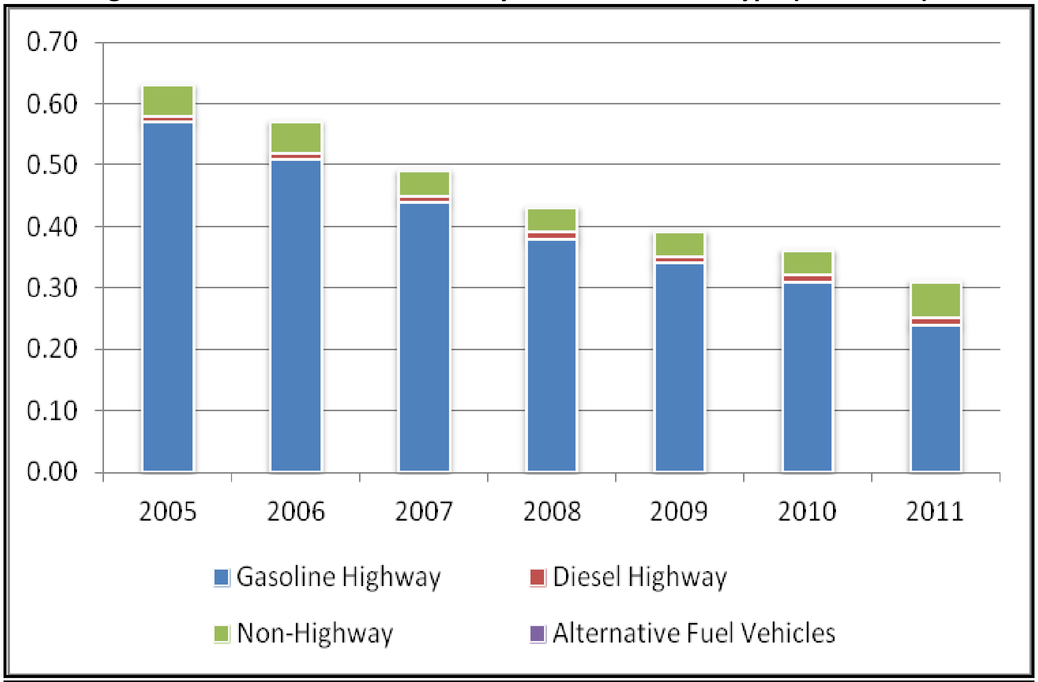
Of the total of CH_4 and N_2O emitted from mobile sources, 86.2% is from gasoline highway vehicles, mainly passenger cars and light-duty trucks. CH_4 and N_2O emissions from mobile sources have decreased every year since 2005 as shown in Table 20 as vehicles have become more fuel-efficient and the vehicle distribution has changed (EPA 2011).

Table 20: Total CH_4 and N_2O Emissions from Mobile Sources ($MMtCO_2e$)[12]

Fuel /Vehicle Type	2005	2006	2007	2008	2009	2010	2011
Gasoline Highway	0.57	0.51	0.44	0.38	0.34	0.31	0.24
Diesel Highway	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Non-Highway	0.05	0.05	0.04	0.04	0.04	0.04	0.06
Alternative Fuel Vehicles	2.6E-03	2.5E-03	3.1E-03	2.9E-03	3.0E-03	3.0E-03	3.0E-03
Total	**0.63**	**0.56**	**0.50**	**0.43**	**0.39**	**0.35**	**0.30**

[12] 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 ($MMtCO_2e$)



Uncertainty

CO_2 Emissions - Excerpted from SIT CO_2FFC Module (ICF 2012a):

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 2012a).

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 2011). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the Department 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 2012b).

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 electiricty. 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).

Method

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 (2,864,034 tons) sent to Iowa landfills in 2011. These amounts are reported annually by individual landfills to the Department's Land Quality Bureau by (DNR 2012a and Jolly 2012).
- The amount of CH_4 emissions avoided from flaring and LFGTE projects was calculated using data reported annually by individual facilities to the Department's Air Quality Bureau on their annual air emissions inventories. Facilities reported flaring 25,954 tons of CH_4 and recovering 17,745 tons of CH_4 for LFGTE projects in 2011 (DNR 2012b).

The Department 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 Department's Air Quality Bureau on their annual air emissions inventories (DNR 2011b). One facility reported burning a total of 33,755 tons of municipal solid waste in 2011.

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 21 below.

Table 21: Proportions of Discards used in the Solid Waste Module

Material	SIT Default Value[13]	2011 Iowa Study
Plastics	17.0 – 18.0%	16.7%
Synthetic Rubber[14]	2.3 – 2.6%	1.0%
Synthetic Fibers[15]	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 Department did subcategorize the proportion of municipal solid waste discards.

Results

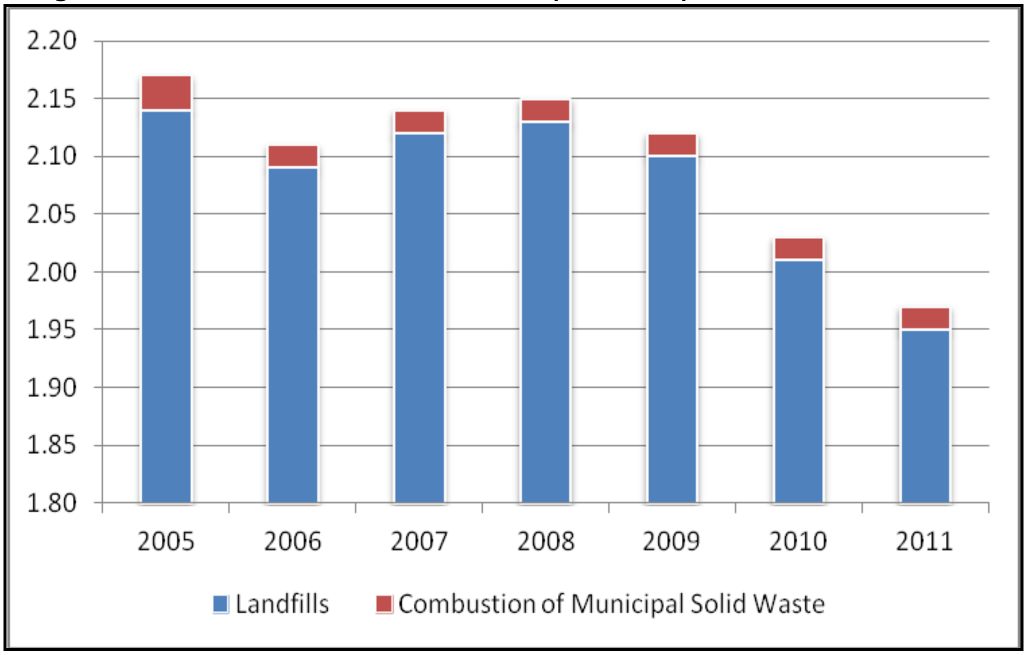
Total GHG emissions from the solid waste category were 1.97 MMtCO2e in 2011, a decrease of 3.03% from 2010 and a decrease of 9.29% from 2005 as shown in Table 22 and Figure 9 on the next page. The decrease from 2010 – 2011 is because less municipal solid waste was burned by power plants to produce electricity in 2011 and more methane emissions were avoided by flaring than in 2010 as shown in Tables 23 and 24 on the next page.

Table 22: GHG Emissions from Municipal Solid Waste (MMtCO_2e)

Pollutant	2005	2006	2007	2008	2009	2010	2011
Landfills	2.14	2.09	2.12	2.13	2.10	2.01	1.95
Combustion of Municipal Solid Waste	0.03	0.02	0.02	0.02	0.02	0.02	0.02
TOTAL	**2.17**	**2.11**	**2.14**	**2.15**	**2.12**	**2.03**	**1.97**

[13] Default values for 2005 – 2008.
[14] The 2011 Iowa waste characterization studies identify this material as “rubber”.
[15] The 2011 Iowa waste characterization studies identify this material as “textiles and leather”.

Figure 9: GHG Emissions from Solid Waste ($MMtCO_2e$)



Approximately 0.83MMtCO_2e of CH_4 emissions were avoided in 2010 by combusting CH_4 in flares or converting it in LFGTE projects as shown in Table 23. This is a 107.50% increase from 2005.

Table 23: CH_4 Emissions from Landfills ($MMtCO_2e$)[16,17]

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

The greatest contributor to GHG emissions from municipal solid waste combustion were CO_2 emissions from plastics, accounting for 77.48% of CO_2 emissions and 75.44% of total combustion emissions as shown in Table 24 on the next page.

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

Table 24: Emissions from Municipal Solid Waste Combustion ($MMtCO_2e$)[18]

Gas/Waste Product	2005	2006	2007	2008	2009	2010	2011
CO_2	0.03	0.01	0.02	0.02	0.02	0.02	0.02
Plastics	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*
Synthetic Rubber	*7.3E-04*	*4.0E-04*	*4.6E-04*	*4.9E-04*	*4.2E-04*	*1.0E-03*	*9.0E-04*
Synthetic Fibers	*5.9E-03*	*3.4E-03*	*3.8E-03*	*4.1E-03*	*3.5E-03*	*3.5E-03*	*3.2E-03*
N_2O	7.4E-04	4.2E-04	4.8E-04	5.1E-04	4.4E-04	5.3E-04	4.7E-04
CH_4	2.0E-05	1.1E-05	1.3E-05	1.4E-05	1.2E-05	1.4E-05	1.3E-05
Total Emissions	0.03	0.02	0.02	0.02	0.02	0.02	0.02

Uncertainty

Excerpted from SIT Solid Waste Module (ICF 2012a):

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 2012a).

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 2012a).

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

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 2012b).

<u>Method</u>

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 2011 (State 2012). For example, to calculate CH_4 emissions, the state population was multiplied by a 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 of 42.60 from Table 8-14 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010* (EPA 2012). Because the 2011 protein value was not available at the time of publication, the 2010 value was used as a surrogate for 2011.

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* data published to date 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 Department calcualted emissions from red meat processing using production numbers from the 2011 Iowa Agricultural Statistics Bulletin (USDA 2011). The Department 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.

Results

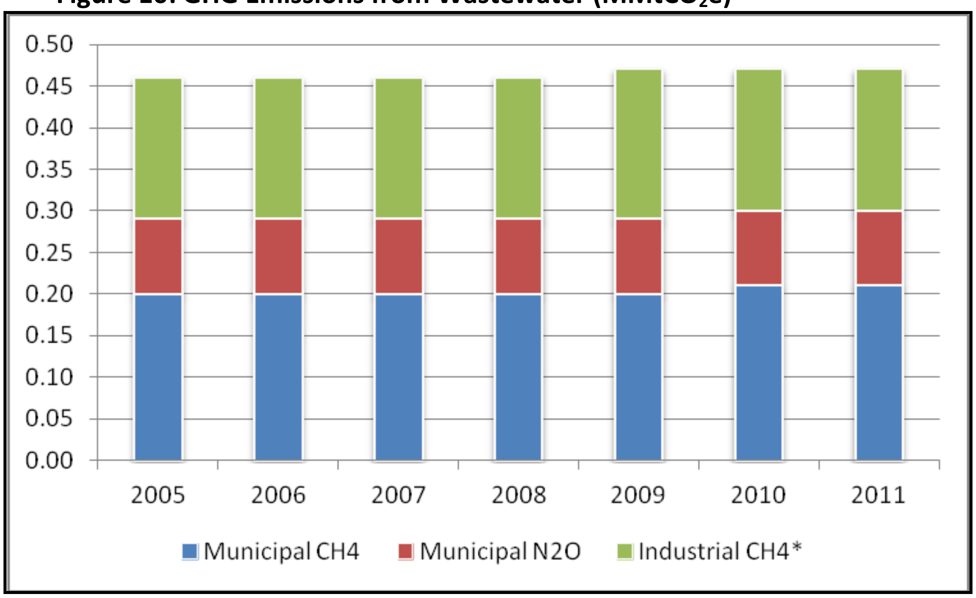
Wastewater emissions account for 0.34% of total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.47 $MMtCO_2e$ in 2011, a 1.22% increase from 2010 and a 3.10% increase from 2005 as shown in Table 25. This increase may be explained by the fact that the default emission factors used remained the same year while Iowa's population and the amount of industrial wastewater emissions from processing red meat increased during the same time period.

CH_4 and N_2O from municipal wastewater treatment accounted for 63.83% (0.30 $MMtCO_2e$) of total wastewater treatment GHG emissions as shown in Figure 10.

Table 25: GHG Emissions from Wastewater ($MMtCO_2e$)[19]

Sector	2005	2006	2007	2008	2009	2010	2011
Municipal CH_4	0.20	0.20	0.20	0.20	0.20	0.21	0.21
Municipal N_2O	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Industrial CH_4	0.17	0.17	0.17	0.17	0.18	0.17	0.17
TOTAL	**0.45**	**0.45**	**0.46**	**0.47**	**0.47**	**0.46**	**0.47**

Figure 10: GHG Emissions from Wastewater ($MMtCO_2e$)



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

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

Uncertainty

Excerpted from SIT Wastewater Module (ICF 2012a):

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 2012a).

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 2012a).

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 2012a).

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. This balance between the emission of carbon and the uptake of carbon is known as carbon flux (ICF 2012b).

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).

Updated forest carbon flux data for 2011 was not available, so the Department assumed the 2011 carbon flux to be equal to 2010. The 2010 value was calculated in a previous GHG inventory as follows:

> Net carbon sequestration in Iowa forests from 2005 – 2010 was calculated using the most recent data[20] available in the United States Department of Agriculture Forestry Service's *Carbon Calculation Tool (CCT) 4.0*. Sequestered carbon was divided into five categories – above ground biomass, below ground biomass, dead wood, litter, and soil carbon. The *Carbon Calculation Tool 4.0* is a computer program that uses publicly available forestry inventory data from the U.S. Forest Service's Forest Inventory and Analysis Program (FIA) to generate state-level annual estimates of carbon stocks on forest land (Smith 2011). Since the Forest Service does not conduct annual carbon stock surveys, carbon emissions and/or storage from forest carbon flux were calculated by using USDA Forest Service estimates of each state's harvested wood stocks in 1992 and 1997. The total change from 1992 – 1997 was divided by 5 (the number of intervening years) to determine the average annual change. This average annual change is then applied to each year, giving total annual change. For the years 1998-2010, the average annual change for 1992-1997 was used as a surrogate (ICF 2012a). The Department used the default SIT value of 0.05 $MMtCO_2e$ for average annual change in carbon stored in wood productions and landfills.

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 Department with the total annual amount of limestone produced for agricultural use as reported by their members (Hall 2012). 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

[20] Carbon Calculation Tool 4.0 – last modified 5/9/2011. Iowa summary data downloaded from the FIA Data Mart < http://www.fia.fs.fed.us/tools-data/> on 7/26/2011.

the material is limestone or dolomite. However, 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 Department 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 first six months of 2011 was 113,409 tons (USDA 2011). The Department assumed that the amount of fertilizer applied during the last six months of 2011 would be the same as the amount (69,163 tons) applied during the last six months of 2010.

Urban Trees

The Department used the same values for as 2010 for 2011 because updated information was not available (Bruemmer 2012).Emissions were calculated using the default SIT data for total urban area (km^2), percent of urban area with tree cover, and carbon sequestration emission factor. The SIT assumes that 33% of urban areas have tree cover. A USDA Forest Service study found that average tree cover in Iowa urban areas was 13.7% (Nowak 2010). However, a more recent canopy cover assessment in Des Moines, Iowa using light detection and ranging (LIDAR) data found that Des Moines had 27% tree coverage. The Department's state urban forester estimated tree coverage to range from 10 - 35% (Bruemmer 2011), so the Department used the SIT default value of 33% to calculate emissions.

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 2012b). 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 2011 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 default values in the SIT are not representative of the vegetation typically burned in Iowa. The SIT default combustion efficiencies and emission factors are provided for primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forest, eucalypt forest, other temperate forests, shrublands, and savanna woodlands. This is not reflective of Iowa's 8% forested land - 3.05 million acres -(Flickinger 2010) and the majority[21] of wildfires and prescribed burns in Iowa are on grasslands (Kantak 2011). Annual fire data is also available from the National Interagency Fire Center (NIFC 2011), but it also does not divide the data into the vegetation types required by the SIT.

[21] 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.

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 2011 (Jolly 2012). While the Department was able to use more accurate Iowa values for the annual amounts of yard waste and food scraps stored in landfills, the Department used the SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon because Iowa-specific data was not available.

Adjustments
2010 emissions from urea fertilization and settlement soil have been updated since the Department's 2010 GHG Inventory Report was published in December 2011 as shown in Table 26. Emissions were recalculated using updated using updated fertilizer data (USDA 2011a and IDALS 2011). This changed the total amount of carbon sequestered in the LULUCF sector from -16.96 $MMtCO_2e$ to -17.02 $MMtCO_2e$.

Table 26: Recalculated LULUCF Emissions ($MMtCO_2e$)

Sector	2010 value published Dec 2011	2010 updated value
Urea Fertilization	0.14	0.11
N_2O from Settlement Soils	0.46	0.43

Results
According to the United States Department of Agriculture Forestry Service's, Iowa had more than 124 million metric tons of carbon (MMtC) stored in its forests and an additional 76 MMtC stored in soil carbon (Smith 2007), resulting in 17.35 $MMtCO_2e$ of forest carbon flux. The two largest contributors to forest carbon flux in Iowa are above ground biomass and soil organic carbon as shown in Table 27.

Table 27: 2010 GHG Sinks from Forest Carbon Flux[22,23]

Category	Emissions ($MMtCO_2e$)
Forest Carbon Flux	-17.35
Aboveground Biomass	*-7.51*
Belowground Biomass	*-1.41*
Dead Wood	*-0.88*
Litter	*-1.02*
Soil Organic Carbon	*-6.35*
Total Wood Products and Landfills	*-0.18*

As shown in Table 28 and Figure 11 on the next page, an additional 0.63 $MMtCO_2e$ was sequestered in urban trees in 2011, and 0.13 $MMtCO_2e$ was sequestered by yard waste and food scraps sent to landfills.

[22] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[23] Negative numbers are carbon sinks.

1.21 $MMtCO_2e$ was emitted from liming of agricultural soils, urea fertilization, and settlement soils. Emissions from forest fires were not included, as earlier discussed under the "Method" heading.

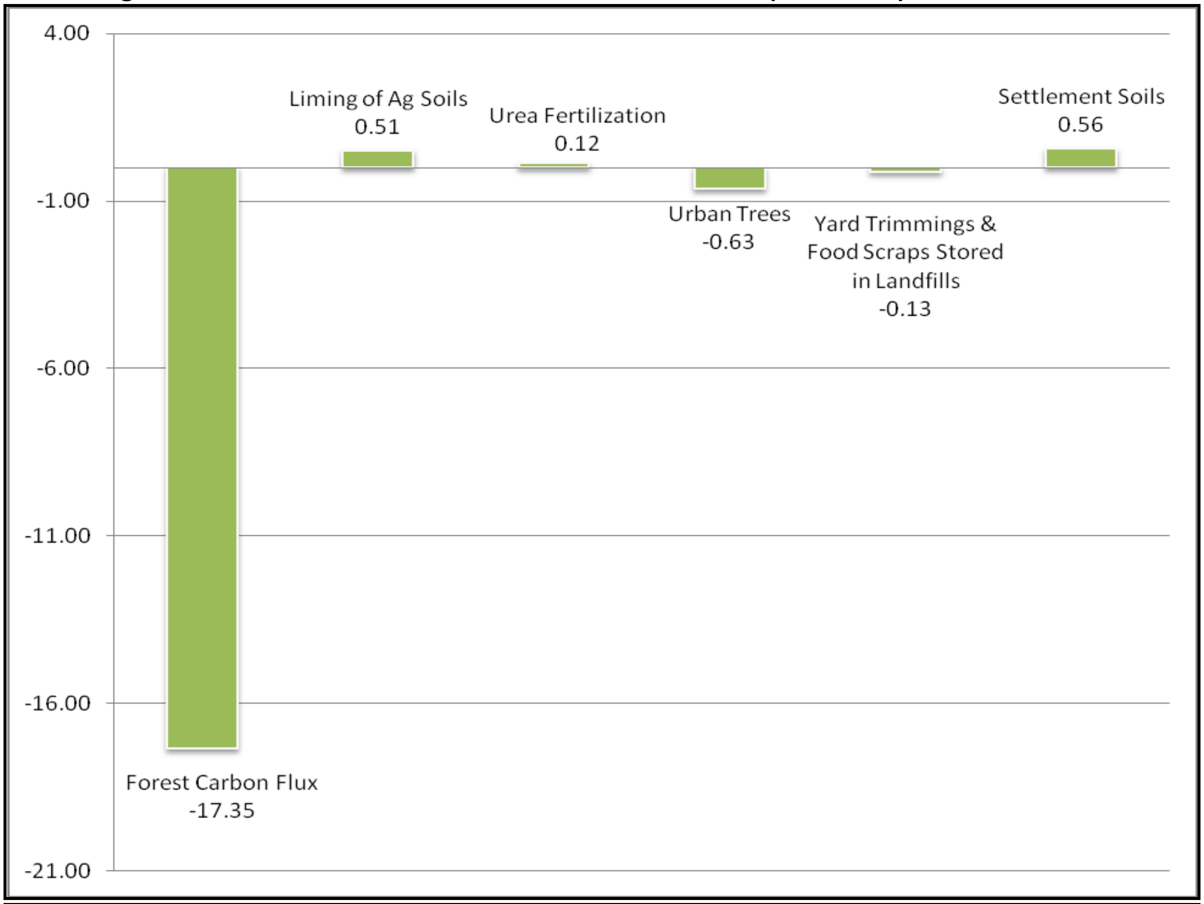
Overall, sources in the LULUCF sector sequestered 16.91 $MMtCO_2e$, also referred to as a carbon sink. This is a decrease of 0.65% from 2010 because the amount of N_2O emitted from settlement soils increased by 30.23%. Emissions of CO_2 are shown above the x-axis in Figure 11 and carbon sinks are shown below the x-axis.

Table 28: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[26, 27]

Sector	2005	2006	2007	2008	2009	2010[24]	2011
Forest Carbon Flux	-17.35	-17.35	-17.35	-17.35	-17.35	-17.35	-17.35
Liming of Ag Soils	0.42	0.45	0.37	0.28	0.27	0.47	0.51
Urea Fertilization	0.15	0.15	0.15	0.15	0.14	0.11	0.12
Urban Trees	-0.60	-0.61	-0.62	-0.62	-0.63	-0.63	-0.63
Yard Trimmings & Food Scraps Stored in Landfills	-0.05	-0.05	-0.04	-0.05	-0.05	-0.05	-0.13
N_2O from Settlement Soils	0.46	0.48	0.53	0.50	0.46	0.43	0.56
Total Sequestered	**-16.97**	**-16.93**	**-16.96**	**-17.09**	**-17.15**	**-17.02**	**-16.91**

[24] Updated value.

Figure 11: 2010 GHG Emissions and Sinks from LULUCF (MMtCO$_2$e)



Uncertainty

One of the largest sources of uncertainty in the LULUCF sector is the lack of Iowa-specific data and emission factors used to calculate emissions and/or sinks from forest carbon flux, urban trees, and settlement soils. A high level of uncertainty is also introduced due to the lack of emissions data from forest fires in Iowa, which was not estimated.

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 2011, 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.

Due to the high uncertainty in soil carbon flux from tillage practices, it was not included in the Departments calculations. Refer to *Chapter 2 – Agriculture* for more information.

Chapter 10 –Electricity Consumption

This chapter includes indirect emissions from electricity consumed at the point of use (e.g. residential electric hot water heaters, televisions, appliances, etc.) and does not include direct emissions generated at the electric power generating station (*see Chapter 3 – Fossil Fuel Combustion*). Electricity consumed by Iowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2012b). 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

State-specific 2011 electricity consumption data will not be published by EIA until June 2013, so the Department projected the 2011 emissions. This was done by using the reference case the EIA's *Annual Energy Outlook (AEO) 2012 with Projections to 2035* (EIA 2012a) and 2010 bulk energy consumption data from the EIA's State Energy Data System (EIA 2012b). To project 2011 emissions, the Department first calculated the state's percent electricity consumption for each sector in 2010, relative to the electricity consumption of the region. The Department then multiplied Iowa's proportion of consumption by the projected 2011 consumption for the West North Central region. A grid loss factor of 6.471% in 2007 was used as a surrogate for 2011.

Transportation

Electricity consumption from electric vehicles in Iowa was not calculated due to a lack of data. According to the Iowa Department of Transportation, 290 Chevy Volts and 27 Nissan Leafs are currently registered in Iowa. The Leaf is a true electric vehicle, while the Volt can use both electricity and gasoline (Lewis 2012). There are also many low-speed, non-highway electric vehicles, such as golf carts, operating in Iowa. 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 2012).

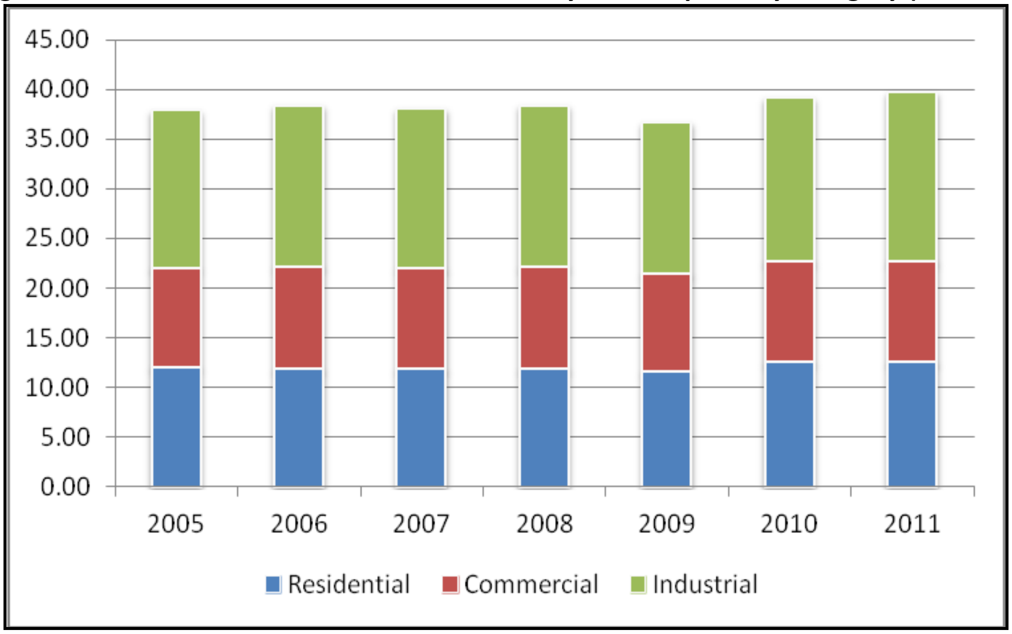
Results

Indirect GHG emissions from electricity consumption were 39.70 MMtCO$_2$e in 2011, increasing 1.45% since 2010 and 4.85% since 2005. Iowa's population has also increased 3.83% since 2005 (State 2012). Industrial users consumed 42.94% of electricity in the state, while residential users consumed 31.53% and commercial users consumed 25.53% as shown in Table 29 and Figure 12 on the next page.

Table 29: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[25]

Sector/Fuel Type	2005	2006	2007	2008	2009	2010	2011
Residential	12.02	11.82	11.81	11.83	11.53	12.52	12.52
Commercial	9.98	10.33	10.15	10.23	9.84	10.13	10.13
Industrial	15.86	16.23	16.07	16.33	15.30	16.48	17.05
Total	**37.86**	**38.38**	**38.04**	**38.39**	**36.67**	**39.13**	**39.70**

Figure 12: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)



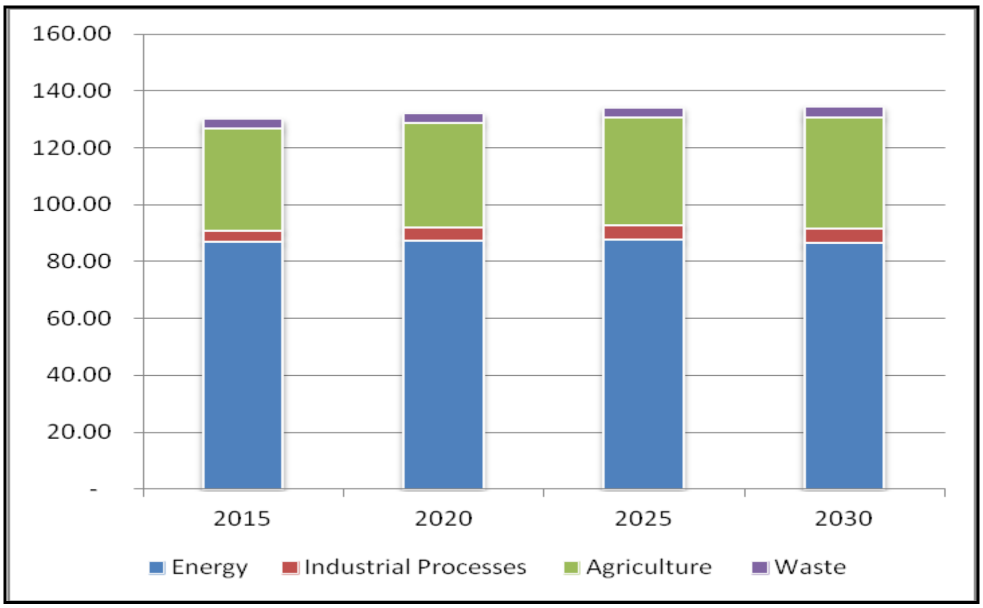
[25] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Forecasting

Iowa Code 455B.104 requires that the Department forecast trends in GHG emissions. The Department projected emissions from 2015 – 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 projected emissions for 2015 – 2030 for each category are shown in Figure 13 below.

The SIT Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2009, using a combination of data sources, national projections for activity data, etc.

Figure 13: Projected Gross GHG Emissions 2015 – 2030 ($MMtCO_2e$)



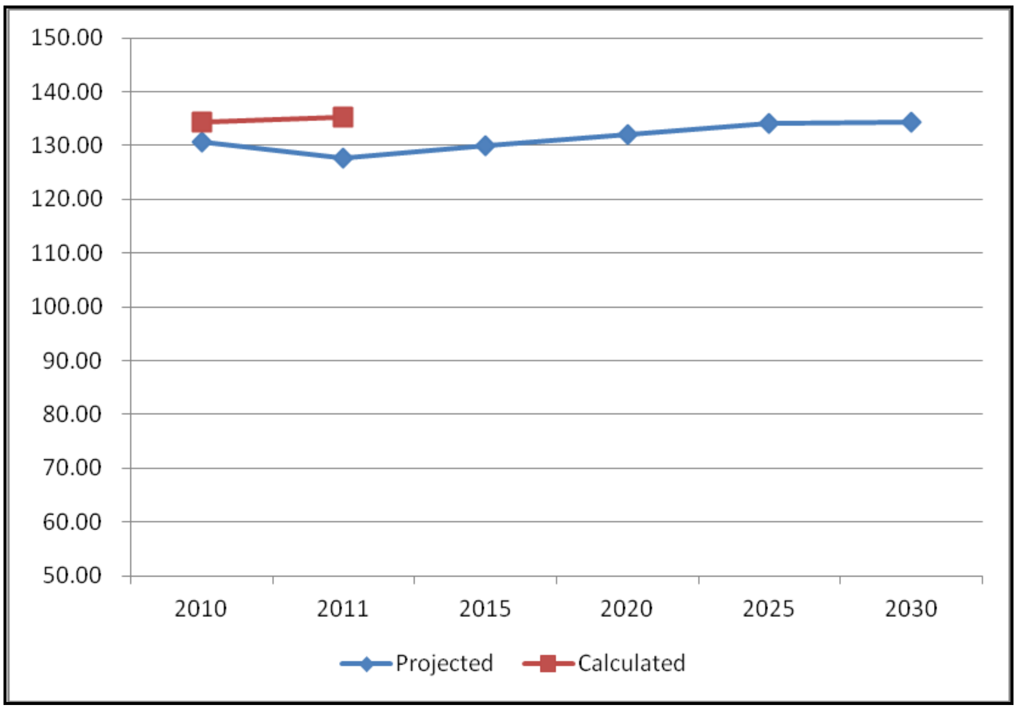
The energy forecast is based on projected energy consumption values from the EIA's *Annual Energy Outlook (2012) with Projections to 2035.* The AEO2012 includes thirty different projection cases, which each address different uncertainties. The Department used the AEO2012 "Reference Case", which assumes that the laws and regulations in currently in effect remain unchanged throughout the projections. 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 AEO2012 includes six key findings:

1. "The rate of growth in energy use slows over the projection period, reflecting moderate population growth, an extended economic recovery, and increasing energy-efficiency in end-use applications.
2. Domestic crude oil production increases.

3. With modest economic growth, increased efficiency, growing domestic production, and continued adoption of nonpetroleum liquids, net importers of petroleum and other liquids make up a smaller share of total U.S. energy consumption.
4. Natural gas production increases throughout the projection period, allowing the United States to transition from a net importer to a net exporter of natural gas.
5. Power generation from renewables and natural gas continues to increase.
6. Total energy-related emissions of carbon dioxide in the United States remain below their 2005 level through 2035."[26]

Because the Projection Tool 's energy projections are done at the regional level, and because the Projection Tool does not account for 2010 and 2011 emissions when making its projections for other categories, the emissions predicted for future years have a significant level of uncertainty as shown in Figure 14. In addition, 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.

Figure 14: Projected vs. Calculated GHG Emissions (MMtCO_2e, Gross)



Retired and Converted Electricity Generating Units

For the short term, the Department predicts approximately an 11.29% decrease in 2011 - 2012 CO_2 emissions from the electric power sector. This is based CO_2 emissions reported to EPA as required by the federal Acid Rain Program (40 CFR 75), comparing the first three quarters of 2012 compared to the first three quarters of 2011. This estimate has some uncertainty as emissions are not evenly dispersed

[26] U.S. Energy Information Administration - *Annual Energy Outlook 2012 with Projections to 2035 (AEO2012)*, June 2012, pages 2 - 4. DOE/EIA-0383(2012). Available at http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.

among the quarters. However, emissions in the fourth quarter (October – December) are typically lower than summertime emissions. Emissions are also expected to decrease in the future as older, less-efficient coal-fired units are switched to less carbon-intensive natural gas, or are replaced with new natural gas-fired units.

References

Agriculture

Baker, J.M. et al. (2007). Tillage and soil carbon sequestration – what do we really know? *Agriculture, Ecosystems, and Environment* 118:1-5.

Bednarek, R. (2012). Email correspondence. Richard Bednarek, State Soil Scientist, Natural Resources and Conservation Service, Des Moines, Iowa. October 31, 2012.

Blanco-Canqui, H. and R. Lal (2008). No-tillage and soil-profile carbon sequestration: an on-farm assessment. *Soil Science Society of America Journal* 72:693-701.

Boddey, R.M, C.P Jantalia, B. Alves, B. and S. Urquiaga. (2009). "Comments on 'No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment'". Soil Science Society of America Journal 73(2):688.

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. #430-R-11-005. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

Franzluebbers, A.J. (2009). "Comments on 'No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment'" Soil Science Society of America Journal 73(2):686-7.

ICF Consulting (2004). Emissions Inventory Improvement Program (EIIP) Volume VIII: Greenhouse Gases. Prepared for the U.S. Environmental Protection and STAPPA/ALAPCO, Washington DC.

ICF International (2012a). State Inventory Tool – Agriculture Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 3, 2012.

ICF International (2012b). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Agriculture Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

IDALS (2011). Fertilizer Tonnage Distribution in Iowa. Iowa Department of Agriculture and Land Stewardship, Commercial Feed and Fertilizer Bureau. Des Moines, Iowa. Available online at < http://www.iowaagriculture.gov/feedAndFertilizer/fertilizerDistributionReport.asp>.

McCarty, J.L. (2010). Agricultural Residue Burning in the Contiguous United States by Crop Type and State. Geographic Information Systems (GIS) Data provided to the EPA Climate Change Division by George Pouliot, Atmospheric Modeling and Analysis Division, EPA. Dr. McCarty's research was supported by the NRI Air Quality Program of the Cooperative State Research, Education, and Extension Service, USDA, under Agreement No. 20063511216669 and the NASA Earth System Science Fellowship.

McCarty, J.L. (2011). "Remote Sensing-Based Estimates of Annual and Seasonal Emissions from Crop Residue Burning in the Contiguous United States". *Journal of the Air & Waste Management Association.* 61: 22-34.

McCarty, J.L., S. Korontzi, C.O. Jutice, and T. Loboda (2009). “The spatial and temporal distribution of crop residue burning in the contiguous United States”. *Science of the Total Environment*. 407 (21): 5701-5712.

Ney, R., J. Schnoor, N. Foster, and D. Forkenbrock (1996). Iowa Greenhouse Gas Action Plan. Iowa Department of Natural Resources and University of Iowa Center for Global and Regional Environmental Research (CGRER). Available online at <http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx>.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx>.

Sucik, M. (2011a). Email correspondence. Michael Sucik, State Soil Scientist, Natural Resources and Conservation Service, Des Moines, Iowa. May 23, 2011.

Sucik, M. (2011b). Email correspondence. Michael Sucik, State Soil Scientist, Natural Resources and Conservation Service, Des Moines, Iowa. December 19, 2011.

USDA (2010). “No-Till” Farming is a Growing Practice. Economic Information Bulletin Number 70. Economic Research Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.ers.usda.gov/Publications/EIB70/EIB70.pdf>.

USDA (2011a). 2011 Annual Statistical Bulletin (Iowa). National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/2011/index.asp>.

USDA (2011b). Quick Stats 2.0: Agricultural Statistics Database. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://quickstats.nass.usda.gov/>.

Wirth, T. (2011). Email correspondence. Tom Wirth, GHG Inventory Coordinator—AFOLU, Climate Change Division, U.S. Environmental Protection Agency, Washington DC. May 19, 2011.

Wollin, T. and W. M. Stigliani (2005). Year 2000 Iowa Greenhouse Gas Emissions Inventory. University of Northern Iowa, Cedar Falls, Iowa. Available online at <http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx>.

Fossil Fuel Consumption

CAMD (2011). Clean Air Markets – Data and Maps. Clean Air Markets Division, U.S. Environmental Protection Agency, Washington D.C. Available online at < http://camddataandmaps.epa.gov/gdm/>. Accessed on October 12, 2012.

Cook, B. (2012). Email correspondence. Brian B. Cook, Climate Change Division, U.S. Environmental Protection Agency, Washington DC. October 11, 2012.

DNR (2012). Annual Title V Emission Inventory Data 2011. Iowa Department of Natural Resources, Des Moines, Iowa.

EIA (2012a) Annual Energy Outlook 2012 with Projections to 2035. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/>.

EIA (2012b) State Energy Data System. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/states/_seds.html>. Accessed on October 18, 2012.

ICF International (2012a). State Inventory Tool – CO_2FFC. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. September 1, 2012.

ICF International (2012b). State Inventory Tool – Stationary Combustion. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. September 1, 2012.

ICF International (2012c). User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

ICF International (2012d). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

IPCC/UNEP/OECD/IEA (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency, Paris, France.

Industrial Processes

Berry, B. (2012). Email correspondence. Bonita Berry, Environmental and Public Affairs Manager, Lafarge North America – Davenport Plant, Buffalo, Iowa. November 7, 2012.

Bertie, W. (2012). Email correspondence. William Bertie, Environmental Manager, Lehigh Cement Company, Mason City, Iowa. November 20-21, 2012.

DNR (2010). Annual Title V Emission Inventory Data 2005 – 2009. Iowa Department of Natural Resources, Des Moines, Iowa.

EIA (2010). 2010 Electric Power Annual. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at (http://www.eia.gov/electricity/annual/customersales-map1.cfm).

EPA (2010). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008. #430-S-10-001. U.S. Environmental Protection Agency, Washington DC. Available online at < http://www.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html >.

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. #430-R-11-005. U.S. Environmental Protection Agency, Washington DC. Available online at < <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

ICF Consulting (2004). Emissions Inventory Improvement Program (EIIP) Volume VIII: Greenhouse Gases. Prepared for the U.S. Environmental Protection and STAPPA/ALAPCO, Washington DC.

ICF International (2012a). State Inventory Tool – IP Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. April 26, 2012.

ICF International (2012b). User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF_6 Emissions from Industrial Processes Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

State Data Center of Iowa (2012). Iowa Quick Facts. State Data Center of Iowa, Des Moines, Iowa. Available online at <http://www.iowadatacenter.org/quickfacts>.

U.S. Census Bureau (2011). U.S. Census Quick Facts. U.S. Census Bureau, Washington DC. Available online at <http://quickfacts.census.gov/qfd/index.html>.

USGS (2010). Crushed Stone: Mineral Yearbook 2010. Minerals Information Service, U.S. Geological Survey, Reston, Virginia. Available online at <http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/myb1-20010-stonc.pd>.

USGS (2012). Soda Ash: Mineral Commodity Summaries 2011. Minerals Information Service, U.S. Geological Survey, Reston, Virginia. Available online at <http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/mcs-2012-sodaa.pdf>.

WRI (2008). CO_2 Emissions from the Production of Ammonia v. 2.0. World Resources Institute Greenhouse Gas Protocol Initiative, Washington DC. Available online at <http://www.ghgprotocol.org/calculation-tools/all-tools>.

Natural Gas Transmission and Distribution

DOT (2012). Distribution, Transmission, and Liquid Annual Data 1990 - 2011. Office of Pipeline Safety, Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation. Washington DC. Available online at <http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print>.

ICF International (2012a). State Inventory Tool – Natural Gas and Oil Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 3, 2012.

ICF International (2012b). User's Guide for Estimating Carbon Dioxide and Methane Emissions from Natural Gas and Oil Systems Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

Little, J. (2011). Email correspondence. Jeff Little. Energy Information Administration. June 8, 2011.

Transportation

EIA (2012a) *Adjusted Sales of Distillate Fuel Oil by End Use*. U.S. Energy Information Administration. Washington DC. Available online at <http://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_SIA_a.htm>.

EIA (2012b) Annual Energy Outlook 2012 with Projections to 2035. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/>.

EIA (2012c) State Energy Data System. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/states/_seds.html>. Accessed on October 18, 2012.

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. #430-R-11-005. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html>.

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. #EPA 430-R-12-001. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

FHWA (2010). FHWA Highway Statistics 2010 – *Private and Commercial Nonhighway Use of Gasoline – 2010 (Table MF-24).* Federal Highway Administration, U.S. Department of Transportation. Available online at <http://www.fhwa.dot.gov/policyinformation/statistics/2010/mf24.cfm>.

ICF International (2012a). State Inventory Tool – CO_2FFC. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. September 1, 2012.

ICF International (2012b). State Inventory Tool – Mobile Combustion. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. September 1, 2012.

ICF International (2012c). User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

ICF International (2012d). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

IDOT (2011). Historical Vehicle Miles of Travel (VMT). Iowa Department of Transportation. Ames, Iowa. Available online at <http://www.iowadot.gov/maps/msp/vmt/30yearvmt.pdf>. Accessed on October 31, 2012.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx>.

Waste: Solid Waste

DNR (2012a). Annual MSW Landfill Data 2011. Iowa Department of Natural Resources, Des Moines, Iowa.

DNR (2012b). Annual Title V Emission Inventory Data 2011. Iowa Department of Natural Resources, Des Moines, Iowa.

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. #430-R-11-005. U.S. Environmental Protection Agency, Washington DC. Available online at < http://www.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html >.

ICF International (2012a). State Inventory Tool – Solid Waste Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 3, 2012.

ICF International (2012b). User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

Jolly, B. (2012). Email correspondence. Becky Jolly, Land Quality Bureau, Iowa Department of Natural Resources, Des Moines, Iowa. August 24, 2012.

MSW (2011). 2011 Iowa Statewide Waste Characterization Study. Prepared by MidAtlantic Solid Waste Consultants for the Iowa Department of Natural Resources, Des Moines, Iowa. September 2011.

Waste: Wastewater Treatment

EPA (2002). Onsite Wastewater Treatment Systems Manual. #625-R-00-008. U.S. Environmental Protection Agency, Washington DC. Available online at <http://water.epa.gov/aboutow/owm/upload/2004_07_07_septics_septic_2002_osdm_all.pdf>.

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. #EPA 430-R-12-001. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

ICF International (2012a). State Inventory Tool – Wastewater Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 3, 2012.

ICF International (2012b). User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

State Data Center of Iowa (2012). Iowa Quick Facts. State Data Center of Iowa, Des Moines, Iowa. Available online at <http://www.iowadatacenter.org/quickfacts>.

USDA (2011). 2011 Annual Statistical Bulletin (Iowa). National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/2011/index.asp>.

LULUCF

Bruemmer, E. (2011) Email correspondence. Emma Bruemmer, State Urban Forester, Iowa Department of Natural Resources, Des Moines, Iowa. July 13, 2011.

Bruemmer, E. (2012) Email correspondence. Emma Bruemmer, State Urban Forester, Iowa Department of Natural Resources, Des Moines, Iowa. October 25, 2012.

Flickinger, A. (2010). Iowa's Forests Today. Aron Flickinger, Special Projects Forester, Iowa Department of Natural Resources, Des Moines, Iowa. Available online at <http://www.iowadnr.gov/portals/idnr/uploads/forestry/ift_intro.pdf>.

Hall, J. (2012). Personal communication. Jan Hall, Iowa Limestone Producers Association, Urbandale, Iowa. October 24, 2012.

ICF International (2012a). State Inventory Tool – Land-Use and Forestry Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. March 21, 2012.

ICF International (2012b). User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Change, and Forestry Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

IDALS (2011). Fertilizer Tonnage Distribution in Iowa. Iowa Department of Agriculture and Land Stewardship, Commercial Feed and Fertilizer Bureau. Des Moines, Iowa. Available online at < http://www.iowaagriculture.gov/feedAndFertilizer/fertilizerDistributionReport.asp>.

Kantak, G. (2011). Email correspondence. Gail Kantak, Wildland Fire Supervisor, Iowa Department of Natural Resources, Des Moines, Iowa. July 13, 2011.

MSW (2011). 2011 Iowa Statewide Waste Characterization Study. Prepared by MidAtlantic Solid Waste Consultants for the Iowa Department of Natural Resources, Des Moines, Iowa. September 2011. Available online at < http://www.iowadnr.gov/Portals/idnr/uploads/waste/wastecharacterization2011.pdf>.

NIFC (2012). Annual Wildfire Statistics 2005 – 2011. National Interagency Fire Center, Boise, Idaho. Available online at <www.nifc.gov/fireinfo/fireinfo_statistics.html>.

Nowak, D.J. and E.J. Greenfield (2010). Urban and Community Forests of the North Central West Region. U.S. Department of Agriculture Forest Service, Newtown Square, Pennsylvania. Available online at < http://www.nrs.fs.fed.us/pubs/34757>.

Reyes, A. (2011). Personal communication. Adriana Reyes, Geologist 3, Iowa Department of Transportation, Ames, Iowa. July 26, 2011.

Smith, J.E., Heath, L.S., and M.C. Nichols (2011). The Carbon Calculation Tool 4.0. U.S. Department of Agriculture Forest Service, Newtown Square, Pennsylvania. Available online at < http://nrs.fs.fed.us/pubs/2394>. Accessed September 16, 2011.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx>.

USDA (2011a). 2011 Annual Statistical Bulletin (Iowa). National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/2011/index.asp>.

Electricity Consumption

Carroll, K. (2011) Email correspondence. Karen Carroll, Transportation Planner 3, Iowa Department of Transportation. August 26, 2011.

EIA (2012a) Annual Energy Outlook 2012 with Projections to 2035. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/>.

EIA (2012b) State Energy Data System. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/states/_seds.html>. Accessed on October 18, 2012.

EIA (2011a). 2011 Annual Energy Outlook 2011 with Projections to 2035. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/>.

EIA (2011b) State Energy Data System. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/states/_seds.html>. Accessed on July 9, 2011.

FTA (2012). National Transit Database. Table 17: Energy Consumption. Federal Transit Administration, Washington DC. Available online at <http://www.ntdprogram.gov/ntdprogram/data.htm>. Accessed November 28, 2012.

ICF International (2012a). State Inventory Tool – Electricity Consumption Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2, 2012.

ICF International (2012b). User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 2012.

Lewis, A. (2012) Email correspondence. Andrew P. Lewis, Office of Vehicle Services, Iowa Department of Transportation. October 17, 2012.

State Data Center of Iowa (2012). Iowa Quick Facts. State Data Center of Iowa, Des Moines, Iowa. Available online at <http://www.iowadatacenter.org/quickfacts>.

Forecasting

ICF International (2012). State Inventory Tool – Projection Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. January 3, 2012.

Appendix A – Iowa GHG Emissions 2005 – 2011 by Sector[27]

Emissions ($MMtCO_2e$)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Agriculture	32.14	34.25	38.73	34.81	34.63	34.07	35.07
Enteric Fermentation	*5.95*	*6.35*	*6.62*	*6.77*	*6.74*	*6.67*	*6.72*
Manure Management	*6.77*	*6.80*	*7.48*	*8.19*	*8.25*	*7.53*	*7.54*
Agricultural Soil Management	*19.42*	*21.10*	*24.63*	*19.85*	*19.63*	*19.86*	*20.80*
Burning of Agricultural Crop Waste	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Fossil Fuel Combustion	60.90	60.68	66.26	69.53	65.38	70.05	69.74
Electric Power Fuel Use	*36.84*	*36.35*	*40.04*	*41.78*	*37.71*	*41.49*	*38.30*
Residential, Commercial, Industrial Fuel Use	*24.07*	*24.32*	*26.21*	*27.75*	*27.66*	*28.56*	*31.43*
Industrial Processes	4.67	4.81	4.83	4.93	4.22	4.62	4.50
Ammonia & Urea Production	*1.01*	*0.91*	*0.95*	*0.87*	*0.60*	*0.84*	*0.75*
Cement Manufacture	*1.27*	*1.29*	*1.27*	*1.31*	*0.84*	*0.72*	*0.79*
Electric Power Transmission & Distribution Systems	*0.16*	*0.16*	*0.15*	*0.16*	*0.16*	*0.16*	*0.14*
Iron and Steel Production	*0.13*	*0.13*	*0.13*	*0.12*	*0.09*	*0.23*	*0.20*
Lime Manufacture	*0.18*	*0.17*	*0.16*	*0.17*	*0.13*	*0.18*	*0.18*
Limestone and Dolomite Use	*0.19*	*0.31*	*0.24*	*0.26*	*0.31*	*0.31*	*0.36*
Nitric Acid Production	*0.68*	*0.75*	*0.81*	*0.90*	*0.90*	*0.99*	*0.94*
ODS Substitutes	*1.03*	*1.07*	*1.09*	*1.11*	*1.18*	*1.18*	*1.13*
Soda Ash Consumption	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Land Use, Land Use Change, and Forestry	-16.97	-16.93	-16.96	-17.09	-17.15	-17.02	-16.91
Forest Carbon Flux	*-17.35*	*-17.35*	*-17.35*	*-17.35*	*-17.35*	*-17.35*	*-17.35*
Liming of Agricultural Soils	*0.42*	*0.45*	*0.37*	*0.28*	*0.27*	*0.47*	*0.51*
Urea Fertilization	*0.15*	*0.15*	*0.15*	*0.15*	*0.14*	*0.11*	*0.12*
Urban Trees	*-0.60*	*-0.61*	*-0.62*	*-0.62*	*-0.63*	*-0.63*	*-0.63*
Yard Trimmings and Food Scraps Stored in Landfills	*-0.05*	*-0.05*	*-0.04*	*-0.05*	*-0.05*	*-0.05*	*-0.13*
Fertilization of Settlement Soils	*0.46*	*0.48*	*0.53*	*0.50*	*0.46*	*0.43*	*0.56*
Natural Gas Transmission & Distribution	1.15	1.15	1.16	1.07	1.17	1.17	1.18
Transmission	*0.65*	*0.65*	*0.66*	*0.56*	*0.66*	*0.66*	*0.66*
Distribution	*0.50*	*0.50*	*0.50*	*0.51*	*0.51*	*0.51*	*0.51*
Transportation	21.88	22.38	22.81	21.97	21.42	22.07	22.41
Waste	2.62	2.56	2.60	2.62	2.59	2.49	2.43
Municipal Solid Waste	*2.17*	*2.11*	*2.14*	*2.15*	*2.12*	*2.03*	*1.97*
Wastewater	*0.45*	*0.45*	*0.46*	*0.47*	*0.47*	*0.46*	*0.47*
Gross Emissions	**123.37**	**125.83**	**136.39**	**134.94**	**129.41**	**134.47**	**135.32**
Sinks	-16.97	-16.93	-16.96	-17.09	-17.15	-17.02	-16.91
Net Emissions	**106.40**	**108.90**	**119.43**	**117.84**	**112.26**	**117.45**	**118.41**

[27] Totals may not equal the exact sum of subtotals in this table due to independent rounding. The 2010 value is as revised by the Department. The 2010 GHG emissions presented in this inventory are lower (2.06 $MMtCO_2e$) than the emissions in the previous 2010 inventory published by the Department in December 2011. The difference can be attributed to improved activity data in the agriculture, fossil fuel combustion, and LULUCF sectors.

Appendix B – Iowa GHG Emissions 2005 – 2011 by Pollutant[28]

Emissions (MMtCO$_2$e)	2005	2006	2007	2008	2009	2010	2011
Gross CO_2	*84.68*	*85.04*	*91.04*	*93.52*	*88.10*	*93.65*	*93.72*
Net CO_2	*67.26*	*67.63*	*73.55*	*75.92*	*70.49*	*76.20*	*76.25*
Fossil Fuel Combustion	*60.60*	*60.37*	*65.93*	*69.19*	*65.06*	*69.61*	*69.29*
Transportation	*21.25*	*21.82*	*22.31*	*21.54*	*21.03*	*21.72*	*22.11*
Industrial Processes	*2.80*	*2.83*	*2.78*	*2.76*	*1.99*	*2.30*	*2.30*
Waste	*0.03*	*0.01*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Land Use, Land Use Change, and Forestry	*-17.42*	*-17.41*	*-17.49*	*-17.60*	*-17.61*	*-17.45*	*-17.47*
CH_4	*15.61*	*15.93*	*16.89*	*17.65*	*17.74*	*17.36*	*17.38*
Fossil Fuel Combustion	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.17*	*0.17*
Transportation	*0.04*	*0.04*	*0.04*	*0.03*	*0.03*	*0.03*	*0.03*
Natural Gas and Oil Transmission and Distribution	*1.15*	*1.15*	*1.16*	*1.07*	*1.17*	*1.17*	*1.18*
Enteric Fermentation	*5.95*	*6.35*	*6.62*	*6.77*	*6.74*	*6.67*	*6.72*
Manure Management	*5.89*	*5.86*	*6.50*	*7.18*	*7.23*	*6.94*	*6.95*
Burning of Agricultural Crop Waste	*0.00*	*0.00*	*0.00*	*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*
Wastewater	*0.36*	*0.37*	*0.37*	*0.38*	*0.38*	*0.37*	*0.37*
N_2O	*22.33*	*24.11*	*27.73*	*22.99*	*22.70*	*22.55*	*23.53*
Fossil Fuel Combustion	*0.23*	*0.23*	*0.25*	*0.26*	*0.24*	*0.27*	*0.27*
Transportation	*0.59*	*0.52*	*0.46*	*0.40*	*0.36*	*0.32*	*0.27*
Industrial Processes	*0.68*	*0.75*	*0.81*	*0.90*	*0.90*	*0.99*	*0.94*
Manure Management	*0.88*	*0.94*	*0.97*	*1.01*	*1.02*	*0.59*	*0.59*
Agricultural Soil Management	*19.41*	*21.09*	*24.63*	*19.84*	*19.63*	*19.86*	*20.80*
Burning of Agricultural Crop Waste	*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*	*0.50*	*0.46*	*0.43*	*0.56*
Municipal Solid Waste (MSW)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Wastewater	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*
HFC, PFC, and SF_6	*1.19*	*1.23*	*1.24*	*1.27*	*1.33*	*1.34*	*1.27*
Industrial Processes	*1.19*	*1.23*	*1.24*	*1.27*	*1.33*	*1.34*	*1.27*
Gross Emissions	**123.82**	**126.31**	**136.91**	**135.43**	**129.86**	**134.90**	**135.89**
Sinks	-17.42	-17.41	-17.49	-17.60	-17.61	-17.45	-17.47
Net Emissions (Sources and Sinks)	**106.39**	**108.90**	**119.42**	**117.84**	**112.25**	**117.45**	**118.42**

[28] Totals may not equal the exact sum of subtotals in this table due to independent rounding. The 2010 value is as revised by the Department. The 2010 GHG emissions presented in this inventory are lower (2.06 MMtCO$_2$e) than the emissions in the previous 2010 inventory published by the Department in December 2011. The difference can be attributed to improved activity data in the agriculture, fossil fuel combustion, and LULUCF sectors