Iowa 2010 Greenhouse Gas Inventory – Challenges and Lessons Learned

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ABSTRACT

Iowa law requires the Department of Natural Resources (DNR) to submit an annual report to the Governor and General Assembly regarding the greenhouse gas emissions in the state during the previous calendar year and forecasting trends in greenhouse gases (GHG). For the 2010 report, the DNR updated Iowa's 2005 statewide GHG emission inventory that was developed for the Iowa Climate Change Advisory Council. Statewide activity data from agriculture, fossil fuel combustion, industrial processes, natural gas transmission and distribution, transportation, solid waste, and wastewater treatment was used to develop the "top-down" inventory and policy-neutral report. It also included carbon sequestered from land use, land use change, and forestry (LULUCF). The completed report will be used to evaluate emission trends and develop a baseline to track progress in reducing emissions.

This paper will address the calculation methods, data availability, challenges, and lessons learned while developing the 2010 statewide GHG inventory. It will also highlight several current and future improvements. Finally, it will describe how Iowa's unique agriculture and industries affect activity data needs and resulting GHG emissions.

INTRODUCTION

Iowa DNR is required by Iowa Code 455B.104 to conduct an annual GHG inventory and "by December 31 of each year, the DNR shall submit a report to the governor and the general assembly regarding the greenhouse gas emissions in the state during the previous calendar year and forecasting trends in such emissions…." This paper focuses on Iowa's 2010 GHG Inventory, which updates Iowa's 2005 Statewide GHG Emission Inventory that was developed by the Center for Climate Strategies (Strait et al. 2008) for the Iowa Climate Change Advisory Council (ICCAC).

The 2010 Iowa GHG Inventory 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). GHG emissions were calculated using the State Inventory Tool (SIT), the standard GHG inventory method developed for states by the United States Environmental Protection Agency (EPA). A majority of states have recently completed GHG inventories utilizing the same methodologies. Benefits of reports like this include the evaluation of emissions trends, development of a baseline to track progress in reducing emissions, and comparison with national trends.

Iowa is home to just over 3 million people, the 30th most populous state in the nation. In 2010, Iowa had 30.8 million acres in farmland, nearly 86% of total land area in the state (State Data Center, 2012). In 2010, Iowa produced 2.2 billion bushels of corn, 496 million bushels of soybeans, 3.9 million cattle, and 19 million pigs (USDA 2011).

Overall, Iowa emits 2.0% of U.S. GHG emissions (EPA 2012). Figures 1 and 2 on the next page compare Iowa and national GHG emissions from different sectors. In addition, Iowa's per capita GHG emissions are 44.82 metric tons carbon dioxide equivalents (CO_2e) per person. This is more than double 2010 U.S. per capita emissions of 22.10 metric tons carbon dioxide equivalents (CO_2e) per person (EPA 2012).

Figure 1. 2010 Iowa GHG emissions by sector

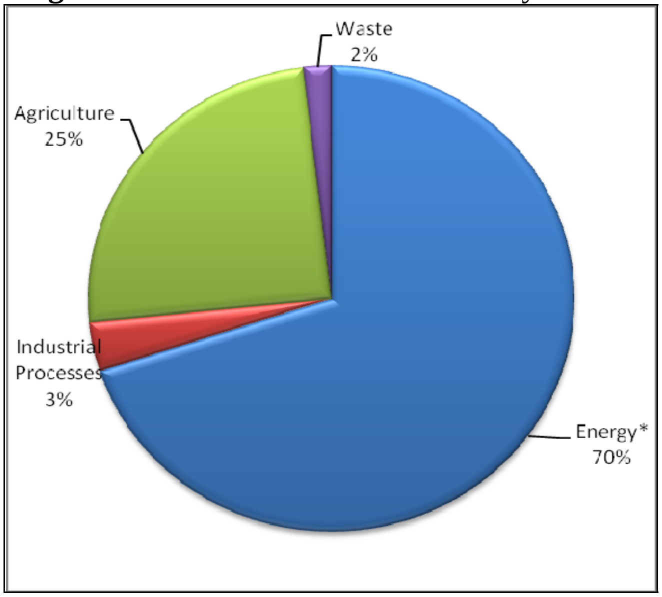
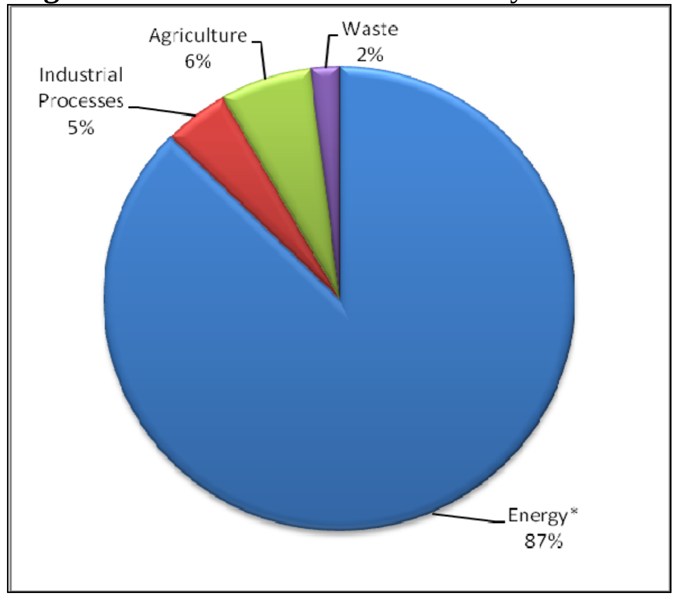


Figure 2. 2010 U.S. GHG emissions by sector



** The energy sector includes fossil fuel combustion, natural gas transmission and distribution, and transportation emissions.*

CHALLENGES

DNR staff faced several challenges in preparing the 2010 Iowa GHG Inventory. The biggest challenge was the timing of the inventory. The Iowa Code requires that the report be completed by December 31 for the previous emission year. This is challenging because most of the activity data needed to calculate emissions is not published within 12 months of the emissions year. Although the DNR was calculating emissions for 2010, at that time the SIT was only populated with activity data up to 2008. This required the DNR to find alternative sources of activity data or use previous years as surrogates.

In addition, current DNR staff did not have experience completing a "top down" inventory for the entire state. The most recent DNR GHG inventories for 2007 – 2009 were "bottom up" inventories based on emission data reported directly to the Department by ethanol production plants and major sources with federally enforceable operating permits (also known as Title V operating permits). The majority of these facilities are now required to report their annual GHG emissions to EPA's federal mandatory GHG reporting program (40 CFR 98) instead of DNR. How would DNR incorporate the facility-level data reported to EPA in its "top down" inventory?

Furthermore, the Iowa Code requires DNR to forecast emission trends. This proved difficult as well. The SIT projection tool is designed to project emissions up to 2030 using historical emissions from 1990 – 2008. However, the 2010 emissions calculated by the DNR were higher than the SIT-projected emissions for 2010. EPA and its contractor, ICF International, were able to assist the DNR with updating the tool to use the more current projections.

Finally, as discussed earlier, Iowa is a leading agricultural state, and not all agricultural activities are under the purview of the DNR, nor are transportation or energy. This required cooperation among several state agencies.

METHOD AND REFINEMENTS BY SECTOR

Iowa's GHG emissions for 2005 - 2010 were calculated using the most recent version of the SIT and using available Iowa-specific activity data. EPA populated the version of the SIT used with default activity data for 1990 – 2008. DNR used Iowa-specific activity data for 2009 and 2010 when it was available. In general, if the 2009 or 2010 activity data was not available, the most recent activity data was used as a surrogate. Please see the full GHG inventory on the DNR's website at http://www.iowadnr.gov/InsideDNR/RegulatoryAir/GreenhouseGasEmissions/GHGInventories.aspx for more detailed information on activity data and calculation methods. GHGs included in the inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFC), hydrofluorocarbons (HFC), and sulfur hexafluoride (SF_6).

After the inventory report was drafted, it was peer-reviewed by several state agencies and several internal DNR staff – climate change, forestry, wastewater, and solid waste. Then it was placed on public notice and open to public comment for fifteen days prior to being finalized. The public comment period was very beneficial as two commenters identified sources of activity data that the DNR had been unable to find.

Agriculture

Four agricultural categories in Iowa – enteric fermentation, manure management, agricultural residue burning, and agricultural soils emit GHGs. Emissions from the first two categories – enteric fermentation and manure management – were calculated using the most recent data available from the USDA. As discussed below, calculating emissions from the second two categories – agricultural residue burning and agricultural soils is more complicated, and the DNR was able to refine previous emission estimates from these categories.

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).

In 2004, Sonoma Technology, Inc. conducted a planned burning emissions inventory for the Central States Regional Air Planning Association. As part of the inventory, Sonoma surveyed the extension offices in 56 of Iowa's 99 counties regarding agricultural burning practices in each county. Sonoma found that in 2002, only 2,247 acres, or 0.009% of agricultural land was burned. 1,660 acres were classified as hay or alfalfa and 587 acres were classified as "other". None of the 54 responding county extension offices reported burning of corn, oat, soybean, or wheat fields (Reid et al. 2004).

Noting this overestimation, the DNR chose to calculate GHG emissions from burning of agricultural residues using the 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 provided the Iowa-specific data from McCarty (2010) to the DNR (Wirth 2011). For this Iowa inventory, the DNR assumed that the percent area burned for 2008 – 2010 was equal to the average percent area burned from 2003 – 2007.

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 1 on the next page.

Table 1. Emissions from agricultural residue burning ($MMtCO_2e$)

Year	McCarty	SIT	% Overestimation
2003	0.003	0.147	+5,576%
2004	0.005	0.191	+3,719%
2005	0.008	0.192	+2,194%
2006	0.011	0.184	+1,612%
2007	0.011	0.189	+1,558%
Total	0.038	0.903	+2,270%

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. Microorganisms in an oxygen-lacking environment carry it out. When ammonia is converted to nitrites (NO_2-) and then nitrates (NO_3-), nitrification occurs. Specialized bacteria carry it out and it 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.

Plant Residues and Legumes

N_2O emissions from nitrogen-fixing crops, including alfalfa and soybeans, and nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans were calculated using the most recent crop production data from USDA (USDA 2010a and Cowles 2011).

Fertilizer Utilization

Fertilizer emissions for 2008 – 2010 were calculated using data from the Iowa DNR of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* website (IDALS 2011). The IDALS fertilizer data is provided per growing season, which is from July – June. The SIT then converts it to calendar year data. So although the DNR was able to obtain the total amount of fertilizer applied during the 2010 growing season (July 2009 – June 2010), the amount of fertilizer applied from July 2010 – December 2010 was not available. Therefore, DNR used the amount applied from July 2009 – December 2009 as a surrogate.

Soil Cultivation and Tillage

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 Soil survey data from NRCS (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, so the DNR estimated the number of cultivated histosol acres by multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2010b) and by the average percentage of each crop that is tilled (USDA 2010c). However, this may be an overestimation as according to NRCS 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 2011).

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 currently include a calculation method for agricultural soil carbon flux. This may be a good source category for EPA to add to the SIT in the future.

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 2010c). Therefore, the DNR did not include CO_2 sequestration or emissions from agricultural tillage practices in this inventory. The DNR plans to quantify the emissions and sequestration in future inventories as more scientific research becomes available.

Fossil Fuel Combustion

State-specific 2010 energy consumption data will not be published by EIA until June 2012, so the DNR projected 2010 energy emissions for every sector (except electric power) using the reference case in EIA's *Annual Energy Outlook (AEO) 2011 with Projections to 2035* (EIA 2011a). To make the projections, the DNR first calculated the state's percent energy consumption for each sector in 2009 relative to the energy consumption of the region. Iowa is in the West North Central U.S. Census region. The DNR then applied Iowa's proportion of consumption to the projected 2011 consumption for the West North Central region. As discussed earlier, CEMS data was used for 2010 CO_2 emissions from the electric power sector. CH_4 and N_2O emissions from that sector were calculated using the fuel consumption data reported by the Acid Rain-affected sources.

In addition, calculated CO_2 emissions for 2005 – 2010 from the electric power sector were replaced with actual CO_2 emissions values measured by continuous emission monitors (CEMS) at electric generating units subject to the federal Acid Rain Program (CAMD 2011). While the CEMS emissions values are more accurate than calculating emissions using the SIT, they may be under-estimated as not every electric generating unit is subject to the Acid Rain Program.

Industrial Emissions

GHG emissions from industrial processes were calculated using a variety of methods, depending on the type of industry and activity data available. For several categories (cement production, lime manufacture, iron and steel production, nitric acid production, and ammonia production and urea consumption) emissions for 2005 – 2009 were calculated using facility-specific data reported to the DNR on either their annual criteria and hazardous air pollutant emissions inventory or greenhouse gas inventory. Emissions were then calculated using either using either World Resource Institute's *The GHG Protocol* or the SIT. The World Resource Institute's *The GHG Protocol* and associated worksheets (2005 – 2008d) is a more accurate method of calculating GHG emissions from industrial processes than the SIT because *The GHG Protocol* worksheets require more detailed activity data than the SIT. If the higher-level activity data was available, the DNR used *The GHG Protocol*. If only basic activity data was available, the DNR used the SIT.

For 2010, GHG emissions from these categories were calculated by the affected facilities themselves using the method required by the new federal GHG reporting program (40 CFR 98). The facilities then provided their total GHG emissions from each category to the DNR for this report as EPA had not yet published its data.

Natural Gas Transmission and Distribution

In general, activity data from the United States DNR of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Pipeline Safety for 2005 – 2009 (DOT 2011). Due to lack of 2010 transmission line data at time of publication, the 2009 estimate was used as a surrogate for 2010. Emissions from natural gas venting and flaring where not calculated due to lack of activity data.

The number of natural gas compressor and gas storage stations was obtained from the Iowa Utilities Board (Stursma 2011). This is a refinement of previous inventories that have calculated GHG emissions using a default ratio of 0.0060 natural gas transmission compressor stations per miles of transmission pipeline and 0.0015 gas storage compressor stations per mile of transmission pipeline. Previous methods overestimate emissions because it estimated 43-50 transmission compressor stations and 11 – 13 storage compressor stations, when there are only 18 transmission compressor stations and 4 storage compressor stations currently in Iowa (Stursma 2011).

Transportation

2010 CO_2 Emissions

State-specific 2010 energy consumption data will not be published by EIA until June 2012, so the DNR projected 2010 transportation CO_2 emissions using the reference case in EIA's *Annual Energy Outlook 2011 with Projections to 2035* (EIA 2011a). To project 2010 energy consumption data, the DNR first calculated the state's percent energy consumption for each transportation fuel in 2009 relative to the energy consumption of the region. Iowa is in the West North Central U.S. Census region. The DNR then multiplied Iowa's proportion of consumption by the projected 2011 consumption for the West North Central region.

Vehicles (CH_4 and N_2O)

Iowa-specific VMT data for highway vehicles by model year was not available, so the VMT was allocated for 2005 – 2008 using the default values in the SIT. 2009 and 2010 VMT were allocated using the 2009 on-road age distribution by vehicle/fuel type from Table A-93 the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009* (EPA 2011). Iowa-specific control technologies by model year were not available either, so the SIT default values for 2005 – 2008 were used. Control technology values from Tables A-97, A-98, A-99, and A-100 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009* (EPA 2011) were used for both 2009 and 2010.

In general, emissions from non-highway vehicles were calculated for 2005 – 2008 using the default emission factors and activity data provided in the SIT. State-specific activity data for 2009 from the EIA and FHWA was added for aviation gas, locomotive diesel, farm diesel, jet fuel kerosene, boat gasoline, construction gasoline, construction diesel, farm gasoline, HD utility, and diesel HD utility vehicles. Emissions from snowmobiles were not calculated because fuel consumption data was not available, and there is no default values in the SIT. Due to a lack of 2010 consumption data at the time of publication, the 2009 consumption values for boat gasoline, locomotive diesel, and farm equipment fuel were used as surrogates for 2010. However, the DNR was able to project the 2010 consumption values for aviation gasoline and jet fuel kerosene value using EIA's *Annual Energy Outlook 2011* (EIA 2011a).

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 2005 – 2008 emissions were calculated using existing data in the SIT. 2009 VMT were derived from the national alternative vehicle VMT in Table A-92 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009* (EPA 2011). The DNR assumed Iowa VMT was 0.77% of federal VMT as the SIT assumed for 2008 (ICF 2011a). The VMT from alternative fuel vehicles were subtracted from the highway VMT in SIT to avoid double-counting. Because the 2010 VMT value was not available, the 2009 value was used as a surrogate.

Municipal Solid Waste

Emissions from municipal solid waste landfills and combustion were calculated using site-specific data collected by the DNR's solid waste and air quality programs. Throughput data reported on individual facility's air emission inventories were used to tabulate the total quantity of landfill gas flared, landfill gas collected in landfill-to-gas-energy projects, and municipal solid waste combusted. The total quantity of municipal solid waste landfill was tabulated from individual landfill reporting to the solid waste program. Emissions were 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 two characterization studies done of Iowa municipal sold waste. The first, *Iowa Statewide Waste Characterization Study* (R.W. Beck 2006), was used to calculate emissions from 2005 – 2009. The second, *2011 Iowa Statewide Waste Characterization Study (*MSW 2011*)*, was used to calculate 2010 emissions.

Wastewater Treatment

<u>Municipal Wastewater</u>

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 2009 and 2010 (U.S. Census Bureau 2011). 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 42.40 from Table 8-14 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009* (EPA 2011). Because the 2010 protein value was not available at the time of publication, the 2009 value was used as a surrogate for 2010.

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 was 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 does not include the Iowa fraction of population without septic systems.

<u>Industrial Wastewater</u>

The SIT calculates GHG emissions from industrial wastewater treatment from four industries – fruits and vegetables, red meat, poultry, and pulp and paper. However, the SIT only contains default activity data for red meat production. The DNR was not able to find Iowa–specific data for fruits and vegetables, poultry, or pulp and paper. The default value in the SIT for 2008 Iowa red meat production was 2,426,579 metric tons. This value was replaced the most recent USDA published value for 2008, which is 3,205,883 metric tons (USDA 2010b). While the DNR was not able to find annual production data for all poultry in the SIT-required units (metric tons per year), the DNR did find and was available to use Iowa chicken production data (USDA 2010b) to calculate emissions.

Land Use, Land Use Change, and Forestry

<u>Forest Carbon Flux</u>

Net carbon sequestration in Iowa forests from 2005 – 2010 was calculated using the most recent data available in the United States DNR 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 2011b). The DNR 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 SIT uses the quantity of limestone and dolomite produced annually in Iowa from the United States Geological Survey's annual *Minerals Yearbook* (USGS 2011). However, the yearbook does not provide the quantity of these minerals applied to agricultural soils, so the SIT applies the national ratio of limestone and dolomite applied to agricultural soils in the data to the Iowa values. For 2009, the national ratio was 91% limestone and 9% dolomite (USGS 2011). Because the use of these minerals is not specified for all limestone and dolomite produced, the SIT also applies another formula to correct for unspecified data.

The DNR obtained improved data from the Iowa Limestone Producers Association (ILPA). The IPLA provided the DNR with the total annual amount of limestone produced for agricultural use as reported by their members (Hall 2011). However, producers do not report the percentage of limestone that is dolomitic. The Iowa DNR of Transportation (DOT) tracks general information for active aggregate sources used for construction, including whether 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 DNR assumed that 50% of the material produced in Iowa for agricultural use is dolomite and 50% is limestone.

Urea Fertilization and Settlement Soils

The SIT default values for fertilizer application were used for 2005 – 2007. The quantity of urea fertilizer applied in growing year 2008 and 2009 was obtained from *Commercial Fertilizers 2009* (Slater 2011). 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 2011c). N_2O emissions from settlement soils were calculated using 10% of the total annual synthetic fertilizer value from the SIT Agriculture module.

Urban Trees

Emissions were calculated 2005 – 2008 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 extrapolated the total urban area values for 2001 – 2008 from the 1990 – 2000 values using the least squares method in Excel. The DNR used this same method to extrapolate the total urban area values for 2009 and 2010. The 2010 value will be updated when the final 2010 US Census is released.

The SIT assumes that 33% of urban areas have tree cover. A recent USDA Forest Service study found that average tree cover in Iowa urban areas was 13.7% (Nowak 2010). However, a recent canopy cover assessment in Des Moines, Iowa using light detection and ranging (LIDAR) data found that Des Moines had 27% tree coverage. The DNR's state urban forester estimated tree coverage to range from 10 - 35% (Bruemmer 2011). The DNR used the SIT default value of 33% to calculate emissions.

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 of wildfires and prescribed burns in Iowa in 2010 were 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.

Landfilled Yard Trimmings and Food Scraps

GHG estimations from this sector were refined by using Iowa-specific data from the 2006 *Iowa Statewide Waste Characterization Study* (R.W. Beck 2006) for the total amount of yard waste and food scraps landfilled. The default values in the SIT overestimated the amount of yard waste landfilled and underestimated the amount of food scraps landfilled because the SIT calculated the annual amount of yard waste and food scraps landfilled by applying the national per capita amount landfilled to the state population.

However, due to lack of Iowa-specific data regarding the content of the yard trimmings, the SIT default values for the composition of the yard waste trimmings (e.g. the percentage of grass,leaves, and branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon were used.

Electricity Consumption

The total kWh of electricity consumed by the residential, commercial, and industrial sectors were calculated using bulk energy consumption data from the U.S. Energy Information Administration's – State Energy Data System (EIA 2011b).

The SIT tool uses emission factors from the Emissions & Generation Resource Integrated Database (eGRID), a comprehensive inventory of electric power systems. The SIT uses emission factors from eGRID 2007 Version 1.1 (2005 data) and uses calendar year 2005 data as surrogates for 2006, 2007, and 2008. However, since the SIT was last published, a newer version of eGRID, (2007 data) has been published, so the Department updated the 2007, 2008, and 2009 emission factors in the SIT with the factors from eGRID2010 Version 1.1. A grid loss factor of 6.471% in 2007 was used for 2008 and 2009 (EPA 2011). Due to a lack of state-specific data, the SIT default value for the percentage of Iowa households in the Midwest Reliability Organization West (MROW) was used.

State-specific 2010 electricity consumption data will not be published by EIA until 2012, so the Department projected 2010 emissions using the reference case in EIA's *Annual Energy Outlook 2011 with Projections to 2035* (EIA 2011a). To project 2010 emissions, the Department first calculated the state's percent electricity consumption for each sector in 2009, 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 2010.

Electricity consumption from electric vehicles in Iowa was not calculated due to a lack of data. According to the Iowa Department of Transportation, only seven electric vehicles (five Volts and two Roadsters) are currently registered in Iowa. There are also many low speed, non-highway electric vehicles, such as golf carts, operating in Iowa. However, the Iowa DOT does not have electricity consumption data for these vehicles (Carroll 2011). In addition, the Federal Transit Administration's National Transit Database shows no data from electric propulsion or electric batteries (FTA 2009).

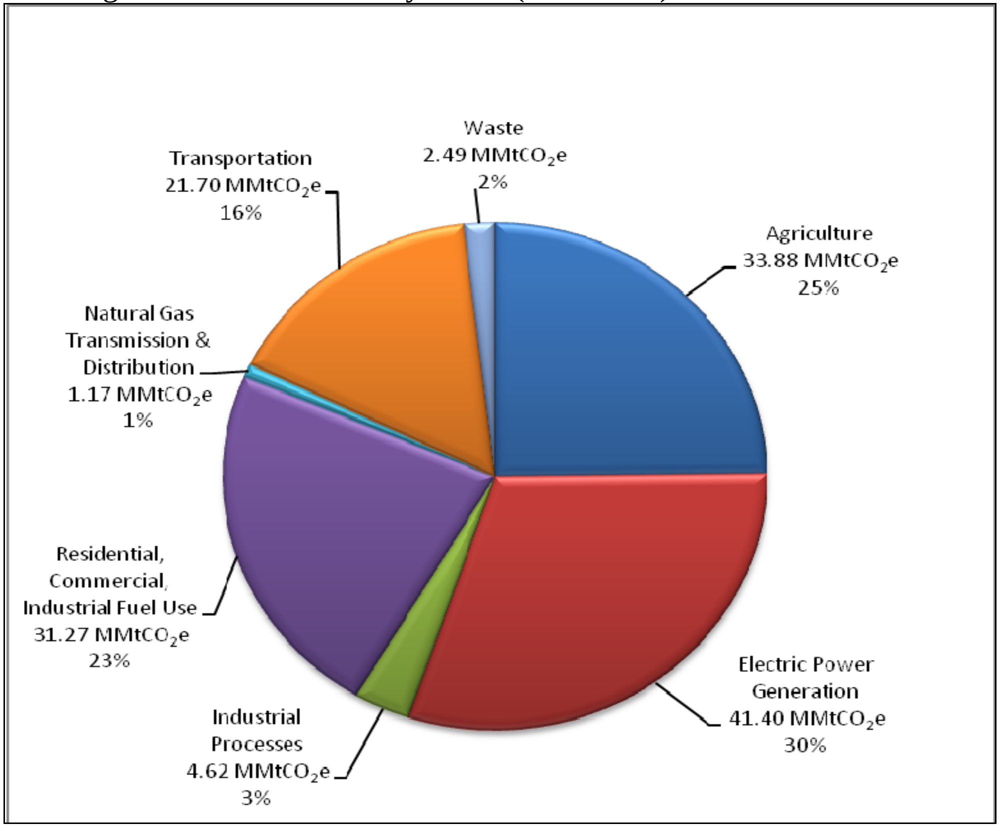
RESULTS

In 2010, total Iowa *gross* greenhouse gas emissions (i.e. excluding carbon sinks) were 136.52 million metric tons carbon dioxide equivalents ($MMtCO_2e$). Table 1 and Figure 1 on the next page present the GHG emissions from each sector. Please note that totals may not equal the exact sum of subtotals in this table due to independent rounding and numbers in parentheses are negative numbers. In addition, the 2005 value is as revised by the DNR and is slightly higher (3.87 $MMtCO_2e$) than the emissions in the previous 2005 inventory conducted by Strait et al. The difference can be attributed to improved activity data and emissions factors since the inventory was conducted. The DNR also determined that the SIT had been over-estimating emissions from both agricultural soils and agricultural burning, as discussed earlier in this paper.

Table 2. Iowa GHG emissions 2005 – 2010, by sector

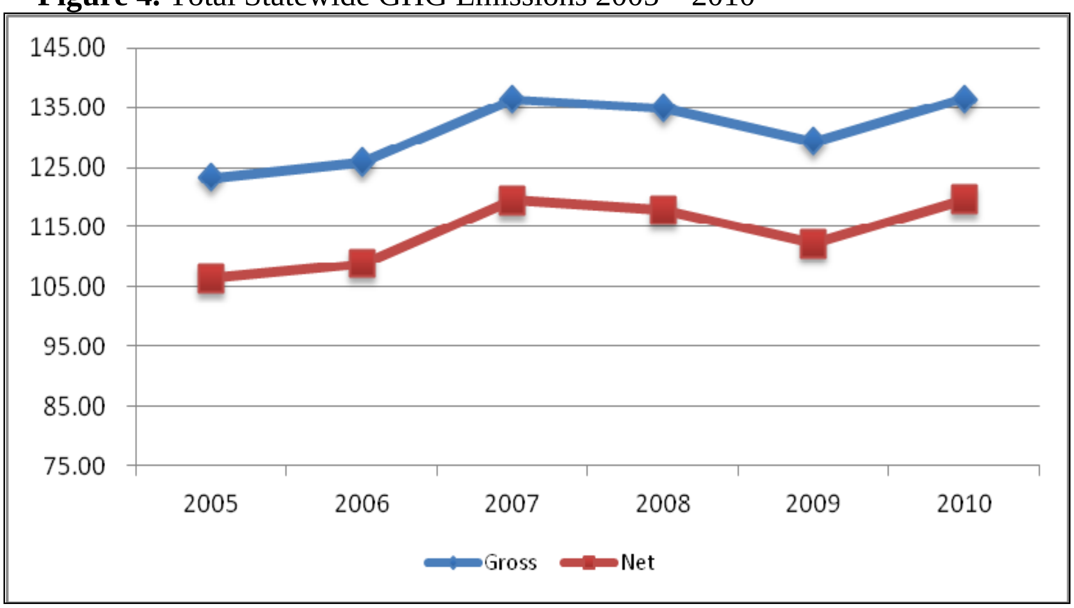
Emissions ($MMtCO_2e$)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Agriculture	32.14	34.25	38.73	34.81	34.63	33.88
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.50
Manure Management	6.77	6.80	7.48	8.19	8.25	7.93
Agricultural Soil Management	19.42	21.10	24.63	19.85	19.63	19.45
Burning of Agricultural Crop Waste	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	72.67
Electric Power Fuel Use	36.84	36.35	40.04	41.78	37.71	41.40
Residential, Commercial, and Industrial (RCI) Fuel Use	24.07	24.32	26.21	27.75	27.66	31.27
Emissions ($MMtCO_2e$)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Industrial Processes	4.67	4.81	4.83	4.93	4.22	4.62
Land Use, Land Use Change, and Forestry (LULUCF)	(16.97)	(16.93)	(16.96)	(17.09)	(17.15)	(16.96)
Natural Gas and Oil Transmission and Distribution	1.15	1.15	1.16	1.07	1.17	1.17
Transportation	21.88	22.38	22.81	21.97	21.42	21.70
Waste	2.62	2.56	2.60	2.62	2.59	2.49
Municipal Solid Waste (MSW)	2.17	2.11	2.14	2.15	2.12	2.03
Wastewater	0.45	0.45	0.46	0.47	0.47	0.46
Gross Emissions	**123.37**	**125.83**	**136.39**	**134.94**	**129.41**	**136.52**
Sinks	**(16.97)**	**(16.93)**	**(16.96)**	**(17.09)**	**(17.15)**	**(16.96)**
Net Emissions	**106.40**	**108.90**	**119.43**	**117.84**	**112.26**	**119.56**
% change in Gross from Previous Year		2.00%	8.40%	(1.07)%	(4.10)%	5.50%
% change in Gross from 2005		2.00%	10.56%	9.38%	4.90%	10.67%

Figure 3. 2010 Iowa gross GHG emissions by sector ($MMtCO_2e$)



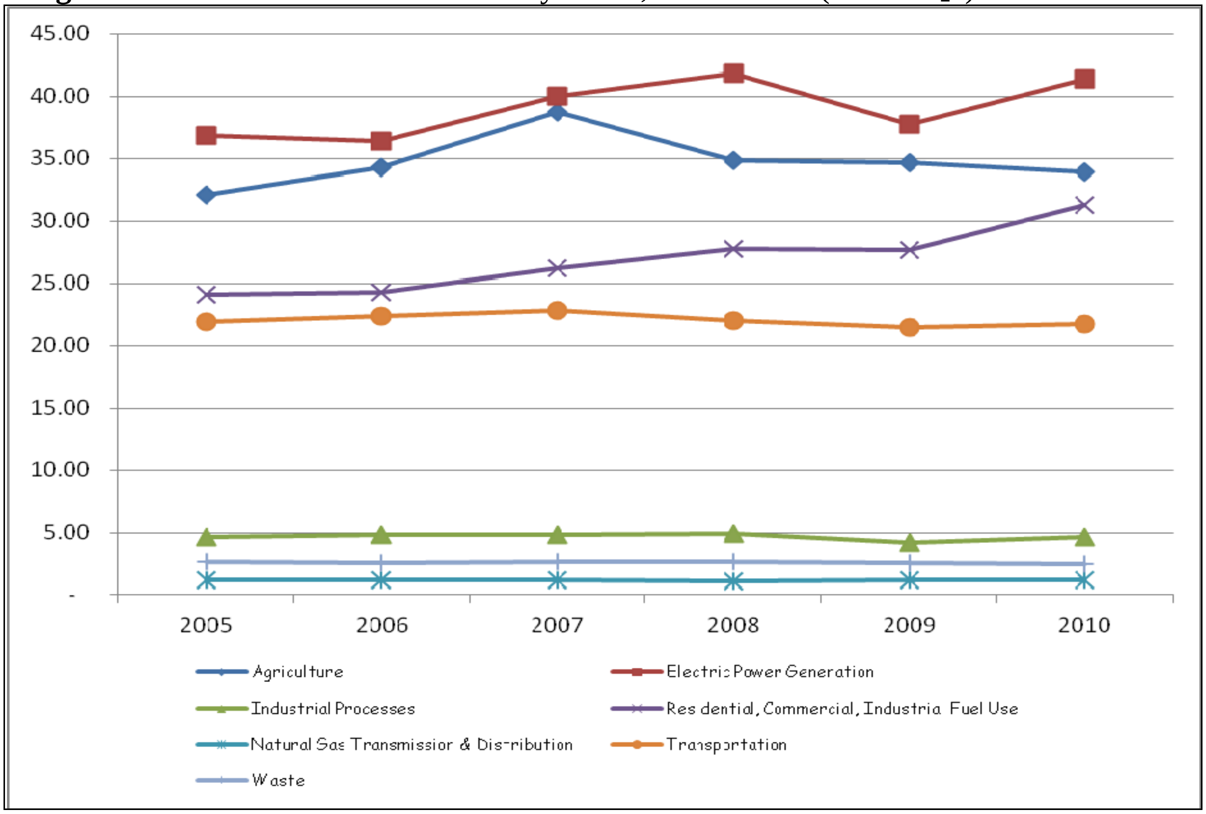
Total 2010 statewide gross GHG emissions increased 5.5% from 2009 and 10.7% from 2005 as shown in Figure 4 partially due to increases in the amount of fossil fuel combusted in the electric power and residential, commercial, industrial (RCI) sectors. Gross GHG emissions decreased 5.1% from 2007 – 2009, mostly due to the economic downturn. Net GHG emissions followed the same trend, as the amount of carbon sequestered remained stable.

Figure 4. Total Statewide GHG Emissions 2005 – 2010



The total gross GHG emissions increased from 2005 – 2010 in each sector except in the industrial processes, transportation, and waste sectors as shown in Figure 5 below.

Figure 5. Iowa Gross GHG emissions by sector, 2005 - 2010 ($MMtCO_2e$)



Emissions trends in each category are summarized as follows:

Agriculture

Agriculture emissions include GHGs from livestock and crop production such as enteric fermentation, manure management, agricultural soils, and agricultural burning. GHG emissions from fossil-fuel fired agricultural equipment are included in the transportation sector. Agricultural emissions increased 5.4% from 2005 – 2010, due to increases in both animal and crop production.

Fossil Fuel Combustion

The fossil fuel combustion sector includes GHG emissions from fossil fuel consumption in two categories – electric power and residential, commercial, industrial (RCI). A 12.4% increase in electric power GHG emissions and a 30.0% increase RCI GHG emissions can be directly attributed to increases in the amount of fossil fuel consumed in each sector.

Industrial Processes

The industrial processes sector includes non-combustion GHG emissions from a variety of processes including cement production, lime manufacture, limestone and dolomite use, soda ash use, iron and steel production, ammonia production, nitric acid production, substitutes for ozone depleting substances (ODS), and electric power and distribution. GHG emissions trends in each sector vary, but overall GHG emissions from this sector decreased 1.1% from 2005 – 2010.

Natural Gas Transmission and Distribution

This sector includes GHG emissions from natural gas transmission and distribution networks.GHG emissions increased 1.6% from 2005 – 2010 partly due to an increase in the miles of transmission lines.

Transportation

Transportation emissions includes GHGs emitted from both highway and non-highway vehicles such as aviation, boats, locomotives, tractors, other utility vehicles, and alternative fuel vehicles. Transportation GHG emissions decreased 0.8% from 2005 – 2010, partly due to a decrease in the amount of gasoline combusted by motor vehicles.

Waste

The waste sector includes GHG emissions from municipal solid waste (MSW) landfills and the treatment of municipal and industrial wastewater. GHG emissions from waste decreased 5.0% from 2005 – 2010, largely due to decreases in the amount of MSW both landfilled and combusted, as well as increases in the amount of methane emissions avoided by flaring and landfill gas to energy (LFGTE) projects.

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

This sector includes 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. The amount of CO_2 sequestered remained stable from 2005 – 2010, decreasing 0.02%. This is mostly due to a lack of more current forest carbon flux data.

CONCLUSIONS – LESSONS LEARNED

The 2010 Iowa GHG Inventory is the fourth statewide GHG inventory prepared for the state to-date, and the first top-down inventory prepared directly by the DNR. Lessons learned included the following:

1) The SIT is very user-friendly and a great tool for calculating statewide emissions. However, it may need to be “tweaked” to meet the state’s specific inventory needs such as an accelerated time frame and incorporating state-specific data.
2) It is very difficult to conduct a full statewide inventory for previous year, as current activity data may not be available. More training in growing or projecting emissions may be helpful.
3) Be a detective. This is the most time-consuming part of completing the inventory, but the activity data you need is out there somewhere and the agency or person holding that data is usually very willing and pleased to share it.
4) If you are able to, allowing time for peer review and public review is helpful. Readers may find mistakes or bias, and may offer alternative sources of activity data.
5) Document all sources of data carefully. This not only explains and justifies your findings, but will also allow your calculations to be reproduced by future inventory staff.
6) Estimate what you can, explain and document what you can’t. Identify sectors that need improvement or have uncertainty. This will provide directions for future inventories and help explain your findings (or lack of). For instance, DNR staff did not have the resources or experience to estimate the quantity of carbon sequestered in agricultural soils. Therefore, that category was not included in the inventory, but the reasons why were documented in the final report.
7) Know your audience. If your inventory will be used my multiple stakeholders such as technical staff, lawmakers, the public, etc., you may need to produce different types of deliverables. DNR published the executive summary and final report separately, but in the future may develop quick facts for the public.

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