Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama

2010

The City of Huntsville
Division of Natural Resources and Environmental Management

DNR AQEI/05-13

Acknowledgement

The Division of Natural Resources is pleased to recognize the contributions to preparation of this report by Ms. Destini Bone, a student intern working for the Division during the summer of 2012. With general direction from DNR staff, Ms. Bone gathered much of the information necessary for preparing this update to the Greenhouse Gas Emissions Inventory to include emissions in 2010. Ms. Bone also performed a number of the requisite calculations to convert these raw data (e.g. electricity consumption, natural gas usage, etc.) into greenhouse gas emission estimates. DNR staff then filled in the remaining gaps in the raw data, performed additional calculations and quality assurance checks, and prepared the final version of the document. Destini's dedication, enthusiasm for this project, and hard work greatly accelerated the preparation of this updated greenhouse gas emissions inventory for the Huntsville area.

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Executive Summary

The City of Huntsville Division of Natural Resources & Environmental Management developed the first greenhouse gas emissions inventory for the Huntsville area in 2009. The initial inventory covered the years 2000 and 2005, and at the time it was compiled periodic future updates were envisioned. This report constitutes the first such update and focuses on the year 2010. Although data for the years 2000 and 2005 are included for comparative purposes, exhaustive detail regarding information sources, sample calculations, etc. is only provided for year 2010 in this report. Wherever there are significant differences in the methodology employed in the 2010 update relative to the initial inventory, those differences are discussed and explained, but it is otherwise deemed unnecessary to repeat all of the details of initial inventory development in this report. For those interested in reviewing the methodology utilized in development of the initial inventory in greater detail, the 2009 report, entitled *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Years 2000 and 2005* (DNR AQEI/12-09; December 2009) is available on the City of Huntsville website at the following address: http://www.huntsvilleal.gov/NatRes/airdata.php

The 2010 inventory focuses on the principal greenhouse gases, i.e. carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These are the gases typically included in local inventories and were the focus of initial inventory development here as well. Of lesser, but growing importance are a number of fluorine compounds. These are included in the national inventory for the U.S. prepared by EPA (Environmental Protection Agency), but are not reflected in the local inventory. The national inventory also includes greenhouse gas emissions associated with agricultural activities, but the local inventory does not. There are other, less significant differences between the national inventory and the approach taken in developing and updating the Madison County inventory, which has a scope similar to most local inventories.

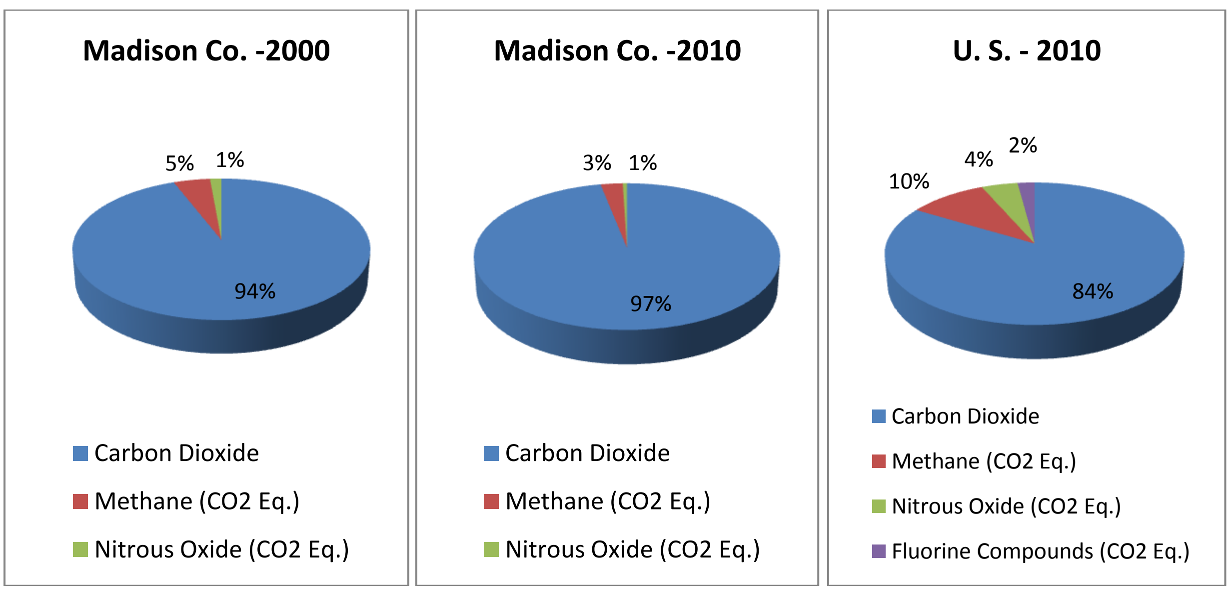
CO_2 is the most important greenhouse gas and is emitted in far larger quantities than any of the other greenhouse gases. However, an equivalent weight of methane, nitrous oxide or the fluorine compounds has a greater "Global Warming Potential" (GWP) than CO_2, and it is therefore conventional practice to express emissions of each of the greenhouse gases in terms of "carbon dioxide equivalent" (CO_2 Eq.). This is done through use of a multiplier that accounts for differences in GWP of the various chemical species. Table ES-1 shows the total emissions of the three principal greenhouse gases in Madison County, expressed in terms of CO_2 Eq., and Figure ES-1 shows their relative importance to the local inventory in years 2000 and 2010. The relative importance of the different greenhouse gases in the 2010 national inventory is included for purposes of comparison.

The differences in relative importance of the greenhouse gases nationally and locally can largely be explained by differences in the scope of the inventories. Significant sources of methane and nitrous oxide emissions in the national inventory are agricultural. Since agricultural emissions are not included in the Madison County inventory, the relative importance of carbon dioxide is even higher locally than in the national inventory. In 2010, carbon dioxide emissions constituted roughly 97 % of total greenhouse gas emissions in Madison County, compared with roughly 84 % of the total in the U.S. inventory.

Table ES-1 – Emissions (Tons CO_2 Eq.) of the Principal Greenhouse Gases in Madison County, Alabama in Years 2000 and 2010. Percentage Contributions are Shown in Parentheses. Percentages from the National Inventory are Included for Comparative Purposes.

	2000		***2010***		***2010 (U.S.)***
CO_2	5,265,982	(94.1 %)	5,693,524	(96.8 %)	83.7 %
CH_4 (CO_2 Eq.)	252,463	(4.5 %)	155,665	(2.7 %)	9.8 %
N_2O (CO_2 Eq.)	79,609	(1.4 %)	31,972	(0.5 %)	4.5 %
Fluorine Compounds		Not Included			2.1 %
TOTAL (CO_2 Eq.)	5,598,054	(100.0 %)	5,881,161	(100.0 %)	100.1 %

Figure ES-1 – Madison County Principal Greenhouse Gas Emissions in Years 2000 and 2010 (Percent). Analogous Information from the 2010 U.S. Inventory is Shown for Comparison.



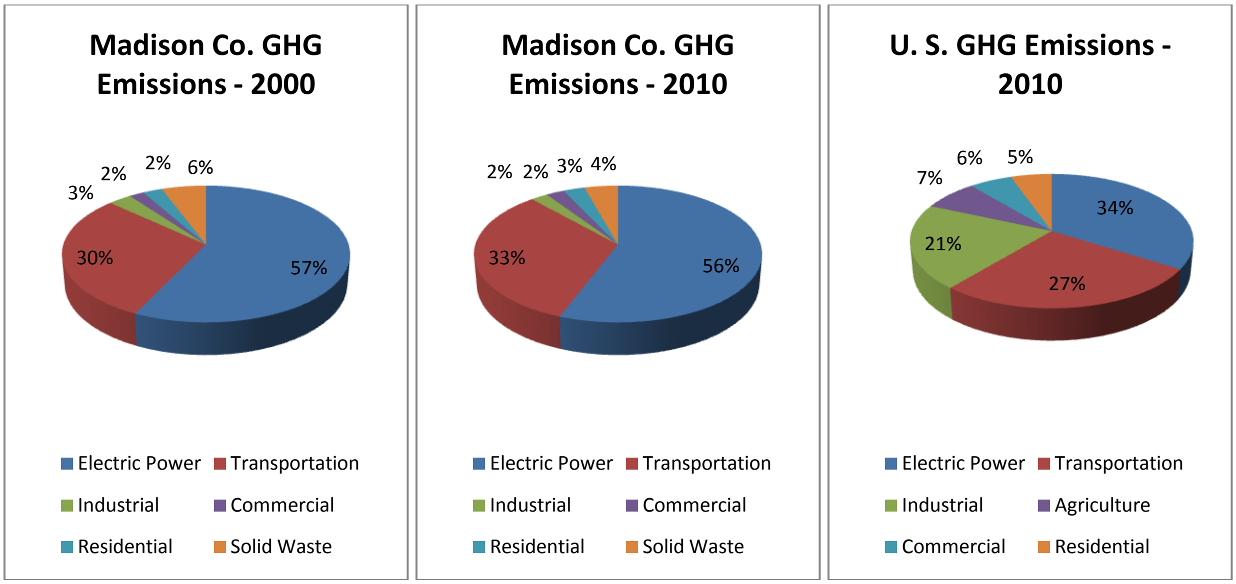
The majority of greenhouse gas emissions are attributable to combustion of fossil fuels (coal, natural gas, gasoline, diesel fuel, etc.). Fuel usage at electric power generating facilities, primarily coal-fired power plants, is responsible for a substantial fraction of national greenhouse gas emissions. Although there are no power plants in Madison County, emissions from the TVA power plants that produce the electricity can be allocated based on electricity usage. The use of this approach is conventional practice in preparing local emission inventories and was employed in preparing the Madison County inventory as well. Emissions associated with electricity usage constitute over half of total emissions in Madison County (roughly 56 % in 2010), compared with approximately 34 % nationally. Conversely, fuel combustion at stationary sources (home and commercial heating, industrial process heating, etc.) is a smaller fraction of total emissions in Madison County than in the U.S. inventory. These differences are the result of much more prevalent use of electricity for space heat (heat pumps) in North Alabama than in other parts of the country and the nature of local industry, which is not highly energy intensive for the most part. Transportation emissions in Madison County constituted about 33 % of total emissions in 2010. Nationally, transportation contributed roughly 27 % of total emissions.

Table ES-2 shows emission totals by source type for years 2000 and 2010 and the corresponding percentages. Percentage contributions by source type in the national inventory are included for comparative purposes. Figure ES-2 shows the relative contributions by source type in Madison County and nationally. As noted previously, the Madison County inventory does not include agricultural emissions, whereas the national inventory does. Another difference involves solid waste management emissions, which are included as a separate category in the local inventory, but are allocated among the industrial, commercial and residential sectors in the national inventory.

Table ES-2 – Greenhouse Gas Emission Totals (Tons CO_2 Eq.) by Source in Madison County in Years 2000 and 2010. Percentage Contributions are Shown in Parentheses. Percentages from the National Inventory are Included for Comparative Purposes.

	2000		***2010***		***2010 (U.S.)***
Electric Power	3,195,192	(57.1 %)	3,280,539	(55.8 %)	(33.8 %)
Transportation	1,660,017	(29.7 %)	1,916,844	(32.6 %)	(26.9 %)
Stationary Source Fuel Use	425,931	(7.6 %)	431,932	(7.3 %)	
Stationary Fuel Use + Solid Waste Mgt.					(31.4 %)
Solid Waste Management	316,914	(5.7 %)	251,846	(4.3 %)	----
Agricultural	Not Included				(7.3 %)
U.S. Territories	Not Applicable				(0.7 %)
Total	***5,598,054***	***(100.1 %)***	***5,881,161***	***(100.0 %)***	***(100.1 %)***

Figure ES-2 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Source Category in Years 2000 and 2010. Analogous Information from the 2010 U.S. Inventory is Shown for Comparison.



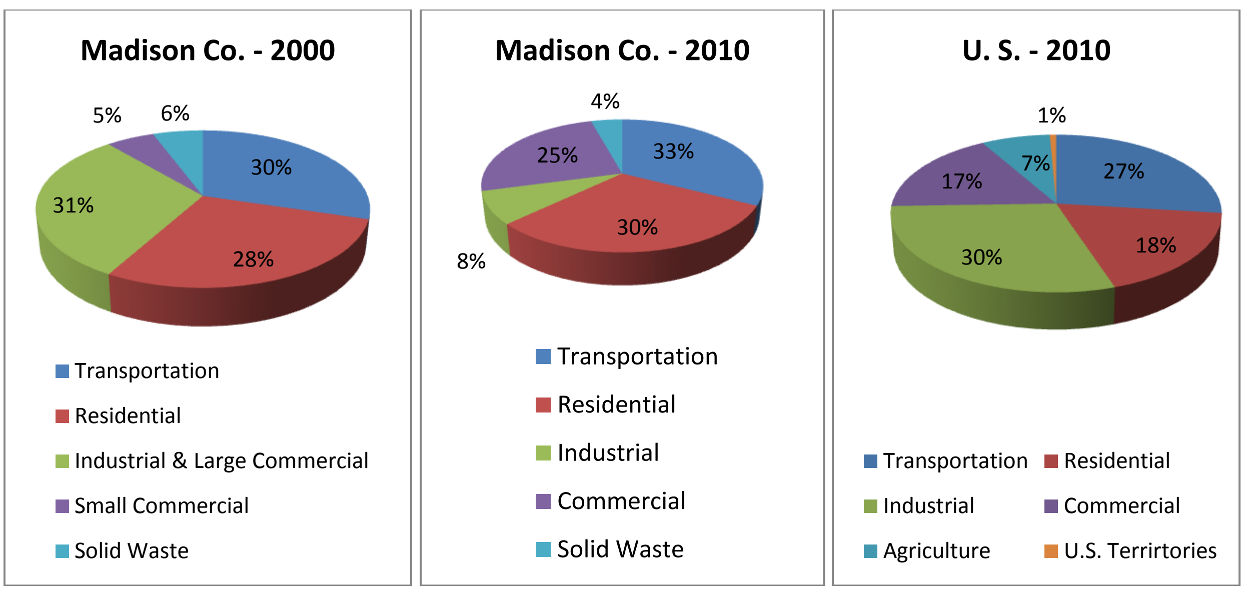
In addition to delineating emissions by the type of source, emissions can be allocated to the different economic sectors. In other words, emissions associated with electric power generation can be assigned to the end users in the residential, commercial and industrial sectors based on their usage. Similarly, stationary source fuel consumption can be broken down by economic sector. Madison County emissions by economic sector are shown in Table ES-3 and in Figure ES-3. The percentage of total emissions attributable to the various economic sectors in the 2010 U.S. inventory is shown for comparative purposes.

The largest sector nationally is the industrial sector, contributing roughly 30 % of total U.S. greenhouse gas emissions in 2010. In Madison County, industrial facilities constitute a much smaller fraction of the overall inventory, comprising just under 8 % of the total. This result is not surprising, given the fact that most industrial facilities in Madison County are not among the more energy intensive industrial operations. Note that in prior greenhouse gas inventory years (2000 and 2005), Huntsville Utilities grouped the large commercial and industrial accounts together. This is reflected in the source category description for Year 2000 in Table ES-3 and in Figure ES-3. Largely as a result of the smaller contribution of industrial emissions to the local inventory than nationally, the relative importance of the remaining source categories is higher in the Madison County inventory than in the U.S. inventory in 2010.

Table ES-3 – Contribution to Greenhouse Gas Emission Totals (Tons CO_2 Eq.) by Economic Sector in Madison County in Years 2000 and 2010 with Emissions from Electricity Consumption and Stationary Source Fuel Combustion Allocated Among the Sectors by Usage. Percentages are shown in Parentheses and are also shown for the 2010 U.S. National Inventory.

	2000	2010	2010 (U.S.)
Industrial		462,629 (7.9 %)	29.6 %
Industrial & Large Commercial	1,721,438 (30.7 %)		
Transportation	1,660,017 (29.7 %)	1,916,844 (32.6 %)	26.9 %
Commercial		1,467,258 (24.9 %)	17.2 %
Small Commercial	310,239 (5.5 %)		
Residential	1,589,448 (28.4 %)	1,782,583 (30.3 %)	18.0 %
Solid Waste Mgt.	316,914 (5.7 %)	251,846 (4.3 %)	Not a Separate Sector
Agricultural	Not Included		7.6 %
U.S. Territories	Not Applicable		0.7 %
Total	***5,598,054 (100 %)***	***5,881,161 (100 %)***	***100 %***

Figure ES-3 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Economic Sector in Years 2000 and 2010, with Emissions from Electricity Consumption Allocated Based on Usage. Analogous Information from the 2010 U.S. Inventory is Shown for Comparison



The transportation sector was the largest contributor to total emissions in the 2010 Madison County inventory, constituting approximately 33 % of the total. In the U.S. as a whole, transportation is responsible for a somewhat lower amount (27 % of total emissions). In contrast, the residential sector contributes a much higher percentage locally than nationally, with residential emissions equal to roughly 30 % of the Madison County inventory in 2010, compared with approximately 18 % nationally. Similarly, commercial emissions are of relatively greater importance locally, constituting just under 25 % of the Madison County inventory compared with roughly 17 % nationally. Emissions attributable to solid waste management were just over 4 % of the Madison County total in 2010, a relatively minor component of the inventory. Nationally, solid waste management is not viewed as a separate economic sector. Rather, these emissions are distributed across the industrial, residential and commercial sectors based on their solid waste generation. On the other hand, agricultural emissions contributed nearly 8 % of the national total, but are not included in the Madison County inventory.

Figure ES-4 presents the emissions data for Madison County by source type in years 2000, 2005 and 2010 as a bar chart, making the changes with time more apparent. Overall, emissions increased by 5 % over the ten-year period, from 5.60 million tons in year 2000 to 5.88 million tons in 2010. In magnitude, the largest increase occurred in the transportation sector, from 1.66 million tons in year 2000 to 1.92 million tons in 2010, an increase of 15.5 %. In contrast, emissions associated with electricity usage, the largest component in the inventory, increased by 2.7 % over the ten-year period, from 3.20 million tons in 2000 to 3.28 million tons in 2010. The emission associated with electricity consumption actually declined slightly from 2005 (3.30 million tons) to 2010 (3.28 million tons). Emissions from stationary fuel combustion, a much smaller component of the overall inventory, increased only slightly from the year 2000 (0.426 million tons) to year 2010 (0.432 million tons), an increase of only 1.4 %. Although there were increased emissions from residential and commercial natural gas combustion, these increases were largely offset by a decrease in emissions from industrial fuel combustion. Finally, emissions from solid waste management decreased over the ten-year period, from 0.317 million tons in 2000 to 0.252 million tons in 2010, a decline of just over 20 %. However, this "decrease" in emissions is primarily due to improvements in the method used to estimate methane emissions from the solid waste landfill rather than drastic changes in solid waste management practices.

Although overall emissions increased by 5 % in Madison County from 2000 to 2010, per capita emissions actually declined because the population increased by a larger percentage than did the greenhouse gas emissions. The population increased by 20.9 %, from 276,972 persons in the year 2000 to a 2010 population of 334,811. Per capita emissions in Madison County were 20.2 tons in year 2000, decreasing to 19.4 tons in 2005, and then to 17.6 tons in 2010. Table ES-4 and Figure ES-5 compare Madison County 2005 per capita emissions with per capita emissions in the U.S., Alabama and surrounding States in 2004 (2004 was the most recent year for which comprehensive state-by-state comparisons of total greenhouse gas emissions were available). The State and national data include emissions from transportation, stationary source fuel combustion and electricity usage and are thus similar in scope to the Madison County inventory. The only difference is the Madison County data include emissions from solid waste management whereas the comparative data do not.

As noted above, 2004 is the most recent year for which comprehensive state-by-state comparisons of per capita total greenhouse gas emissions are available. However, more recent comparisons of carbon dioxide emissions by state are available. Carbon dioxide is the principal

Figure ES-4 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005 and 2010 by Source. Values are in millions of tons.

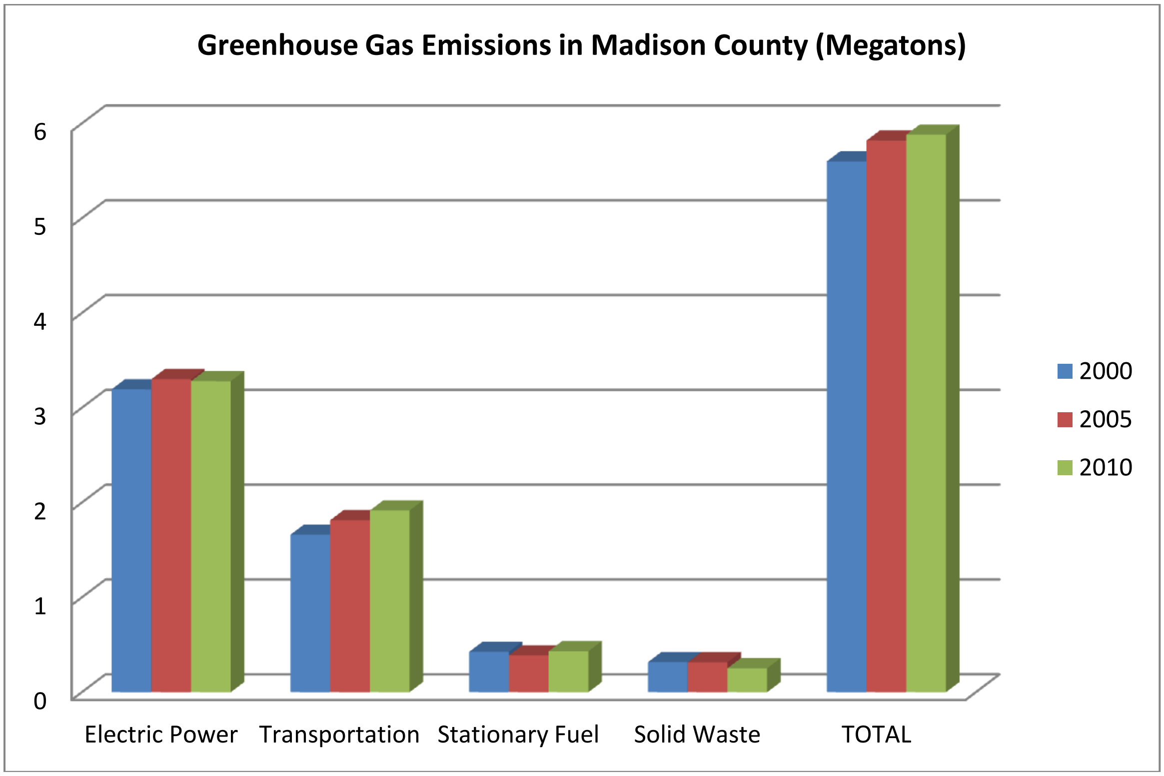


Table ES-4 – Per Capita Greenhouse Gas Emissions for the United States, Selected States and Madison County, Alabama. All values are for Year 2004 unless otherwise shown.

	Per capita Emissions (Tons per Year)
United States	22.7
United States (2010)	22.4
Florida	18.0
Madison County, Alabama (2005)	***19.4***
Madison County, Alabama (2010)	***17.6***
Georgia	23.4
Tennessee	25.8
Mississippi	26.5
Alabama	28.6

Figure ES-5 – Comparison of per Capita Greenhouse Gas Emissions in Alabama and Adjoining States and in the United States as a Whole (Tons/Year CO_2 Eq.). All values are for 2004 unless otherwise shown.

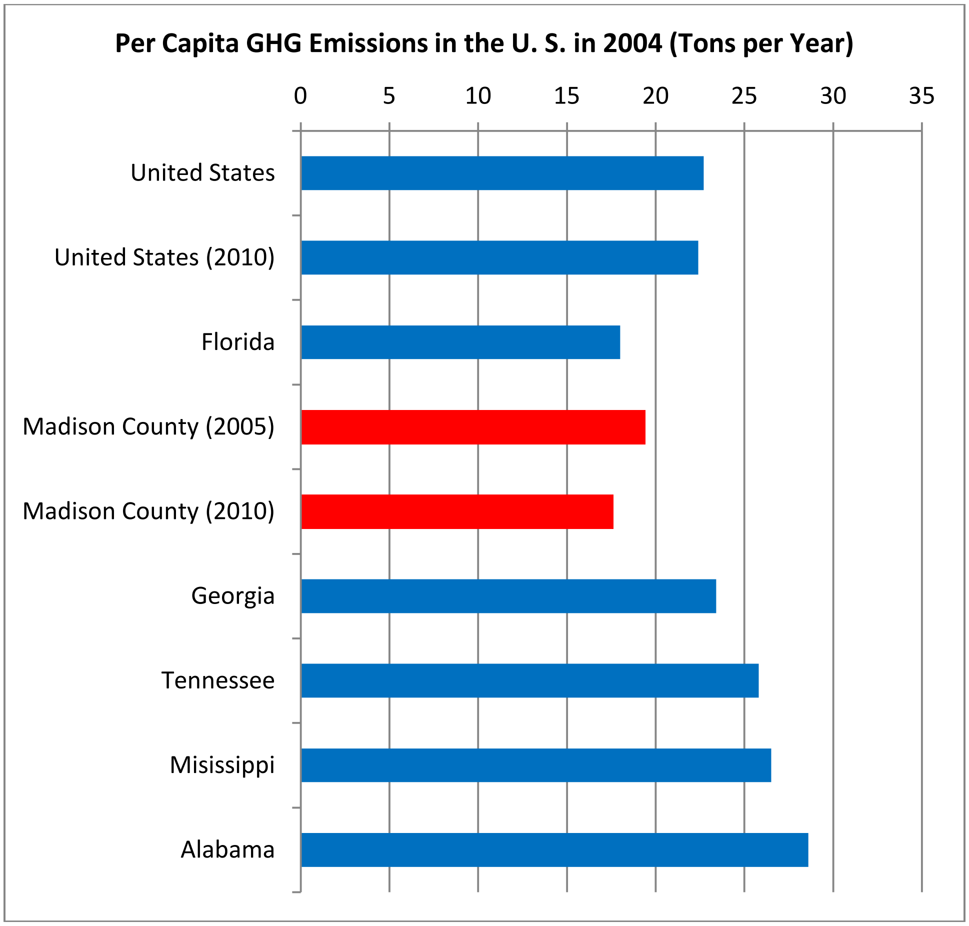
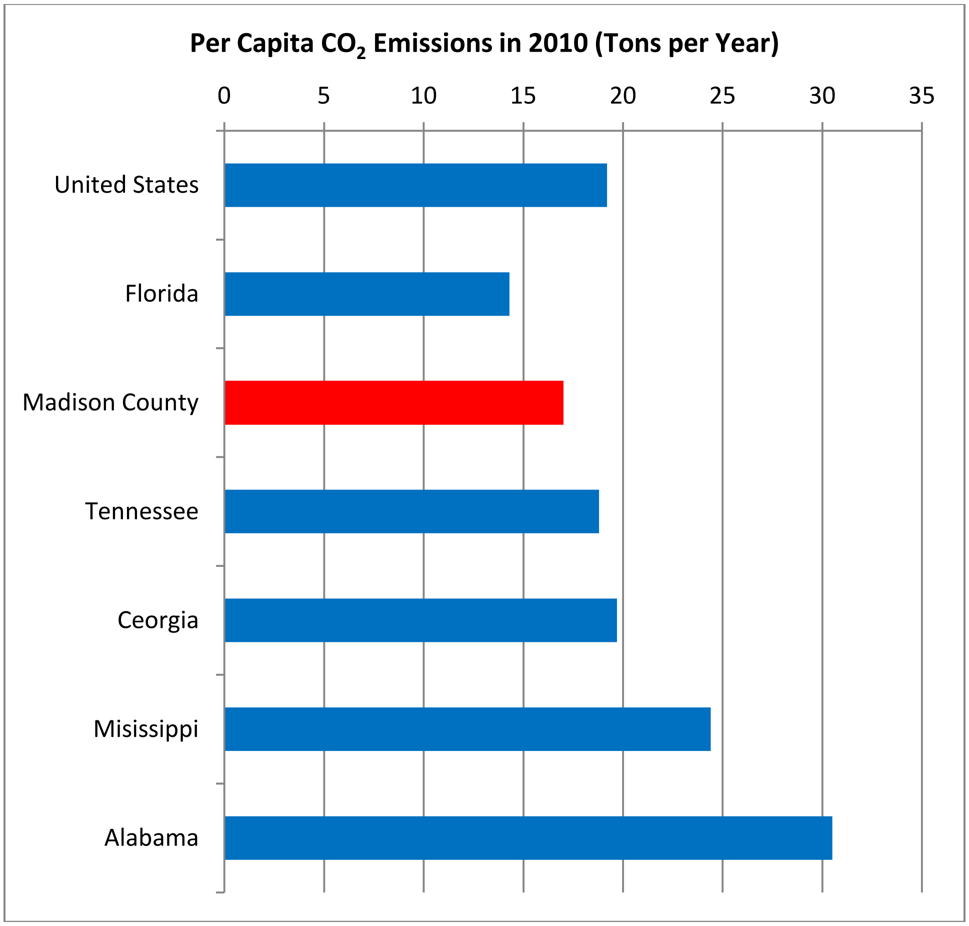


Table ES-5 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion in 2010 for the United States, Selected States and Madison County, Alabama.

	Per capita Emissions (Tons per Year)
United States	19.2
Florida	14.3
Madison County, Alabama	***17.0***
Georgia	19.7
Tennessee	18.8
Mississippi	24.4
Alabama	30.5

Figure ES-6 – Comparison of per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion in Alabama and Adjoining States, and in the United States as a Whole in 2010 (Tons/Year).



greenhouse gas and is also the most readily quantified. Per capita carbon dioxide emissions for Madison County, Alabama, adjoining States and the U.S. as a whole are shown in Table ES-5 and in Figure ES-6. These State and national carbon dioxide data include emissions from transportation, stationary source fuel combustion and electricity generation and are thus fairly similar in scope to the Madison County inventory. A minor difference is the Madison County data include emissions from solid waste management whereas the comparative data do not. A more significant difference is that unlike the data for total greenhouse gas emissions shown in Table ES-4 and Figure ES-5, there is no adjustment to reflect electricity imports and exports among States. The carbon dioxide emissions are based on electricity *generated* within each State, rather than on the electricity *usage* within each State. Thus, the per capita emissions are inflated for those States which generate far more electricity than is consumed within the State, and the per capita emissions are understated for those States which import significant amounts of their electricity from other States.

Despite the fact that the 2010 carbon dioxide emission data shown in Table ES-5 and Figure ES-6 are based on electricity generation rather than consumption, which makes them less directly comparable to the Madison County data, they are more current and therefore are useful for presentation with the 2010 update to the Madison County inventory. Furthermore, they show a similar pattern to the more complete and representative data presented for 2004. In general, the 2010 carbon dioxide data show the same overall pattern as the 2004 total greenhouse gas emissions data. Per capita emissions are lower in the Northeastern States and in the States along the Pacific Coast of the contiguous U.S., and tend to be higher in the Southeast and Midwest. A number of factors affect per capita emissions, including climate, the mix of power generating facilities that serve the area (coal-fired power plants contribute a large fraction of emissions nationally), transportation patterns and the types of industrial sources.

As shown in Table ES-4, per capita total GHG emissions in Madison County in 2005 were somewhat lower than the 2004 national average of 22.7 tons per person, and are on the low end of the range for the Southeastern United States. In Alabama, per capita emissions of 28.6 tons are nearly 50 % higher than in Madison County (19.4 tons). The fact that most of the industrial facilities in Madison County are not highly energy intensive provides a partial explanation for the lower per capita emissions in Madison County than in the State of Alabama as a whole.

The 2010 per capita carbon dioxide emissions shown in Table ES-5 exhibit a pattern very similar to that of the 2004 total GHG emissions. The Madison County per capita CO_2 emissions of 17.0 tons per person are somewhat lower than the national average of 19.2 tons per person and toward the low end of the range for the Southeastern United States. In Alabama, per capita emissions of 30.5 tons were 79 % higher than in Madison County. Note that the 2010 per capita carbon dioxide emissions in Alabama are actually higher than the per capita total greenhouse gas emissions shown for 2004. This is largely because the 2010 data reflect emissions from electricity *generation* rather than those associated with electricity *consumption.* In other words there is no adjustment in per capita emissions for electricity that is generated within the State and exported to neighboring States as there is for the 2004 data. Consequently, for States such as Alabama that export significant amounts of electricity to neighboring States, the per capita emissions are somewhat inflated. It is also true that Alabama is home to a number of energy intensive industries, whereas Madison County is not.

In examining per capita emissions of total greenhouse gases in Madison County over time, it is clear that there has been a fairly dramatic decrease from 2000 to 2010. Per capita emissions have declined from 20.2 tons in 2000 to 19.4 tons in 2005 (a decrease of 4 %) and from 19.4 tons in 2005 to 17.6 tons in 2010 (a decrease of over 9 %). Overall, per capita GHG emissions decreased by 13 % from the year 2000 to the year 2010. However, this reduction in per capita greenhouse gas emissions is not associated with a decrease in per capita energy usage, which is virtually unchanged in Madison County from 2000 to 2010. Rather, it resulted entirely from a change in the power mix utilized by TVA, which relied less heavily on coal-fired electricity generation in 2010, with an increased percentage coming from nuclear and natural gas-fired generation facilities.

Greenhouse Gas Emissions from City of Huntsville Municipal Operations

In addition to developing a County-wide inventory, Natural Resources quantified emissions from City of Huntsville municipal government operations for the years 2000, 2005 and 2010. This information is summarized for years 2000 and 2010 in Table ES-6 and depicted graphically for all three years in Figure ES-7. Percent contribution of electricity consumption, transportation fuel combustion and stationary source fuel combustion to total emissions is also shown in Table ES-6 (for years 2000 and 2010) and is depicted graphically for years 2000, 2005 and 2010 in Figure ES-8.

Emissions from municipal operations were virtually unchanged from 2000 to 2005, equalling roughly 46 thousand tons in each of the two years, but then decreased to 44,545 tons in 2010, a reduction of roughly 3 %. There were substantial changes in the three emissions categories, i.e. electricity consumption, stationary fuel combustion and transportation. Emissions associated with electricity usage increased from 25.3 thousand tons in year 2000 to 26.6 thousand tons in 2005, an increase of 5.2 %, but then decreased to 23.1 thousand tons in 2010, a decline of roughly 13 % over the five-year period. The decrease over the ten-year period from 2000 to 2010 was 8.4 %. Emissions from natural gas combustion also declined dramatically from 2000 to 2010, dropping from roughly 6700 tons in 2000 to 6100 tons in 2010, a reduction of 8.7 %. Thus, there were substantial reductions in greenhouse gas emissions associated with City facilities over the ten-year period. However, there was a countervailing increase in emissions associated with operation of the City fleet over the same period of time. Emissions from gasoline and diesel fuel use in City vehicles increased from 14,125 tons in 2000 to 15,316 tons in 2010, an increase of 8.4 %. Consequently, despite the substantial decrease in GHG emissions associated with operation of municipal facilities, the overall reduction was only 3.3 %.

Table ES-6 – Greenhouse Gas Emissions (Tons CO_2 Eq.) From City of Huntsville Municipal Government Operations in Years 2000 and 2010.

	2000		***2010***	
Electricity Consumption	25,253	(54.8 %)	23,125	(51.9 %)
Stationary Source Fuel Combustion	6,684	(14.5 %)	6,104	(13.7 %)
Transportation Fuel Combustion	14,125	(30.7 %)	15,316	(34.4 %)
Total	46,062	(100.0 %)	44,545	(100.0 %)

Figure ES-7 – City of Huntsville Municipal Government Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005 and 2010.

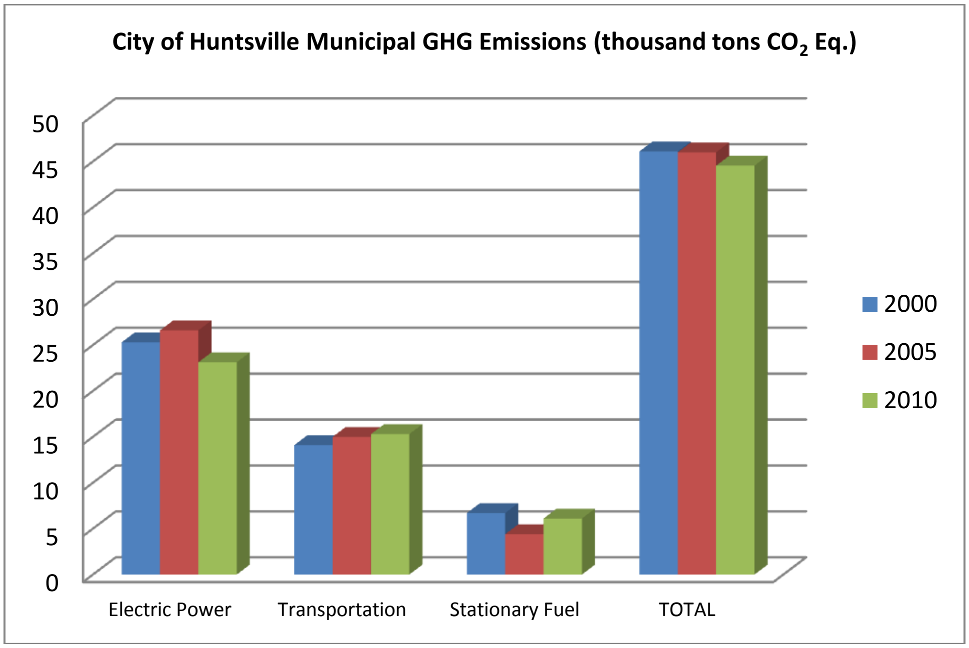
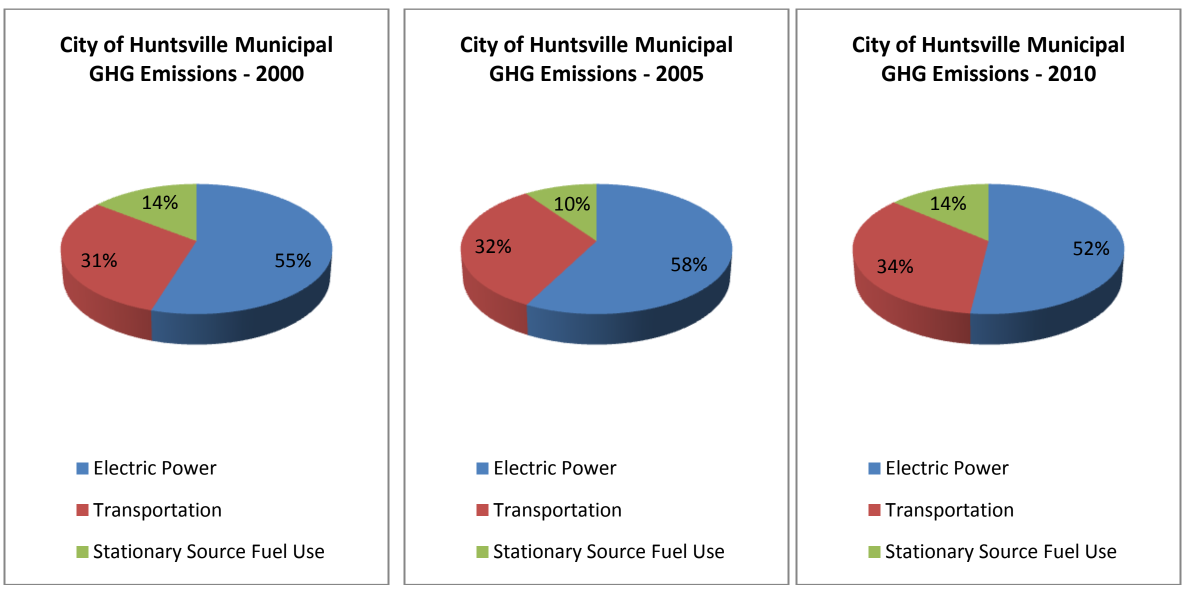


Figure ES-8 – City of Huntsville Municipal Operations Greenhouse Gas Emissions (CO_2 Eq.) by Source in Years 2000, 2005 and 2010.



The relative contributions to overall emissions from City of Huntsville operations by the three usage sectors, i.e. electricity consumption, transportation fuel usage and natural gas combustion, are fairly similar to those for the community as a whole, both in year 2000 and year 2010. In 2000, roughly 55 % of municipal government emissions resulted from electricity consumption, compared with a corresponding value of 57 % County-wide. Electricity usage accounted for roughly 52 % of municipal operation emissions in 2010, whereas emissions from electricity use contributed approximately 56 % of the total across Madison County. Emissions from motor vehicles were also comparable for municipal operations in 2000 (31 % of the total) and for Madison County as a whole (30 % of total emissions). In 2010, these percentages are fairly similar as well, with roughly 34 % of total emissions from municipal operations attributed to motor vehicles and 33 % of total County-wide emissions being from the transportation sector. The balance of City government emissions in year 2000 (14.5 %) were from natural gas combustion, while this source category only accounted for 8 % of County-wide emissions. Emissions from solid waste management made up the balance of County-wide emissions in 2000, but this is not a category of emissions from municipal operations since the City of Huntsville neither owns nor operates the solid waste disposal facilities. From 2000 to 2010, the relative contribution of natural gas combustion to total greenhouse gas emissions for City of Huntsville government declined slightly to roughly 14 % of the total, and also declined slightly for the community as a whole to just over 7 % of total emissions.

Since electricity consumption and stationary source fuel combustion are both associated with the operation of City facilities, including the wastewater treatment plants and lift stations, about two-thirds of the total emissions from municipal operations are attributable to fixed facility operations (66 %) and roughly one-third of the total emissions are from operation of the City’s motor vehicle fleet (34 %).

Introduction

The City of Huntsville Division of Natural Resources and Environmental Management has regularly compiled fairly comprehensive emissions inventories for many years, summarizing the results in the Division's Air Quality Reports.[1] These inventories have traditionally focused on criteria pollutants[2] and have been expanded in recent years to include Hazardous Air Pollutants.[3] In other words, emissions inventories have encompassed pollutants subject to regulation under the Clean Air Act, and have not included emissions of "greenhouse gases," i.e. compounds implicated in climate change, which have only become subject to regulation under the Clean Air Act in the past few years.[4] In 2009, the Division compiled the first greenhouse gas emissions inventory for the Huntsville area, focusing on the years 2000 and 2005.[5] At the time the initial inventory was compiled, periodic updates were envisioned. This document presents the results of the first such update and focuses on the year 2010.

Although data for the years 2000 and 2005 are included for comparative purposes, exhaustive detail regarding information sources, sample calculations, etc. is only provided for year 2010 in this report. Wherever there are significant differences in the methodology employed in the 2010 update relative to the initial inventory, those differences are discussed and explained, but it is otherwise deemed unnecessary to repeat all of the details of initial inventory development in this report. For those interested in reviewing the methodology utilized in development of the initial inventory in greater detail, the 2009 report, entitled *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Years 2000 and 2005* (DNR AQEI/12-09; December 2009) is available on the City of Huntsville website at the following address: http://www.huntsvilleal.gov/NatRes/airdata.php

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[1] The most recent Air Quality Reports can be accessed on the Division's website: http://www.huntsvilleal.gov/NatRes/airdata.php

[2] Criteria pollutants are those pollutants for which the federal Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards. The six criteria pollutants are particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, lead and ozone. Ozone is a secondary pollutant, and ozone precursors (Volatile Organic Compounds and nitrogen oxides) are regulated as criteria pollutants.

[3] There are currently 187 chemical compounds or groups of compounds subject to regulation as Hazardous Air Pollutants under the Clean Air Act.

[4] EPA made an "Endangerment Finding," concluding that greenhouse gas emissions constitute a threat to public health and welfare, in December 2009. Shortly before issuing the Endangerment Finding, EPA promulgated the "Mandatory Greenhouse Gas Reporting Rule" (October 2009). In May 2010, EPA and DOT (Department of Transportation) issued Greenhouse Gas (GHG) and CAFE (Corporate Average Fuel Economy) Standards for new light-duty vehicles and engines for Model Years 2012-2016. In June 2010, EPA promulgated the "Tailoring Rule," establishing permitting thresholds for "major sources" of GHG emissions. Since that time, EPA and DOT have established standards for medium and heavy duty engines and vehicles (September 2011), EPA proposed NSPS (New Source Performance Standards) for GHG emissions from new power plants (April 2012), and EPA and DOT extended the GHG and CAFE standards for passenger vehicles to cover MY 2017-2025 (October 2012).

[5] This report, *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Years 2000 and 2005* (DNR AQEI 12-09), December 2009, can be accessed on the Division's website: http://www.huntsvilleal.gov/NatRes/Madison_County_AL_GHG_Inventory.pdf

The greenhouse gases addressed in EPA's emissions reporting rule, and subject to regulation under the Clean Air Act as a result of the "endangerment finding," [6] are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Anthropogenic emissions of carbon dioxide, primarily from combustion of fossil fuels, greatly exceed those of the remaining greenhouse gases and greenhouse gas emissions are typically expressed in terms of "carbon dioxide equivalent" (CO_2 Eq.). Methane is emitted from livestock, some agricultural practices and solid waste decomposition. Combustion processes produce nitrous oxide emissions, as does agricultural use of nitrogen fertilizers, and the flourine compounds are emitted from certain industrial processes, high voltage electricity transmission and distribution, and increasingly from their use as substitutes for ozone depleting compounds such as CFCs (Chlorofluorocarbons) and HCFCs (Hydrochlorofluorocarbons). Although the fluorine compounds have a high CO_2 Eq. value on a unit basis, they are emitted in far smaller quantities than carbon dioxide, methane and nitrous oxide, and comprise a small fraction of the total greenhouse gas emissions nationally, on a CO_2 Eq. basis.[7] For this reason, and because Huntsville does not have significant industrial sources of fluorine compound emissions, this inventory focuses on carbon dioxide, methane and nitrous oxide.

Since a large fraction of anthropogenic carbon dioxide emissions result from combustion of fossil fuels, it is not surprising that electrical power generation is the largest source of greenhouse gas emissions in the U.S., followed by transportation.[8] Industrial emissions, including combustion and process emissions, follow transportation in importance as greenhouse gas emissions sources in the U.S., with the agricultural, residential and commercial sectors of the economy being smaller, but still important sources.

There are important differences between the approach taken in developing a greenhouse gas emissions inventory for the Huntsville area and the approach the Division has historically employed in developing criteria pollutant and Hazardous Air Pollutant (HAP) inventories. The first involves the geographical scope of the inventory. Because criteria pollutant and HAP emissions have long been subject to regulation under the Clean Air Act, the geographical scope of the inventories coincides with jurisdictional lines. Since the Division's regulatory jurisdiction does not extend beyond the City limits, only those emissions occurring within the corporate limits of Huntsville are reflected in the Division's criteria pollutant and HAP inventories. However, it would be very difficult to quantify electrical consumption within the City limits because the service area of Huntsville Utilities, the local electricity provider, extends beyond the corporate limits of Huntsville and includes all of Madison County. Given the magnitude of greenhouse gas emissions associated with electrical power generation, the geographical scope

[6] Before EPA can regulate emissions under the Clean Air Act, they must first make a finding that those emissions are pervasive and pose a danger to human health or welfare. This is referred to as an "endangerment finding."

[7] EPA compiles a national greenhouse gas inventory and has established a web page summarizing the national inventory, both by the type of greenhouse gas (in CO_2 Eq.) and by emissions sources (in CO_2 Eq.). The web address is: http://www.epa.gov/climatechange/emissions/usgginventory.html

[8] See preceding footnote.

has therefore been expanded to encompass all of Madison County. Since the City of Huntsville does not currently include any industrial sources that are subject to permitting requirements due to their greenhouse gas emissions, there is no compelling reason to limit the geographical scope of the inventory to the City of Huntsville proper.[9]

The second key difference in the approach taken in developing the greenhouse gas emissions inventory is also related to electricity usage. In the criteria pollutant and HAP inventories, only those pollutants emitted directly by the various source categories are included. As noted above, the largest source of greenhouse gas emissions in the U.S. is electrical power generation, and it is important that these emissions be included in the inventory. However, although Huntsville Utilities distributes electricity in the Huntsville area, Huntsville Utilities does not generate electricity. Rather, they purchase electrical power from the Tennessee Valley Authority (TVA), and TVA doesn't have a power plant in Huntsville or Madison County. Consequently, the greenhouse gases associated with power generation occur outside the geographical area covered by the inventory. Nevertheless, they can be attributed to electricity consumption within the inventory area, and these indirect emissions are included in the greenhouse gas emissions inventory.

A third difference in the approach taken in developing the initial greenhouse gas emissions inventory involved an effort to quantify emissions associated with municipal operations. This established a baseline for the City as an entity and allows the Division to assess the effect on overall emissions resulting from energy conservation efforts by the City over time, as well as the countervailing impact of continued growth, both in area and in population. Consequently, the 2010 inventory quantifies energy usage and greenhouse gas emissions attributable to City of Huntsville municipal operations. The City of Huntsville, as a legal entity, is a municipal corporation organized under Alabama law. Huntsville is a Class 3 city with a Mayor-Council form of government.[10] Like most municipal governments in the United States, the City of Huntsville provides a number of services to its citizens. Among the host of services provided by the City of Huntsville are police and fire protection, sanitation, wastewater collection and treatment, passive and active recreation services, land use planning and regulation, inspection of building construction, roadway and drainage system construction and maintenance, parking and public transportation, and enforcement of ordinances adopted to protect public health and welfare, including nuisance abatement. Provision of these services requires a substantial workforce, maintenance of an array of public buildings and operation of a sizeable fleet of vehicles. Greenhouse gas emissions are associated with City electricity consumption,

[9] Under EPA's "Tailoring Rule," a new "major source" of greenhouse gas emissions is required to obtain a PSD (Prevention of Significant Deterioration) permit prior to commencing construction, and a "major source" of greenhouse gas (GHG) emissions is required to obtain an operating permit under Title V of the Clean Air Act. A "major source" of GHG emissions is defined as a source that emits or has the potential to emit 100,000 Tons per Year of GHGs on a CO_2 Eq. basis. There are currently no industrial major sources of GHG emissions in Huntsville. The landfill operated by the Solid Waste Disposal Authority (SWDA) is the only major source of GHG emissions within the Huntsville City limits.

[10] Title 11 ("Counties and Municipal Corporations") of the Code of Alabama, 1975, contains the statutory provisions governing the incorporation procedure, form of government for the various classes of cities in Alabama, and the powers, duties and authorities of Alabama municipalities. See § 11-40-1, *et. seq.* (ALA. CODE, 1975).

natural gas combustion for facility heating and gasoline and diesel fuels burned in vehicle fleet operation.

As noted previously, the county-wide greenhouse gas emissions inventory focuses on the principal greenhouse gases, i.e. carbon dioxide, methane and nitrous oxide, but does not include the fluorine compounds (perfluorocarbons, hydrofluorocarbons and sulfur hexafluoride). Omission of these compounds probably has a very small effect on the area-wide inventory expressed in carbon dioxide equivalent emissions. Of potentially greater consequence is the fact that the inventory does not attempt to quantify greenhouse gas emissions resulting from livestock and agricultural operations. Although Madison County has experienced significant population growth in recent decades and urbanization has proceeded relatively rapidly, agriculture remains a very important part of the local economy. In 2011 Madison County had the highest cotton production of any county in Alabama, and was second in the State in corn and soybean production.[11] Based on USDA (United States Department of Agriculture) estimates, Madison County had 20,500 head of cattle at the start of 2012 (1.7 % of the total in Alabama).

Another source of greenhouse gas emissions that is not included in the inventory is biomass combustion. Open burning of vegetative debris from land clearing activities, prescribed burning on Redstone Arsenal and agricultural burning are the principal biomass combustion sources in Madison County. Overall, biomass combustion is probably a relatively small contributor to the greenhouse gas emissions inventory in the Huntsville area, and these emissions would be more difficult to quantify with a reasonable level of accuracy than the larger combustion sources. Furthermore, emissions from biomass combustion are at least partially offset by carbon dioxide uptake in vegetative re-growth. Future inventories may be expanded to include these three emissions categories, i.e. fluorine compound emissions, agricultural emissions of methane and nitrous oxide, and biomass combustion.

[11] Based on data from the U.S. Department of Agriculture National Agricultural Statistics Service. 2011 production data for leading crops in Alabama can be found at the following web address: http://www.nass.usda.gov/Statistics_by_State/Alabama/Publications/County_Estimates/index.asp

Methodology & Results

Emissions from Electricity Consumption in Madison County

As noted previously, Huntsville Utilities distributes electrical power throughout Madison County, but does not operate any Electricity Generating Units. Rather, power is purchased from the Tennessee Valley Authority (TVA) for distribution to Huntsville Utilities customers. Since Huntsville Utilities is the sole electric power utility operating in Madison County, they are the only entity from which information on distributed power was needed. Huntsville Utilities currently categorizes electric accounts as industrial, commercial, and residential, whereas in prior years the large commercial accounts were categorized with the industrial customers. Total electricity sales by account type for the years 2000, 2005, and 2010, based on data provided by Huntsville Utilities, is shown in Table 1.

In order to translate the electricity consumption information into GHG emissions information, data on TVA net power generation and emissions were taken from EPA's eGRID

Table 1 – Electricity Consumption in Madison County in 2000, 2005, and 2010. (Based on data from Huntsville Utilities). Note that for years 2000 and 2005, the categories were "residential," "industrial and large commercial," and "small commercial." For 2010, the categories are "residential," "commercial," and "industrial."

Account Type	*Year 2000 (GWh)*	*Year 2005 (GWh)*	*Year 2010 (GWh)*
Industrial			561
Industrial & Lrg Commercial	2145	2323	
Small Commercial	282	341	
Commercial			2241
Residential	2012	2281	2735
TOTAL	4439	4945	5537

(Emissions & Generation Resources Integrated Database)[12] for the years 2000 and 2005. For 2010, TVA net generation and carbon dioxide emissions data were obtained from TVA,[13] whereas the e-GRID emission factors for the TVA PCA (Power Control Area) for 2009 were used for nitrous oxide and methane. Although use of these e-GRID emission factors for 2009 introduces some error, any such error is small because both methane and nitrous oxide are small contributors to total greenhouse gas emissions from power generation in terms of carbon dioxide equivalents. Thus, small changes in the TVA power mix from 2009 to 2010, and the resultant effect on methane and nitrous oxide emission factors, will have an inconsequential effect on the total GHG emissions estimate for power generation in 2010. The information on TVA power generation and greenhouse gas emissions is summarized in Table 2.

To convert the emissions of methane and nitrous oxide per gigawatt-hour to "carbon dioxide equivalent" emissions, the emission factor for each gas was multiplied by its GWP (Global Warming Potential), taken from the IPCC (Intergovernmental Panel on Climate Change) Second Assessment Report, as cited in the Fourth Assessment Report.[14] The GWP for nitrous oxide, based on a 100-year time horizon, is 310. For methane, the GWP = 21, again for a 100-year time horizon. Using these values for GWP, the carbon dioxide equivalent emission factor for TVA electricity generation in 2010 is calculated as follows:

$$(1179.6 \text{ lb/MWh} \div 2000 \text{ lb/ton} * 1000 \text{ MWh/GWh}) + (16.44 \text{ lb/GWh} * 310 \div 2000 \text{ lb/ton}) + (14.1 \text{ lb/GWh} * 21 \div 2000 \text{ lb/ton}) = 592.5 \text{ tons } CO_2 \text{ Eq./GWh in Year 2010}$$

[12] eGRID (Emissions & Generation Resource Integrated Database) contains comprehensive information on electric power generation and associated emissions of criteria pollutants and greenhouse gases in the United States. It includes detailed information at the plant and company levels, and summary data by State, by electric grid region, and by electric grid sub-region. The most recent version of eGRID contains data for 2004, 2005, 2007 and 2009. Data for 1996 through 2000 has been archived, but is still accessible using previous versions of eGRID. The eGRID web address is:
http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

[13] Provided in e-mail communications from Karen Utt, Tennessee Valley Authority, to Daniel Shea, Division of Natural Resources, dated October 12, 2012 and October 17, 2012.

[14] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007:The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. This report can be accessed at the following web address: http://www.ipcc.ch/index.htm

Note that the values for GWP utilized here, and included in the Fourth Assessment Report, are actually from the Second Assessment Report (denoted "SAR" in the Fourth Assessment Report). The use of the values from SAR facilitates evaluation of emission trends, and the continued use of these values for GWP is consistent with international convention, with the national greenhouse gas emissions inventories prepared by EPA for the United States, and with the EPA's Mandatory Greenhouse Gas Reporting Rule and "Tailoring" Rule for permitting greenhouse gases under the Clean Air Act.

The updated GWP values included in the Fourth Assessment Report are 25 for methane and 298 for nitrous oxide.

Table 2 – Net Power Generation and Greenhouse Gas Emissions Data for TVA in 2000, 2005, and 2010. (Taken from EPA's eGRID and TVA).

	2000	***2005***	***2010***
Net Power Generation(MWh)	153,393,767	158,320,339	146,835,592
CO_2 Emissions (Tons)	109,556,428	105,144,715	86,603,474
CO_2 Emissions (lb/MWh)	1,428.4	1328.3	1179.6
NO_x Emissions (Tons)	285,034.4	190,282.90	70,980
N_2O Emissions (Pounds)	--	3,570,316	--
N_2O Emissions (lb/GWh)	--	22.55	16.44
CH_4 Emissions (Pounds)	--	2,427,139	--
CH_4 Emissions (lb/GWh)	--	15.33	14.10

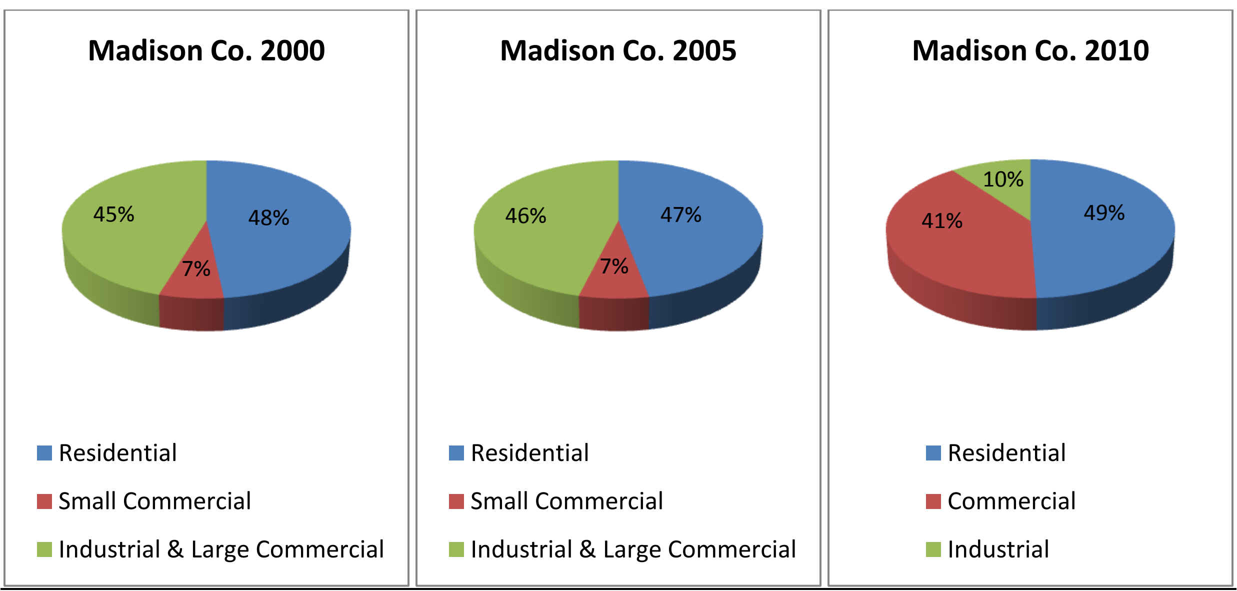
Note: For 2010, N_2O and CH_4 emission factors are taken from eGRID 2012 and are based on 2009 data. Power generation, CO_2 and NO_x emissions data were provided by TVA for 2010.

Finally, multiplying the electricity consumption for Madison County (see Table 1) by these emissions factors yields the greenhouse gas emissions from electricity use in 2010, expressed in terms of tons of carbon dioxide equivalent emissions. The results of these calculations are presented in Table 3. The values for years 2000 and 2005 are included for comparison. Figure 1 depicts the relative contribution to total emissions from electricity consumption by economic sector.

Table 3 – Madison County Greenhouse Gas Emissions (Tons CO_2 Eq.) from Electricity Consumption in 2000, 2005, and 2010 by Economic Sector. Note that large commercial users were grouped with the industrial facilities in 2000 and 2005, but not in 2010.

	2000	***2005***	***2010***
Industrial	1,543,971	1,551,299	332,197
Commercial	202,984	227,720	1,327,883
Residential	1,448,238	1,523,252	1,620,458
TOTAL	3,195,192	3,302,271	3,280,539

Figure 1 – Greenhouse Gas Emissions from Electricity Consumption by Economic Sector in Years 2000, 2005 and 2010 in Madison County.



Note: Huntsville Utilities categorized electricity sales as "residential," "small commercial," and "industrial and large commercial" in 2000 and 2005. In 2010, the categories were "residential," "commercial," and "industrial."

Emissions from Electricity Consumption by City of Huntsville Municipal Government

As mentioned in the Introduction, the City of Huntsville owns and operates a number of facilities to support provision of public services. These include office buildings, recreational facilities, wastewater treatment plants and pumping stations, police and fire stations, and equipment storage and maintenance facilities. The City's General Services Department is responsible for maintaining most of these facilities, including management of utility usage and payment of utility costs. However, the City's Water Pollution Control Department, which is funded entirely by charges for sewer use, is responsible for payment of utility billings for their wastewater treatment plants and pumping stations. Therefore, to obtain total electricity consumption by the City of Huntsville, billing history information was obtained from both the General Services Department and from Water Pollution Control. This information is shown in the following Table (Table 4).

Multiplication of the emission factors for electricity consumption developed in the preceding section by the usage data in Table 4 yields the greenhouse gas emissions associated with municipal electricity use, in terms of carbon dioxide equivalents, for 2010. Recall that this emission factor is 592.5 tons CO_2 Eq./GWh for 2010. This compares with factors of 719.8 tons CO_2 Eq./GWh in year 2000 and 667.8 tons CO_2 Eq./GWh in year 2005. Greenhouse gas emissions associated with electricity usage by the City of Huntsville are presented in Table 5.

Table 4 – Electricity Usage (GWh) by City of Huntsville Municipal Government in Years 2000, 2005, and 2010. (Data provided by the City of Huntsville General Services and Water Pollution Control Departments).

	2000	***2005***	***2010***
General Services	19.57	23.16	23.84
Water Pollution Control	15.52	16.62	15.19
TOTAL	35.08	39.77	39.03

Table 5 – Greenhouse Gas Emissions (Tons CO_2 Eq.) Associated with Electricity Usage by City of Huntsville Municipal Government in Years 2000, 2005, and 2010.

	2000	***2005***	***2010***
General Services	14,084	15,463	14,126
Water Pollution Control	11,169	11,096	8,999
TOTAL	25,253	26,559	23,125

Emissions from Natural Gas Combustion in Madison County

Determination of total electricity usage in Madison County is relatively straightforward because Huntsville Utilities is the only public utility that distributes electricity in Madison County. On-site electric power generation, e.g. by solar cells or use of emergency generators burning diesel fuel, is presently a tiny fraction of that provided by Huntsville Utilities and can be ignored with no perceptible effect on the accuracy of the greenhouse gas emission inventory. In contrast, quantification of the amount of natural gas combusted in Madison County is a bit more difficult. While the Huntsville Utilities Electric Department serves all of Madison County, the service area of the Gas Department includes the City of Huntsville, Redstone Arsenal, the City of New Hope, portions of unincorporated Madison County, and small areas of Limestone and Marshall Counties. The North Alabama Gas District provides natural gas to the City of Madison, portions of unincorporated Madison County, and areas in Colbert and Limestone Counties. Thus, neither of the two principal natural gas suppliers serves the entire County and the service area of each extends beyond the Madison County borders. However, for the year 2010, both Huntsville Utilities and North Alabama Gas were able to provide information on total natural gas sales in Madison County by account type, an improvement over prior inventory years.

In addition to the complication arising from natural gas providers whose service areas do not coincide with Madison County boundaries, there are several other difficulties inherent in efforts to quantify County-wide natural gas combustion emissions. First, large users of natural gas may opt to purchase natural gas from a supplier other than Huntsville Utilities, and pay Huntsville Utilities a "tariff," i.e. a gas transportation fee for delivering the gas through their distribution system. However, the volume of transported gas in Fiscal Year 2010 was obtained from the Annual Report for Huntsville Utilities.[15] This allowed an approximate correction for transported gas. Note that Huntsville Utilities' 2010 Fiscal Year covered the period October

[15] The Huntsville Utilities Annual Reports can be accessed at their website: www.hsvutil.org

2009 – September 2010, so the time frame does not coincide with the 2010 calendar year, but for large industrial users there was probably a relatively small difference in total usage from October – December 2009 and that from October – December 2010, so any associated error in greenhouse gas emission estimation is correspondingly small.

Other complications in estimating fuel use at stationary sources are less easily overcome. Many large natural gas users are on interruptible service, i.e. they are compelled to use an alternate fuel source when natural gas demand is very high and there is concern about the ability to meet residential demand. These users typically have on-site storage of a backup fuel, most commonly LPG (Liquefied Petroleum Gas)[16] or distillate fuel oil. Finally, some businesses and residents, particularly in more rural areas, use LPG as their main source of heat, utilizing on-site storage tanks to supply their furnaces and water heaters. There are a number of independent LPG suppliers in the area, with customers both inside and outside Madison County.

For purposes of greenhouse gas emissions inventory development, natural gas consumption is based on information provided by Huntsville Utilities and North Alabama Gas District. Huntsville Utilities provided total natural gas usage in Madison County by account type, i.e. industrial, commercial, and residential for the year 2010. Similarly, North Alabama Gas District was able to provide information on total gas sales in Madison County by account type, but the totals were designated as "residential" or "commercial" and did not include a separate industrial category. No attempt was made to quantify local propane sales and the portion of those sales to users in Madison County. The information on natural gas usage used in inventory development is summarized in Table 6.

To estimate greenhouse gas emissions resulting from natural gas combustion, an emission factor of 120.6 lb CO_2/1000 ft^3 was obtained from the Energy Information Administration, the agency within the U.S. Department of Energy responsible for compiling and reporting energy statistics.[17] Emission factors for methane (2.3 lb/1,000,000 scf) and for nitrous oxide (2.2 lb/1,000,000 scf) were taken from AP-42.[18] Note that AP-42 provides an emission factor of 120 lb CO_2/ 1000 scf, essentially the same as the factor from the EIA. Converting the nitrous oxide and methane emission factors to CO_2 Eq. using the GWP values discussed earlier yields

$$(2.2 \text{ lb}/10^6 \text{ ft}^3) \div (1000) * 310 = 0.68 \text{ lb } CO_2 \text{ Eq.}/1000 \text{ ft}^3 \text{ for } N_2O$$

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[16] Note that natural gas and LPG both consist primarily of simple alkanes: natural gas consists primarily of methane (CH_4), whereas LPG consists primarily of propane (C_3H_8) or butane (C_4H_{10}).

[17] The Energy Information Administration website has a table of carbon dioxide emission factors for various fuels, which can be accessed at: http://www.eia.doe.gov/oiaf/1605/coefficients.html
Details on the methodology used to develop these emission factors can be found in the document *"Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program";* Office of Policy and International Affairs, U.S. Department of Energy; January 2007. This document is available at the following web address: http://www.eia.doe.gov/oiaf/1605/January2007_1605bTechnicalGuidelines.pdf

[18] *Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Supplement D;* Office of Air Quality Planning and Standards, USEPA; July 1998. Table 1.4-2: "Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion." AP-42 can be accessed at the following web address: http://www.epa.gov/ttn/chief/ap42/index.html

and

$(2.3 \text{ lb}/10^6 \text{ ft}^3) \div (1000) * 21 = 0.05 \text{ lb } CO_2 \text{ Eq.}/1000 \text{ ft}^3$ for CH_4

Adding these values to the EIA CO_2 emission factor gives a CO_2 Eq. value of 121.3 lb CO_2 Eq./1000 ft^3 of natural gas combusted. The usage information in Table 6 was then multiplied by the CO_2 Eq. emission factor for natural gas combustion to obtain total greenhouse gas emissions from natural gas combustion. Table 7 shows the results of these calculations. Figure 2 depicts the relative contribution to total emissions from natural gas combustion by economic sector.

Table 6 – Madison County Natural Gas Combustion in Years 2000, 2005 and 2010, in Thousands of Standard Cubic Feet. (Based on information from Huntsville Utilities, and North Alabama Gas District).

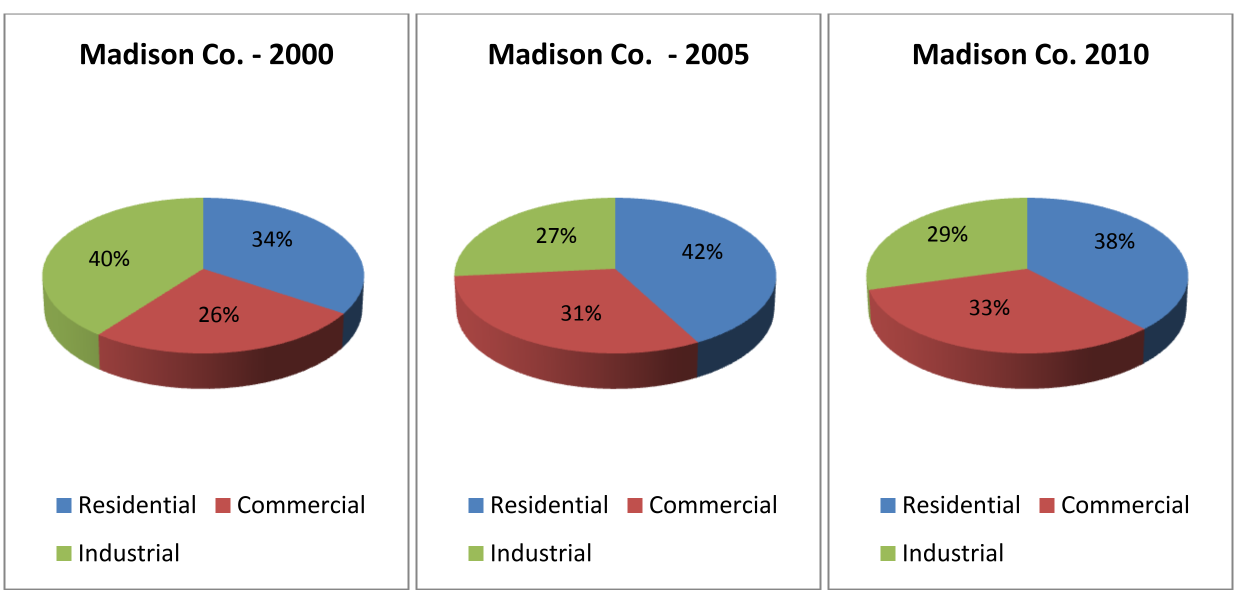
	2000	***2005***	***2010***
Huntsville Utilities			
Residential (1000 ft^3)	1,785,169	1,984,915	2,153,738
Commercial (1000 ft^3)	1,768,423	1,975,869	2,082,708
Industrial (1000 ft^3)	2,689,759	620,013	686,520
Transported Gas (1000 ft^3)		1,048,965	1,376,124
Adjusted Industrial (1000 ft^3)*	2,689,759	1,668,978	2,062,644
North Alabama Gas District	543,101 (2001)	668,822	
Residential (1000 ft^3)			518,722
Commercial			214,733
TOTAL (1000 ft^3)	6,786,452	6,298,584	7,032,545

* Adjusted Industrial Usage was obtained by adding the volume of transported natural gas in 2005 and 2010 to the natural gas sold to industrial users by Huntsville Utilities.

Table 7 – Madison County Greenhouse Gas Emissions (Tons CO_2 Eq.) from Natural Gas Combustion by Economic Sector in Years 2000, 2005 and 2010.

	2000	***2005***	***2010***
Huntsville Utilities			
Residential	108,271	120,385	130,657
Commercial	107,255	119,836	126,348
Industrial	163,134	101,224	125,131
North Alabama Gas District			
Residential	32,939	40,564	31,468
Commercial			13,027
TOTAL	411,598	382,009	426,630

Figure 2 – Madison County Greenhouse Gas Emissions from Natural Gas Consumption by Economic Sector in Years 2000, 2005 and 2010.



Emissions from Natural Gas Combustion by City of Huntsville Municipal Government

Total natural gas consumption for the year 2010 by the City of Huntsville municipal government was obtained from the City's General Services and Water Pollution Control Departments. In addition, an estimate of methane production from anaerobic digestion at the City's wastewater treatment plants was obtained from Water Pollution Control, along with a description of its disposition.[19] Since the digester gas is burned in industrial engines that drive the aeration basin blowers at the Vermont Road Treatment Plant, and any excess gas is burned in a flare, the methane is not emitted to the atmosphere. For this reason, the digester gas is treated as an additional volume of natural gas, after adjustment for the difference in the methane content of the digester gas relative to pipeline natural gas. Water Pollution Control estimates volume of digester gas produced as 24,000 ft^3/day, with a methane content of 65 % by volume. The equivalent volume of natural gas is thus:

$$(24{,}000\ ft^3/day)*(365\ days/year) * (0.65) = 5{,}694{,}000\ ft^3/year$$

Natural gas volumes combusted in municipal operations in 2010 are shown in Table 8. Usage in the years 2000 and 2005 are shown for comparison.

Using the emission factor of 121.3 lb CO_2 Eq./1000 ft^3 of natural gas combusted developed in the preceding section, the usage data in Table 8 can be converted to greenhouse gas emissions data. The results of these calculations are shown in Table 9.

Table 8 – Natural Gas and Wastewater Treatment Plant Digester Gas Volumes Combusted by the City of Huntsville Municipal Government in Years 2000, 2005 and 2010 (data from City of Huntsville General Services and Water Pollution Control Departments).

	2000	***2005***	***2010***
General Services Department (1000 ft^3)	65,327	53,280	71,980
Water Pollution Control Dept. (1000 ft^3)	39,190	15,103	22,972
Equivalent Volume of Digester Gas (1000 ft^3)	5,694	5,694	5,694
TOTAL (1000 ft^3)	110,211	74,077	100,646

[19] Anaerobic digestion is utilized as a unit operation at the City's Vermont Road Treatment Plant, the largest of Huntsville's wastewater treatment facilities. In anaerobic digestion, wastewater solids, predominantly primary sludge and waste activated sludge, receive additional treatment in the digester. Organic matter in the raw sludge is converted to simple organic acids as a result of bacterial digestion and anaerobic respiration, and the organic acids are in turn converted to methane and carbon dioxide by methanogenic bacteria. The other wastewater treatment plants operated by Water Pollution Control utilize aerobic digestion, which does not produce methane gas as a product of the treatment process.

Table 9 – Greenhouse Gas Emissions (Tons CO_2 Eq.) from Natural Gas and Digester Gas Combustion by the City of Huntsville Municipal Government in Years 2000, 2005 and 2010.

	2000	2005	2010
General Services Department	3,962	3,231	4,366
Water Pollution Control Dept	2,377	916	1,393
Digester Gas	345	345	345
TOTAL	6,684	4,493	6,104

Emissions from Industrial Coal and Petroleum Coke Combustion in Madison County

In Huntsville and Madison County, Alabama natural gas is the principal fuel used to provide industrial process heat. Distillate oil and Liquefied Petroleum Gas are used in far smaller quantities, primarily as a back-up fuel at facilities that have interruptible natural gas service. Coal is used by relatively few industrial facilities in this area. However, based on information in the Natural Resources criteria pollutant emissions inventory database, two facilities used coal or petroleum coke in the year 2000. One of these plants closed in 2003, and there was only one industrial facility in Huntsville using coal and petroleum coke in 2005 and in 2010. Emission factors for bituminous coal and petroleum coke were obtained from the Energy Information Administration.[20] For bituminous coal, the factor is 4,950 pounds CO_2/ton of coal burned, and for petroleum coke the factor is 6,767 lb CO_2/ton of coke burned. Methane and nitrous oxide emission factors for coal and petroleum coke combustion were also taken from values tabulated by the Energy Information Administration. These factors are 0.53 lb CH_4 and 0.08 lb N_2O per ton of coal burned, and 0.2 lb CH_4 and 0.04 lb N_2O per ton of petroleum coke burned. Multiplication by the GWP for these gases, as in preceding sections, yields an overall factor in terms of CO_2 Eq.

4,950 lb/ton + (0.53 lb/ton * 21) + (0.08 lb/ton * 310) = 4,986 lb CO_2 Eq./ton of coal

and

6,767 lb/ton + (0.2 lb/ton * 21) + (0.04 lb/ton * 310) = 6,783 lb CO_2 Eq./ton of coke

[20] See footnote 17.

Table 10 shows the quantities of coal and petroleum coke burned in 2000, 2005, and 2010 and the greenhouse gas emissions associated with combustion of these fuels.

Table 10 – Quantities of Coal and Petroleum Coke Combusted by Huntsville Industries and Associated Greenhouse Gas Emissions in Years 2000, 2005 and 2010.

	2000	***2005***	***2010***
Coal Burned (tons)	4262	830	689
Petroleum Coke Burned (tons)	1119	1023	1057
GHG Emissions from Coal (tons CO_2 Eq.)	10,538	2052	1718
GHG Emissions from Coke (tons CO_2 Eq.)	3795	3469	3584
TOTAL (tons CO_2 Eq.)	14,333	5521	5302

Emissions from Transportation Sources in Madison County

Transportation fuel combustion is the second largest source of greenhouse gas emissions in the United States, as noted in the introduction[21]. The principal fuels used in transportation are gasoline, diesel fuel, and aviation fuels (aviation gasoline and jet fuel), and combustion of these fuels produces the principal greenhouse gas emissions of CO_2, N_2O and CH_4. For most transportation sources, a fairly accurate estimate of carbon dioxide emissions can be obtained directly from the total volume of each type of fuel burned. Carbon dioxide is by far the predominant greenhouse gas emitted from transportation fuel combustion. In contrast, quantification of nitrous oxide and methane emissions from transportation sources is far more difficult because these emissions vary by vehicle type and model year. For aircraft emissions, airport fuel throughput is a poor measure of local greenhouse gas emissions because much of the fuel is burned at cruising altitude far from the originating airport. On the other hand, planes landing in Huntsville were fueled elsewhere and the emissions associated with landing are therefore not reflected in the fuel throughput at the local airports. Thus, the number of landings and takeoffs, coupled with information on aircraft type, provides the best estimate of aviation emissions in the Huntsville area.

This inventory includes most, but not all, of the greenhouse gas emissions associated with transportation fuel combustion. On-road mobile source emissions are included, as well as the

[21] Reference footnote 7.

emissions from non-road equipment operated by governmental entities. To the extent untaxed fuel is utilized by private companies for non-road equipment operation, the resulting emissions are not reflected in this inventory because information on the volume of untaxed fuel supplied to private companies was not readily available.[22] Aviation emissions are included in this inventory, but emissions from railroad locomotives, barges and pleasure boats are not. Although this inventory does include the vast majority of transportation related greenhouse gas emissions, future inventories could be improved by inclusion of these smaller emission source categories.

Greenhouse Gas Emissions from Gasoline and Diesel Fuel Combustion

Fuel consumption estimates for Madison County are based on fuel tax revenues, and fuel consumption data collected from tax exempt entities. This is an acceptable methodology for estimating fuel consumption within a geographical area[23]. Fuel tax revenue data for years 2010 was obtained from the Madison County Tax Assessor's office. Since, on-road motor vehicle fuel is taxed at the rate of $0.03 per gallon, motor vehicle fuel tax revenue can readily be translated to the total volume of taxed fuel sold in Madison County. In the year 2010, county fuel tax revenue was $5,141,813, which equates to fuel sales of 171,393,767 gallons.

Clearly, the volume of fuel determined from fuel tax revenue does not include transportation fuels that are not taxed. These include fuel used by governmental entities, which are tax exempt, as well as non-road fuels that are not subject to the tax. Although, quantification of untaxed fuel used by private companies in non-road equipment would be difficult, and was not attempted, information on the volume of fuels used was provided by several governmental entities, including the U.S. government motor pool on Redstone Arsenal, Madison County government, the City of Huntsville, Huntsville Utilities and the Madison County School system.[24] The fuel consumption values for 2000 and 2005 were obtained using the same methodology. This information is summarized in Table 11.

Although the untaxed fuel totals shown in Table 11 include the volume of diesel and the volume of gasoline used, the fuel volume derived from fuel tax revenue does not – both diesel fuel and gasoline are taxed at $0.03 per gallon. However, greenhouse gas emissions from combustion of diesel fuel differ from those resulting from burning gasoline, so it is necessary to

[22] Note that non-road mobile sources such as farm equipment and construction equipment are technically not transportation sources and are accounted for separately in the national inventory. In this local inventory all mobile source emissions are included in the transportation sector. Nationally, aircraft emissions exceed greenhouse gas emissions from these "non-transportation mobile sources" as well as those from ships and boats and those from rail (see Footnote 7).

[23] *Estimation of Mobile Source Fuel Consumption and Area VMT: EIIP (Emissions Inventory Improvement Program) Volume IV - Mobile Sources: Preferred and Alternative Methods*; Office of Air Quality Planning & Standards, USEPA; July 1997. This document can be accessed at the following web address: http://www.epa.gov/ttn/chief/eiip/techreport/

[24] Fuel consumption data was obtained from the City of Huntsville Fleet Management Division, Madison County – School Board Transportation, Huntsville Utilities – Fleet Services, and Redstone Arsenal – Environmental Management Division.

Table 11 – Transportation Fuel Throughput (gallons) in Madison County, Alabama in Years 2000, 2005 and 2010.

Year 2000	***Total Fuel***	***Gasoline***	***Diesel Fuel***
Taxed Fuel	142,033,333		
City of Huntsville		786,818	544,100
Madison County (2002)		450,660	403,884
Madison County Schools		27,902	154,079
Huntsville Utilities		209,323	205,567
Redstone Arsenal		2,385,088	124,142
Year 2005			
Taxed Fuel	156,927,700		
City of Huntsville		794,029	620,228
Madison County		438,281	476,228
Madison County Schools		33,370	310,607
Huntsville Utilities		213,620	240,020
Redstone Arsenal		3,448,717	168,263
Year 2010			
Taxed Fuel	171,393,767		
City of Huntsville		894,691	575,125
Madison County		440,538	482,617
Madison County Schools		24,646	337,685
Huntsville Utilities (2011)		236,467	277,592
Redstone Arsenal		4,269,560	177,436

determine the fraction of the total that consists of diesel, and the fraction that consists of gasoline.

In order to split the total fuel volume into volume of diesel fuel and volume of gasoline, 2010 vehicle registration data were obtained from the Madison County Tax Assessor's office. These data include information on the number of vehicles in each of several vehicle classes as well as the age distribution of the county-wide fleet. As alluded to in the Introduction, the Division of Natural Resources has been compiling criteria pollutant emissions inventories for many years. An important element of criteria pollutant inventory development is quantifying emissions from mobile sources, which in turn requires knowledge of the local vehicle fleet mix. Therefore, the supporting information used to develop historical criteria pollutant emissions inventories includes vehicle registration data, as well as mobile source emissions modeling results and a variety of characteristics of each vehicle class, including average fuel economy.[25]

Assuming that the vehicle miles travelled within Madison County is independent of vehicle type, i.e. a passenger car travels as many miles each year as a light duty truck or a heavy duty diesel vehicle, the total amount of fuel used by vehicles in each class is inversely proportional to the average fuel efficiency of vehicles in that class, and directly proportional to the total number of vehicles in that class. For each vehicle class, this relationship can be expressed as:

(Fraction of total fleet in the vehicle class, expressed as a decimal)*(Total VMT, in miles) ÷ (Average fuel efficiency of the vehicle class, in miles per gallon) = (Fuel used by vehicles in the vehicle class, in gallons)

For 2010, mobile source emission inventory documentation includes the total number of vehicles and the number of vehicles in each of eleven different vehicle classes, taken from Madison County vehicle registration data.[26] As was the case in previous mobile source emissions modeling efforts, some vehicle classes reported by Madison County had to be sub-divided to allocate those vehicles among the larger number of vehicle classes utilized by the MOVES (Motor Vehicle Emissions Simulator) model, e.g. Madison County doesn't distinguish between passenger and commercial light duty trucks, or short-haul and long-haul single-unit trucks. National data (MOVES defaults) were used to proportion the vehicles within a class when necessary to populate the MOVES vehicle classes. MOVES defaults were also utilized to proportion the vehicles as either diesel-fueled or gasoline-fueled within each vehicle class.[27] In order to allocate the VMT among vehicle classes, it is also necessary to know the average fuel efficiency of each vehicle class. This information was obtained for Year 2010 from the Federal Highway Administration Office of Policy Information.[28] The information on the Madison County Fleet composition is summarized in Table 12.

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[25] Reference footnote 1. The criteria pollutant emission inventory for the year 2010 is summarized in the 2012 Air Quality Report.

[26] There are 11 vehicle classes utilized by the currently approved mobile source emissions model (MOVES). They are: 1. Motorcycles, 2. Passenger cars, 3. Light-duty trucks (passenger), 4. Light-duty trucks (commercial), 5. Buses, 6. Refuse trucks, 7. Short-haul single-unit trucks, 8. Long-haul single-unit trucks, 9. Motor homes, 10. Short-haul semi-trucks, and 11. Long-haul semi-trucks. These vehicle classes differ from those utilized by the previous series of mobile source emissions models (MOBILE) which was used for inventory years prior to 2010.

[27] MOVES (Motor Vehicle Emissions Simulator) 2010b is the current version of the MOVES model and is the EPA vehicle emissions model currently used for regulatory purposes. The user can input as much information from local data sources as is available. The model uses national or regional default values when more specific local data is unavailable. Additional information on the MOVES model can be found at the following website: http://www.epa.gov/otaq/models/moves/index.htm

[28] FHWA OPI (Federal Highway Administration Office of Policy Information) is responsible for compiling an array of highway statistics about the vehicle fleet mix, vehicle miles travelled, road and bridge condition and fuel economy. The average fuel economy for each vehicle class was taken from their publication *Highway Statistics: 2010*, Section 5.3 – National Tables, Table VM-1 – Vehicle miles of travel and related data, by highway category and vehicle type. This publication can be accessed at the following web address: http://www.fhwa.dot.gov/policyinformation/statistics/2010/

Table 12 – Madison County Fleet Composition, by Vehicle Class, Fuel Type, and Average Fuel Efficiency in 2010.

Year 2010

Vehicle Class	***Fraction of Fleet***	***Fraction of Class Gasoline-Fueled***	***Fraction of Class Diesel-Fueled***	***Avg. Fuel Eff. Fleet (mpg)***
Motorcycles	0.0266	1	0	43.4
Passenger Cars	0.3748	0.9962	0.0038	23.3
Light-duty Trucks	0.4525	0.9768	0.0232	17.2
LD Trucks (Comm.)	0.1276	0.8947	0.1053	17.2
Buses	0.0002	0	1	7.2
Refuse Trucks	0.0022	0.04	0.96	7.3
S-Unit Trucks (SH)	0.0018	0.3	0.7	7.3
S-Unit Trucks (LH)	0.0002	0.3	0.7	7.3
Motor Homes	0.0020	0.5	0.5	7.3
Semi Trucks (SH)	0.0093	0	1	5.9
Semi Trucks (LH)	0.0029	0	1	5.9

Note that the equation on the preceding page is for each vehicle class. Thus there are eleven equations, each with two unknowns (Vehicles Miles Travelled), and (total fuel usage by vehicles in the class). For example, passenger cars constituted 37.48 % of the total on-road fleet in 2010 based on vehicle registration data, and the average fuel economy for this vehicle class was 23.3 miles per gallon. The equation for passenger cars is thus:

(0.3748)*(Total VMT) ÷ 23.3 mpg = (Fuel used by passenger cars)

This equation can be rewritten as:

(0.0161 gal/mile) * (Total VMT) = (Fuel used by passenger cars)

None of these individual equations are amenable to solution because each equation has two unknown quantities. However, if all eleven of these equations are summed, the resultant equation has only one unknown (Total VMT) since the total amount of fuel is known. Summing the values of (Fleet Fraction) * (VMT) ÷ (Fuel Efficiency) for each vehicle class for the year 2010 yields:

(0.05336 gallons/mile) * (Total VMT) = 179,110,124 gallons of fuel

Thus, Total VMT for year 2010 = 3,356,349,693 miles. This equates to an overall fuel efficiency of 18.74 miles/gal.

Each vehicle class was then allocated a fraction of total VMT based on the relative number of vehicles in that class. E.g. for the year 2010, 37.48 % of total VMT was attributed to passenger cars. For passenger cars, 99.62 % were gasoline-fueled and only 0.38 % were diesel-fueled. Therefore, the gasoline and diesel fuel used by passenger cars in 2010 are calculated as:

(0.3748)* (0.9962)*(3,356,348,693 miles) ÷ (23.3 mpg) = 53,784,533 gallons of gasoline

And

(0.3748)* (0.0038)*(3,356,348,693 miles) ÷ (23.3 mpg) = 205,161 gallons of diesel fuel

The results of these calculations for each vehicle class in year 2010 are presented in Table 13. As shown in the Table, summing the values for all vehicle classes yields total gasoline consumption of 165,126,981 gallons and total diesel consumption of 13,983,143 gallons.

Table 13 – Distribution of VMT (Vehicle Miles Travelled) and Fuel Consumption (gallons) by Vehicle Class in Madison County, Alabama in 2010.

Year 2010

Vehicle Class	*VMT (miles)*	*Gasoline Usage (gallons)*	*Diesel Fuel Usage. (gallons)*
Motorcycles	89,278,902	2,057,118	-0-
Passenger Cars	1,257,959,865	53,784,533	205,161
LD Trucks	1,518,412,601	86,231,711	2,048,091
LD Trucks (Comm.)	428,270,221	22,277,521	2,621,910
Buses	671,270	-0-	93,232
Refuse Trucks	7,383,970	40,460	971,043
S-Unit Trucks (SH)	6,041,430	248,278	579,315
S-Unit Trucks (LH)	671,270	27,586	64,368
Motor Homes	6,712,700	459,774	459,774
Semi Trucks (SH)	31,214,052	-0-	5,290,517
Semi Trucks (LH)	9,733,414	-0-	1,649,731
TOTALS	3,356,349,693	165,126,981	13,983,143

Note: Summing the columns may not yield the exact totals shown due to rounding.

CO_2 emission estimates for gasoline and diesel consumption can now be calculated by multiplying total gasoline usage and total diesel usage by the appropriate emissions factor published by the EIA (Energy Information Administration),[29] as shown below.

(gasoline) = 19.647 lbs/ gal x 165,126,981 gals ÷ 2000 lb/ton = 1,622,125 tons CO_2

(diesel) = 22.381 lbs/ gal x 13,983,143 gals ÷ 2000 lbs/ ton = 156,478 tons CO_2

As stated previously, mobile source emissions of N_2O and CH_4 are dependent on both the type of vehicle and the model year. EPA has published tables of weighted average emission factors for methane and nitrous oxide by vehicle class and model year.[30] Unlike the CO_2 emission factors for diesel-fueled and gasoline-fueled vehicles, which are expressed in terms of the amount of fuel consumed, the methane and nitrous oxide emission factors are based on miles of travel. In development of the greenhouse gas emission inventories for 2000 and 2005, average N_2O and CH_4 emission factors were calculated for each vehicle class using the age distribution of vehicles in that class taken from Madison County registration data. These factors were then multiplied by the VMT apportioned to each vehicle class using the methodology described above. Finally, summing the emissions for each vehicle class yielded the on-road mobile source emission estimates for methane and nitrous oxide in 2000 and 2005. Performance of these calculations was rather time-consuming and tedious, and is described in detail in the preceding greenhouse gas emissions inventory report.[31] Although essentially the same algorithm was used in deriving the 2010 on-road mobile source N_2O and CH_4 emission estimates, the calculations were performed within the MOVES model rather than by spreadsheets constructed by DNR for that purpose. This approach was preferred in 2010 for two reasons: 1.) the 2010 GHG emissions inventory coincides with a criteria pollutant inventory year, so mobile source modeling runs were necessary for preparation of that inventory, and 2.) EPA's current regulatory model for mobile source emissions (MOVES) includes N_2O and CH_4 emissions as output, whereas the previously utilized mobile source model (MOBILE 6.2) did not. The MOVES model output nitrous oxide and methane emissions estimates are summarized in Table 14. Additional details on model input, as well as sample output files are relegated to the Appendices.

Based on the input vehicle fleet composition and VMT, the MOVES2010 model yielded total on-road emissions of methane = 224 tons in 2010 (219.3 tons from gasoline combustion and 4.7 tons from diesel combustion) and total on-road nitrous oxide emissions = 35 tons in 2010 (34.9 tons from gasoline combustion and < 1 ton from diesel combustion). The 2010 on-road methane emission estimates calculated by the MOVES model are fairly similar to those

[29] Reference footnote 17. The emission factors are 19.647 lb CO_2/gallon gasoline and 22.381 lb CO_2/gallon diesel fuel. These differ slightly from the factors used in the previous GHG emissions inventory.

[30] *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Direct Emissions from Mobile Combustion Sources*; EPA430-K-08-004; USEPA Office of Air and Radiation; May 2008. Emission factors were taken from Tables 2 and 3. Factors for methane range from 0.0005 grams/mile to 0.4090 grams/mile, depending on vehicle class and model year. Factors for nitrous oxide range from 0.0010 grams/mile to 0.1726 grams/mile, depending on vehicle class and model year. Generally, factors are lowest for diesel-fueled passenger cars (LDDV) and highest for heavy duty gasoline vehicles (HDGV). This EPA document can be accessed at: http://www.epa.gov/climateleaders/documents/resources/mobilesource_guidance.pdf

[31] See footnote 5.

estimated by DNR for year 2000 and 2005 (255 tons and 196 tons, respectively), but the MOVES 2010 on-road nitrous oxide emissions estimates are dramatically lower than those determined by DNR for 2000 and 2005 (167 tons and 150 tons, respectively). This is attributed to the larger number of vehicles that met EPA's Tier 2 Tailpipe standards in 2010. The Tier 2 standards apply to Model Year 2004 and newer vehicles, and impose much more stringent limits for nitrogen oxides in vehicle exhaust.

Applying the Global Warming Potentials to the on-road mobile source emissions of methane and nitrous oxide in 2010 yields the following:

(224 tons CH_4) * (21) = 4,704 tons CO_2 Eq. for methane

And

(35 tons N_2O) * (310) = 10,850 tons CO_2 Eq. for nitrous oxide

Greenhouse gas emissions for on-road mobile sources in Madison County are summarized in Table 14.

Table 14 – Greenhouse Gas Emissions from Gasoline and Diesel Transportation Fuel Usage in Madison County, Alabama in Years 2000, 2005 and 2010. All values are in Tons Per Year.

	2000	***2005***	***2010***
CO_2	1,458,386	1,617,570	1,778,603
CH_4	255	196	224
N_2O	167	150	35
TOTAL (CO_2 Eq.)	1,515,509	1,668,532	1,794,281

Greenhouse Gas Emissions from Aviation in Madison County

Nationally, aviation is the second largest source of greenhouse gas emissions within the transportation sector.[32] The Huntsville International Airport is the largest of three area airports and the only airport providing commercial airline service. Although two smaller airports are located within Madison County (i.e. one at Redstone Arsenal and the other located northeast of Huntsville in Meridianville), emission estimates for these facilities are not included in this Report.

Aviation emissions depend on a variety of factors, including the type of fuel used, type of aircraft, engine type, engine load and flying altitude.[33] As noted previously, emission estimates can be based on aviation landing and take-off operations (LTOs)[34] which occur near the airport at altitudes of less than 3000 feet. LTO data was obtained from the Huntsville International Airport for the year 2010. The emission estimates are made by multiplying the LTO data by default emissions factors for each greenhouse gas, developed by averaging emissions from a number of different aircraft that purportedly represent a typical civil aviation passenger aircraft fleet [35]. The emission factors are 2680 kg (5908 lb) per LTO cycle for CO_2, 0.3 kg (0.66 lb)/ LTO cycle for CH_4 and 0.1 kg (0.22 lb) /LTO cycle for N_2O. To convert the emissions of methane and nitrous oxide per LTO cycle to CO_2 Eq. emissions, the emission total for each gas was multiplied by its GWP. These calculations are shown below, and the CO_2 Eq. emissions estimates from aviation operations are summarized in Table 15.

Year 2010:

(40,922 LTO) * (5908 lb/LTO) ÷ (2000 lb/ton) = 120,884 tons CO_2
(40,922 LTO) * (0.66 lb/LTO) ÷ (2000 lb/ton) = 13.5 tons CH_4 = 284 tons CO_2 Eq.
(40,922 LTO) * (0.22 lb/LTO) ÷ (2000 lb/ton) = 4.5 tons N_2O= 1395 tons CO_2 Eq.

Figure 3 shows the contributions of gasoline, diesel and aviation fuel combustion to total transportation emissions in Madison County.

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[32] See Footnote 7.

[33] *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories Background Paper: Aircraft Emissions;* Intergovernmental Panel on Climate Change; 2000. This document can be accessed at the following website: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_5_Aircraft.pdf

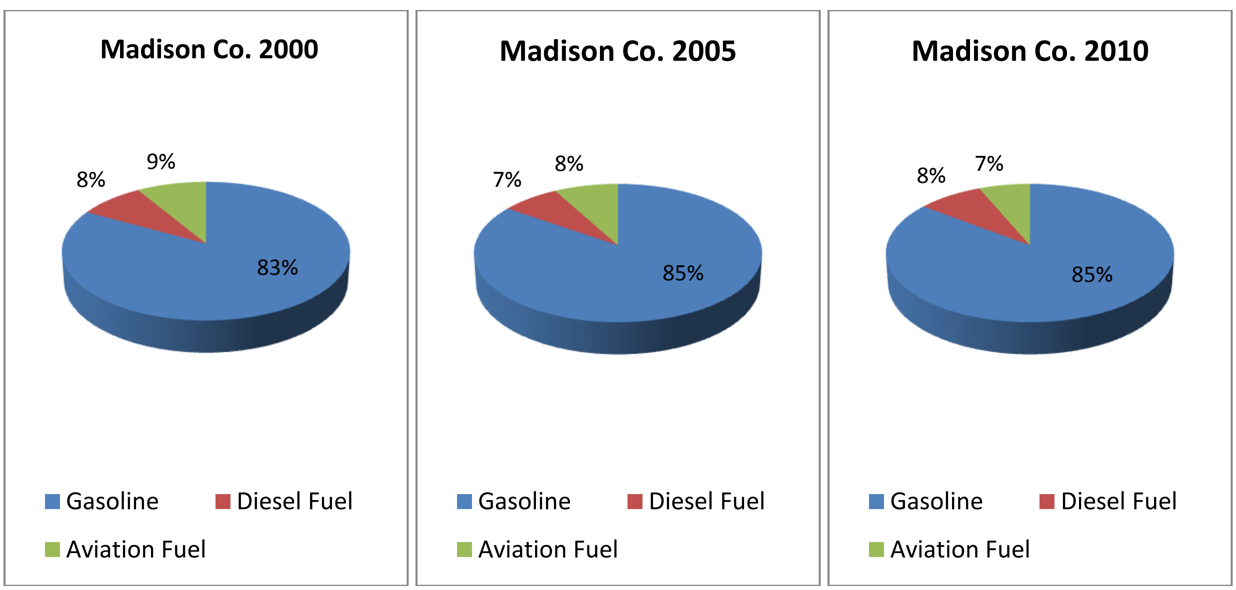
[34] Landing/ Take-Off operations (e.g. taxi-in, take-off, climb-out, and approach landing. These operations occur below an altitude of 3000 feet.)

[35] Reference Footnote 33 (Table 2; p 97)

Table 15 – Madison County Greenhouse Gas Emissions (Tons) from Aviation in Years 2000, 2005 and 2010.

	2000	***2005***	***2010***
LTO Cycles	48,250	48,729	40,922
CO_2	142,531	143,945	120,884
CH_4	16	16	14
CH_4 (CO_2 Eq.)	334	338	284
N_2O	5	5	5
N_2O (CO_2 Eq.)	1,643	1,674	1,395
Total GHG Emissions (CO_2Eq.)	144,508	145,957	122,563

Figure 3 – Greenhouse Gas Emissions from Gasoline, Diesel and Aviation Transportation Fuel Combustion in Years 2000, 2005 and 2010.



Emissions from Transportation Fuel Consumption by City of Huntsville Municipal Government

Fuel usage data by the City of Huntsville fleet in 2010 was provided by the Fleet Management Division of the City, and is included in Table 11. Since carbon dioxide emission estimates are based on gasoline and diesel usage, calculation of these emissions is straightforward.

For Year 2010:

(gasoline) = 19.647 lbs/gal x 894,691 gal ÷ 2000 lb/ton = 8789 tons CO_2

(diesel) = 22.381 lbs/gal x 575,125 gal ÷ 2000 lbs/ ton = 6436 tons CO_2

Estimation of nitrous oxide and methane emissions from the City of Huntsville mobile source fleet was done by assigning proportional shares of the MOVES model calculated emissions based on VMT. VMT was in turn calculated from total gasoline and diesel usage, Madison County vehicle registration data, and average fuel economy by vehicle type. This approach is essentially the same as that employed in allocating County-wide VMT, but for the City fleet, gasoline vehicles and diesel vehicles were treated separately since City usage of each type of fuel was known. Inherent in this approach are two key assumptions. First, the distribution of vehicle types in the City fleet mirrors the Madison County registration data with a few obvious exceptions (e.g. the City fleet includes no tractor-trailer trucks). Second, VMT is proportional to the number of vehicles in each vehicle class, i.e. each passenger car travels as many miles as a light duty truck and each bus travels as many miles as a refuse vehicle. Thus, the fuel consumed by each vehicle type is directly proportional to VMT and inversely proportional to fuel economy. Based on these considerations, the approximate composition of the City fleet in 2010, by vehicle type and fuel type, is as summarized in Table 16.

Recall that for each vehicle class, the volume of fuel consumed is expressed in the following equation:

(Fraction of total fleet in the vehicle class, expressed as a decimal)*(Total VMT, in miles) ÷ (Average fuel efficiency of the vehicle class, in miles per gallon) = (Fuel used by vehicles in the vehicle class, in gallons)

Also recall that for each vehicle class, the above equation has two unknowns, but if the equations are summed, the only unknown is total VMT since the total amount of fuel is known. Summing these equations for the gasoline-fueled vehicles and the diesel-fueled vehicles in the City fleet yields the following two equations.

(Gasoline VMT) ÷ 20.24 mpg = 894,691 gal. gasoline. Thus, Gasoline VMT = 17,414,825 miles

And

(Diesel VMT) ÷ 7.295 mpg = 575,125 gal. diesel. Thus, Diesel VMT = 4,195, 638 miles

Now, proportioning total methane and nitrous oxide emissions from the MOVES model runs to the City fleet based on VMT yields the following:

For Methane

(17,414,825 miles ÷ 3,214,482,833 miles) * 219.3 tons CH_4 = City gasoline fleet CH_4

City gasoline fleet CH_4 = 1.19 tons = 24.95 tons CO_2 Eq.

And

(4,195,638 miles ÷ 141,866,860 miles) * 4.7 tons CH_4 = City diesel fleet CH_4

City diesel fleet CH_4 = 0.14 tons = 2.92 tons CO_2 Eq.

Table 16 – City of Huntsville Municipal Fleet Composition, by Vehicle Class, Type of Fuel, and Average Fuel Efficiency in Year 2010

		Year 2010	
Vehicle Class	***Fraction of Gasoline Fleet***	***Fraction of Diesel Fleet***	***Avg. Fuel Eff. (mpg)***
Motorcycles	0.0271	-0-	43.4
Passenger Cars	0.3819	-0-	23.3
Light-duty Trucks	0.4610	-0-	17.2
LD Trucks (Comm.)	0.1300	-0-	17.2
Buses	-0-	0.0476	7.2
Refuse Trucks	-0-	0.5238	7.3
S-Unit Trucks (SH)	-0-	0.4286	7.3
S-Unit Trucks (LH)	-0-	-0-	7.3
Motor Homes	-0-	-0-	7.3
Semi Trucks (SH)	-0-	-0-	5.9
Semi Trucks (LH)	-0-	-0-	5.9

For Nitrous Oxide

(17,414,825 miles ÷ 3,214,482,833 miles) * 34.9 tons N_2O = City gasoline fleet N_2O

City gasoline fleet N_2O = 0.19 tons = 58.6 tons CO_2 Eq.

And

(4,195,638 miles ÷ 141,866,860 miles) * 0.5 tons N_2O = City diesel fleet N_2O

City diesel fleet N_2O = 0.015 tons = 4.6 tons CO_2 Eq.

Transportation-related greenhouse gas emissions from City of Huntsville municipal operations are summarized in Table 17.

Table 17 – Greenhouse Gas Emissions From City of Huntsville Municipal Fleet Operations in Years 2000, 2005 and 2010. All values are in Tons Per Year.

	2000	***2005***	***2010***
CO_2	13,787	14,709	15,225
CH_4	1.5	1.3	1.2
N_2O	< 1	< 1	< 1
TOTAL (CO_2 Eq.)	14,125	14,986	15,316

Emissions from Solid Waste Management in Madison County

The City of Huntsville established the Solid Waste Disposal Authority (SWDA) of the City of Huntsville, a non-profit public corporation,[36] to oversee development and implementation of a comprehensive solid waste management system for the City of Huntsville and Madison County. The solid waste management system includes the operation of a waste-to-energy facility and municipal solid waste landfill, a curbside collection recycling program and household hazardous waste management program.

Greenhouse gas emissions include CO_2 from the combustion of waste at the waste-to-energy (WTE) facility and methane emissions associated with decomposition of the municipal solid waste in the landfill. The WTE facility includes two mass burn waterwall units with a combined capacity of 690 tons per day. Heat released from the combustion of solid waste is

[36] Statutory provisions governing solid waste disposal authorities in Alabama are codified in Chapter 89A of Title 11 of the Code of Alabama, § 11-89A-1, *et. seq.* (ALA CODE, 1975).

recovered in water-filled tubes in the furnace walls to produce steam. The steam is then piped to Redstone Arsenal for use in heating and air conditioning systems as well as other steam-driven equipment on the installation. Note that carbon dioxide released from combustion of municipal solid waste in the WTE facility is partially offset by the uptake of CO_2 by re-growing biomass, e.g. by trees harvested for paper production. Using the accounting convention developed by the Intergovernmental Panel on Climate Change, these so-called "biogenic carbon" emissions should be accounted for separately in greenhouse gas emission inventories because they are part of the natural carbon cycle and do not contribute to increases in atmospheric carbon dioxide concentrations.[37] On the other hand, municipal waste also contains "non-biogenic carbon," primarily in plastics that should be included. National default values for the percentage of biogenic and non-biogenic carbon are 65 % and 35 %, respectively.[38] Since the WTE facility also combusts the wastewater treatment sludge from the City of Huntsville treatment plants, one might expect the biogenic carbon fraction to be higher in the WTE solid waste feed than the national default value. (Surprisingly, the reported biogenic CO_2 emissions for the steam plant in 2010 are actually lower than this default percentage, constituting roughly 56 % of the total). The national default was used to separate biogenic and non-biogenic emissions in previous inventory years, i.e. for the years 2000 and 2005, but because the waste-to-energy facility is now subject to EPA's mandatory greenhouse gas reporting rule,[39] reported values for methane, nitrous oxide, biogenic carbon dioxide and non-biogenic carbon dioxide are utilized in the 2010 GHG inventory. Note that the energy recovery at the WTE plant is indirectly reflected in the inventory because use of the steam by Redstone Arsenal has greatly reduced the amount of natural gas burned on the installation for steam production.

Greenhouse Gas Emissions from the Waste to Energy Facility in Madison County

For the previous GHG inventories prepared for Years 2000 and 2005, DNR used waste throughput data provided by the SWDA and emission factors from AP-42 (see Footnote 18) to estimate GHG emissions from the WTE facility. However, this wasn't necessary in 2010 since this facility is subject to the Mandatory Greenhouse Gas Reporting Rule. For 2010, emissions from the facility were taken from the annual report submitted by the SWDA pursuant to these reporting requirements.[40]

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[37] Intergovernmental Panel on Climate Change. *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3, Pg. 6.28, (Paris France 1997).

[38] *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emission Inventories: Version 1.0;* CARB (California Air Resources Board), California Climate Action Registry, ICLEI (Local Governments for Sustainability), and The Climate Registry; September 2008.

[39] On October 30, 2009, EPA promulgated the Mandatory Greenhouse Gas Reporting Rule, which requires facilities with GHG emissions of 25,000 metric tons or more to report those emissions annually, beginning with emissions in 2010. The GHG reporting regulations are codified in 40 CFR Part 98.

[40] Greenhouse gas emissions from fixed facilities subject to the Mandatory Greenhouse Gas Reporting Rule are available on-line at http://www.epa.gov/ghgreporting/

Reported greenhouse gas emissions for the WTE in 2010 are 127,510 tons biogenic CO_2, 99,083 tons non-biogenic CO_2, 77.3 tons CH_4 (1,623 tons CO_2 Eq.), and 9.9 tons N_2O (3080 tons CO_2 Eq.). Total GHG emissions from the facility were 231,296 tons CO_2 Eq. However, since the biogenic CO_2 emissions are viewed as part of the natural carbon cycle, the total steam plant GHG emissions for inventory purposes are 103,786 tons CO_2 Eq., the total excluding the biogenic CO_2 emissions.

Greenhouse Gas Emissions from the Huntsville Municipal Solid Waste Landfill

Methane gas is produced by the anaerobic decomposition of organic matter in municipal solid waste. The landfill operated by the SWDA is the only municipal solid waste landfill (MSWLF) in Madison County which is permitted to accept putrescible waste. The SWDA MSWLF includes both active and closed areas that generate methane gas from anaerobic decomposition. (Note that anaerobic decomposition of compacted municipal waste proceeds slowly over time in a MSWLF). According to information provided by the SWDA, the landfill includes an area of 75 acres that was opened in the mid 1940's and closed in 1989, a second area of 61 acres that closed in 1993 and an active area of roughly 24 acres in which municipal solid waste, industrial waste and ash from the WTE facility is deposited. Each of these areas produce methane gas, whereas the portion of the landfill dedicated to bulk trash, construction and demolition debris and other non-putrescible waste does not produce appreciable amounts of methane.

For previous GHG inventory years (2000 and 2005), emissions estimates for the landfill were obtained from landfill gas generation rates and methane content taken from the five-year reports submitted pursuant to applicable air pollution control regulations.[41] Mass emissions of methane were then calculated from these volumetric data using the ideal gas law and molecular weight of methane.[42] For 2010, these calculations were not necessary because the MSWLF is now subject to the Mandatory Greenhouse Gas Reporting Rule. Consequently, methane emissions were taken from the report submitted by the SWDA pursuant to these reporting requirements.[43]

In 2010, reported methane emissions from the landfill were 7,050 tons (148,060 tons CO_2 Eq.). Note that the methane emissions reported for 2010 are based on the estimation protocol prescribed by the Mandatory Greenhouse Gas Reporting Rule, which yields lower estimates than

[41] *City of Huntsville Air Pollution Control Rules and Regulations; Chapter 18 – Control of Municipal Solid Waste Landfill Gas Emissions*; *September 8, 2011.*

[42] The ideal gas law describes the relationship between the temperature, pressure and volume of an ideal gas and is expressed mathematically as: PV = n RT, where P = pressure, V = volume, n = number of moles of gas, R = the universal gas constant and T = absolute temperature. With pressure measured in atmospheres, volume measured in cubic feet, absolute temperature measured in degrees Rankine, and n expressed in pound moles, the value of the universal gas constant is $0.7302\ atm\bullet ft^3\bullet lb\text{-}mol^{-1}\bullet R^{-1}$. There are 16 pounds of methane per lb mol.

[43] See Footnote 40.

those that result from use of the algorithm prescribed in the Air Pollution Control Rules and Regulations.

GHG emissions from solid waste management in Madison County are summarized in Table 18.

Table 18 – Greenhouse Gas Emissions (Tons) from Solid Waste Disposal in Madison County in Years 2000, 2005 and 2010.

	2000	2005	2010
Waste-to-Energy Facility			
Biogenic CO_2	132,250	140,749	127,510
Non-biogenic CO_2	71,212	75,788	99,083
CH_4			77
CH_4 (CO_2 Eq.)			1,623
N_2O			10
N_2O (CO_2 Eq.)			3,080
Municipal Solid Waste Landfill			
CH_4	11,700	11,411	7,050
CH_4 (CO_2 Eq.)	245,702	239,624	148,060
TOTAL (CO_2 Eq.)	449,164	456,161	379,356
TOTAL (Excluding Biogenic CO_2)	316,914	315,412	251,846

Comparison of Inventory Results with CACP Software Output

A number of communities have utilized the Clean Air Climate Protection (CACP) software to develop greenhouse gas emissions inventories. Natural Resources used the CACP software to provide a comparative check of the emission estimates made using the methodologies discussed in the report. Version 1.1 (released in 2005) was used by Natural Resources in preparation of the initial GHG Emissions Inventory Report, whereas CACP -2009 Version 3.0 was used for the present report covering the year 2010.[44] The CACP software estimates community wide GHG emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O), reported as total CO_2 Eq. for five community sectors: residential, commercial, industrial, transportation, and waste disposal. The scope of the CACP inventory is very similar to the scope of the inventory developed by Natural Resources, both in terms of the pollutants included, which are the same, and the sources included, which are very similar. Although the CACP software does include a solid waste disposal emission estimation module, it does not have sufficient flexibility to accommodate the combination of waste disposal methods utilized in Madison County. Consequently, CACP software estimates of emissions from solid waste disposal are not included in this comparison.

CACP software inputs consisted of the raw data gathered by Natural Resources for use in preparation of the greenhouse gas emissions inventory. These include electricity consumption by sector, i.e. residential, commercial and industrial, natural gas usage by sector, coal usage by industrial sources, and volume of transportation fuels consumed by each vehicle class. The CACP software outputs are shown in Table 19, along with the results of local inventory development and percent differences between the two methodologies.

A significant change in the CACP-2009 software relative to the earlier version is the requirement to input emission factors for electricity usage whereas the previous version used regional factors. Thus, for Madison County in years 2000 and 2005, average factors for Region 9 of the national electrical grid, i.e. the Southeast Electric Reliability Council[45] were applied by the CACP v1.1 software. This Region covers much of the southeastern U. S. and the factor therefore reflects average emissions across this area. Consequently, the factor based on TVA data is more accurate for Madison County since TVA provides the power purchased by Huntsville Utilities. Therefore, these were the factors input to the CACP-2009 software. As a result, since Natural Resources was inputting both the electricity usage data and the emission factors, the CACP-2009 software was providing nothing more than an arithmetic check. The small differences in the tabulated comparison between the DNR and CACP results in Table 19

[44] Version 1.1 of the CACP software was developed by Torrie Smith Associates in collaboration with the International Council for Local Environmental Initiatives (ICLEI), State and Territorial Air Pollution Control Program Administrators (STAPPA) and Local Air Pollution Control Officials (ALAPCO). Development of the software was supported by the Environmental Protection Agency (EPA) and made available to STAPPA and ALAPCO affiliated agencies for use in developing greenhouse gas emission inventories. Since development of version 1.1, a new version of the software was released in 2009. Natural Resources used CACP Version 1.1 for comparison with the Year 2000 and 2005 GHG Emissions Inventory results, and utilized the newer version, CACP-2009 Version 3.0 for comparison with the 2010 GHG Emissions Inventory results.

[45] The U. S. electrical grid is subdivided into 13 North American Electricity Reliability Council (NERC) regions. Alabama is located in region 09 known as the Southeast Electricity Reliability Council (SERC).

are thus solely due to the number of decimal places used in the input data and any differences in rounding convention.

A minor difference in methodology is related to stationary source fuel combustion. The Natural Resources inventory accounts for industrial coke combustion emissions, whereas the CACP software does not include petroleum coke as a fuel. However, because industry in Huntsville utilizes such a small amount of coke, this difference is inconsequential. There are also differences in the emission factors utilized for natural gas combustion. The factors for CO_2 are almost identical, but the CACP software is using a much lower factor for nitrous oxide than the factor utilized by DNR from AP-42, whereas the CACP factor for methane is much higher than the factor from AP-42. The net effect of these differences is a slightly higher total for fuel combustion in the DNR inventory (+ 1.1 %).

With respect to on-road transportation emissions, input to the CACP software consisted of gasoline and diesel fuel usage by each of three vehicle classes – light duty, medium duty and heavy duty. The CO_2 emissions estimates produced by the CACP software agree closely with the DNR results, but the CACP nitrous oxide emissions estimates were much higher than those produced by the MOVES model utilized by DNR and the CACP methane emission estimates were much lower than the MOVES estimates. Overall, the DNR results for on-road GHG emissions were 1.3 % higher than the CACP estimate. The difference in aviation estimates is far greater. DNR utilized the number of LTO's (Landing and Take-off Operations) to estimate emissions whereas the CACP input was the volume of aviation gasoline and jet-fuel dispensed. The CACP approach yielded much higher estimates - roughly 61 % higher than those obtained by DNR. However, since aviation is a small contributor to the transportation emissions inventory relative to on-road sources, the total transportation emission estimates showed good agreement, with the CACP estimates being 3.7 % higher than the DNR results.

The combined totals for the electricity, fuel combustion and transportation sectors agreed very well, with the CACP software providing a total of 5.64 million tons CO_2 Eq. as opposed to the DNR total of 5.59 million tons CO_2 Eq., a difference of 1.2 %.

Table 19 – Comparison of Division of Natural Resources (DNR) Madison County, Alabama Greenhouse Gas Emissions Inventory Results with CACP Software Outputs for Year 2010.

Sector		GHG	DNR	CACP	% Difference
Electricity					
	Residential	CO_2	1,613,084	1,613,103	< 0.1
		N_2O	22	22	< 0.1
		CH4	19	19	< 0.1
		Total (CO_2 Eq.)	***1,620,458***	***1,620,457***	***< 0.1***
	Commercial	CO_2	1,321,841	1,321,742	< 0.1
		N_2O	18	18	< 0.1
		CH4	16	16	< 0.1
		Total (CO_2 Eq.)	***1,327,883***	***1,327,768***	***< 0.1***
	Industrial	CO_2	330,685	330,878	< 0.1
		N_2O	5	5	< 0.1
		CH4	4	4	< 0.1
		Total (CO_2 Eq.)	***332,197***	***332,386***	***< 0.1***
Fuel Combustion					
	Residential	CO_2	161,149	160,564	0.4
		N_2O	3	0.3	89.7
		CH4	3	15	- 388
		Total (CO_2 Eq.)	***162,125***	***160,976***	***0.7***
	Commercial	CO_2	138,536	138,033	0.4
		N_2O	3	0.3	89.6
		CH4	3	13	- 401
		Total (CO_2 Eq.)	***139,375***	***138,387***	***0.7***
	Industrial	CO_2	129,659	127,848	1.4
		N_2O	2	0.3	87.2
		CH4	2	2	- 5.3
		Total (CO_2 Eq.)	***130,432***	***127,999***	***1.9***

Table 19 (Continued) – Comparison of Division of Natural Resources (DNR) Madison County, Alabama Greenhouse Gas Emissions Inventory Results with CACP Software Outputs for Year 2010.

Transportation

Gasoline	CO_2	1,622,125	1,598,147	1.5
	N_2O	35	108	- 210
	CH4	219	87	60.5
	Total (CO_2 Eq.)	***1,637,549***	***1,633,500***	***0.2***
Diesel	CO_2	156,478	157,375	- 0.6
	N_2O	0.5	0.5	10.0
	CH4	5	0.4	91.6
	Total (CO_2 Eq.)	***156,732***	***157,523***	***- 0.5***
Aviation	CO_2	120,884	197,288	- 63.2
	N_2O	5	0	100
	CH4	14	0	100
	Total (CO_2 Eq.)	***122,563***	***197,288***	***- 61.0***
Grand Total	***(CO_2 Eq.)***	***5,629,314***	***5,696,284***	***- 1.2***

Analysis and Discussion of Inventory Results – Madison County

The results of greenhouse gas emissions inventory development for Madison County are summarized in Table 20.

Table 20 – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005 and 2010.

	2000	***2005***	***2010***
Electricity Usage			
CO_2	3,170,334	3,284,222	3,265,610
CH_4 (CO_2 Eq.)	888	791	820
N_2O (CO_2 Eq.)	23,970	17,258	14,109
TOTAL (CO_2 Eq.)	3,195,192	3,302,271	3,280,539
Stationary Fuel Combustion			
Natural Gas			
CO_2	409,223	379,805	424,062
CH_4 (CO_2 Eq.)	169	157	170
N_2O (CO_2 Eq.)	2,206	2,047	2,398
TOTAL (CO_2 Eq.)	411,598	382,009	426,630
Coal and Coke			
CO_2	14,296	5,509	5,282
CH_4 (CO_2 Eq.)	4	1	5
N_2O (CO_2 Eq.)	33	11	15
TOTAL (CO_2 Eq.)	14,333	5,521	5,302
Totals for Stationary Fuel Combustion			
CO_2	423,519	385,314	429,344
CH_4 (CO_2 Eq.)	173	158	175
N_2O (CO_2 Eq.)	2,239	2,058	2,413
TOTAL (CO_2 Eq.)	425,931	387,530	431,932

Table 20 (Continued) – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005 and 2010.

	2000	***2005***	***2010***
Transportation Fuels			
Gasoline			
CO_2	1,321,431	1,486,280	1,622,125
CH_4 (CO_2 Eq.)	5,357	4,126	4,605
N_2O (CO_2 Eq.)	51,633	46,654	10,819
TOTAL (CO_2 Eq.)	1,378,421	1,537,060	1,637,549
Diesel Fuel			
CO_2	136,955	131,290	156,478
CH_4 (CO_2 Eq.)	9	12	99
N_2O (CO_2 Eq.)	124	169	155
TOTAL (CO_2 Eq.)	137,088	131,471	156,732
Aviation Fuels			
CO_2	142,531	143,945	120,884
CH_4 (CO_2 Eq.)	334	338	284
N_2O (CO_2 Eq.)	1,643	1,674	1,395
TOTAL (CO_2 Eq.)	144,508	145,957	122,563
Totals for Transportation Fuels			
CO_2	1,600,917	1,761,515	1,899,487
CH_4 (CO_2 Eq.)	5,700	4,476	4,988
N_2O (CO_2 Eq.)	53,400	48,497	12,369
TOTAL (CO_2 Eq.)	1,660,017	1,814,488	1,916,844

Table 20 (Continued) – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005 and 2010.

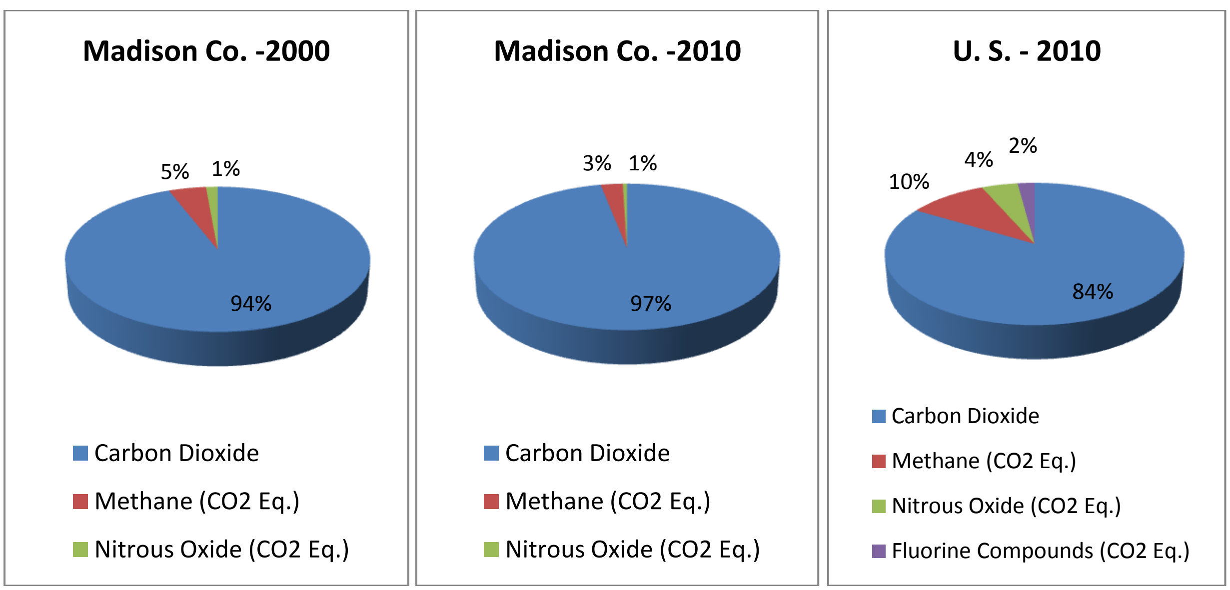
	2000	***2005***	***2010***
Solid Waste Management			
Municipal Waste Combustion			
"Biogenic" CO_2	132,250	140,749	127,510
"Non-biogenic" CO_2	71,212	75,788	99,083
CH_4 (CO_2 Eq.)			1,623
N_2O (CO_2 Eq.)			3,080
Municipal Solid Waste Landfill			
CH_4 (CO_2 Eq.)	245,702	239,624	148,060
Totals for Solid Waste Management			
CO_2	71,212	75,788	99,083
CH_4 (CO_2 Eq.)	245,702	239,624	149,683
N_2O (CO_2 Eq.)			3,080
TOTAL (CO_2 Eq.)	316,914	315,412	251,846
GRAND TOTALS			
CO_2	5,265,982	5,507,993	5,693,524
CH_4 (CO_2 Eq.)	252,463	245,049	155,665
N_2O (CO_2 Eq.)	79,609	67,813	31,972
TOTAL (CO_2 Eq.)	5,598,054	5,819,701	5,881,161

The inventory results show that the overall anthropogenic greenhouse gas emissions for sources evaluated in Madison County were 5.60 million tons CO_2 Eq. in 2000, and 5.82 million tons CO_2 Eq. in 2005, a 4.0 % increase from 2000. In 2010, total GHG emissions were 5.88 million tons, an increase of 1.1 % from the year 2005 and an increase of 5.1 % over the ten-year period from 2000 to 2010. Carbon dioxide is by far the predominant greenhouse gas in the inventory, constituting roughly 97 % of the total in year 2010 on a CO_2 Eq. basis, which is somewhat higher than in previous inventory years (94 % in 2000 and 95 % in 2005). Methane emissions were 2.7 % of the total in 2010 on a CO_2 Eq. basis, while nitrous oxide emissions were only 0.5 % of the 2010 total. The contributions of the three principal greenhouse gases to the year 2000, year 2005 and year 2010 inventories are shown in Table 21, and are depicted graphically for years 2000 and 2010 in Figure 4. For purposes of comparison, Table 21 and Figure 4 also show the contributions of the different greenhouse gases to the national inventory in 2010.

Table 21 – Percent Contributions of the Principal Greenhouse Gases to Total Greenhouse Gas Emissions in Madison County, Alabama in Years 2000, 2005 and 2010, on a CO_2 Eq. Basis. Corresponding Information from the U.S. National Inventory for 2010 is Shown for Comparison.

	2000	*2005*	*2010*	*2010 (U.S.)*
CO_2	94.1	94.6	96.8	83.7
CH_4	4.5	4.2	2.7	9.8
N_2O	1.4	1.2	0.5	4.5
Fluorine Compounds		Not Included		2.1
TOTAL	100.0 %	100.0 %	100.0 %	100.1 %

Figure 4 – Madison County Principal Greenhouse Gas Emissions for Years 2000 and 2010. Analogous Information from the 2010 U.S. Inventory is Shown for Comparison.



Nationally, the relative contributions of the various greenhouse gases to the overall 2010 inventory were 83.7 % CO_2, 9.8 % CH_4, 4.5 % N_2O and 2.1 % fluorine compounds.[46] The lower percentage of methane in the local inventory (2.7 % versus 9.8 % nationally) is attributable in part to the scope of the local inventory. EPA's national inventory identifies "enteric fermentation," i.e. livestock production, as the second largest contributor to methane emissions in the United States, and the local inventory doesn't include emissions from agricultural sources such as animal husbandry. The largest source of methane emissions nationally is listed as "natural gas systems," presumably leaks from pipelines and local distribution networks. The local inventory made no attempt to quantify methane emissions from natural gas leaks. Similarly, the lower percentage of nitrous oxide in the local inventory is largely attributable to the exclusion of agricultural sources since the national inventory identifies "agricultural soil management" as the largest contributor to N_2O emissions in the U. S. [47]

Electricity consumption is responsible for the largest share of greenhouse gas emissions in Madison County, equal to 55.8 % of the total in year 2010, a slightly lower percentage than in previous inventory years. Combustion of transportation fuels is the second largest contributor, constituting 32.6 % of the total emissions in the 2010 inventory, a slightly higher percentage than in 2000 or 2005. Following these two dominant source categories is stationary source fuel combustion with 7.3 % of the 2010 total, and solid waste management, which makes up the remainder (4.3 % in 2010). The contributions to total emissions from stationary source fuel combustion can be further broken down into the industrial, residential and commercial components. In 2010, industrial fuel combustion was 2.1 % of total greenhouse gas emissions, residential was 2.8 % and commercial was 2.4 %. Contributions by source category are summarized for years 2000, 2005 and 2010 in Table 22 and are shown graphically for years 2000 and 2010 in Figure 5, along with comparable data from the 2010 national inventory.

The national percentages by source category differ substantially from those characterizing the local inventory. Although the largest category nationally as well as locally, electric power accounted for only 33.8 % of total U.S. greenhouse gas emissions in 2010 compared with 55.8 % of the total in Madison County. Transportation was the second largest contributor to U.S. emissions and to local emissions, and the percentages are fairly similar, with transportation accounting for 26.9 % of total U.S. emissions compared with 32.6 % locally. Industrial emissions contribute far more to the national inventory than to the Madison County inventory, with the 2010 industrial contribution equal to 20.4 % of the total, while locally that contribution was only 2.1 % in 2010. For the commercial sector, the contribution was 5.6 % nationally and 2.4 % locally, while the residential sector contributed 5.4 % nationally and only 2.8 % locally.

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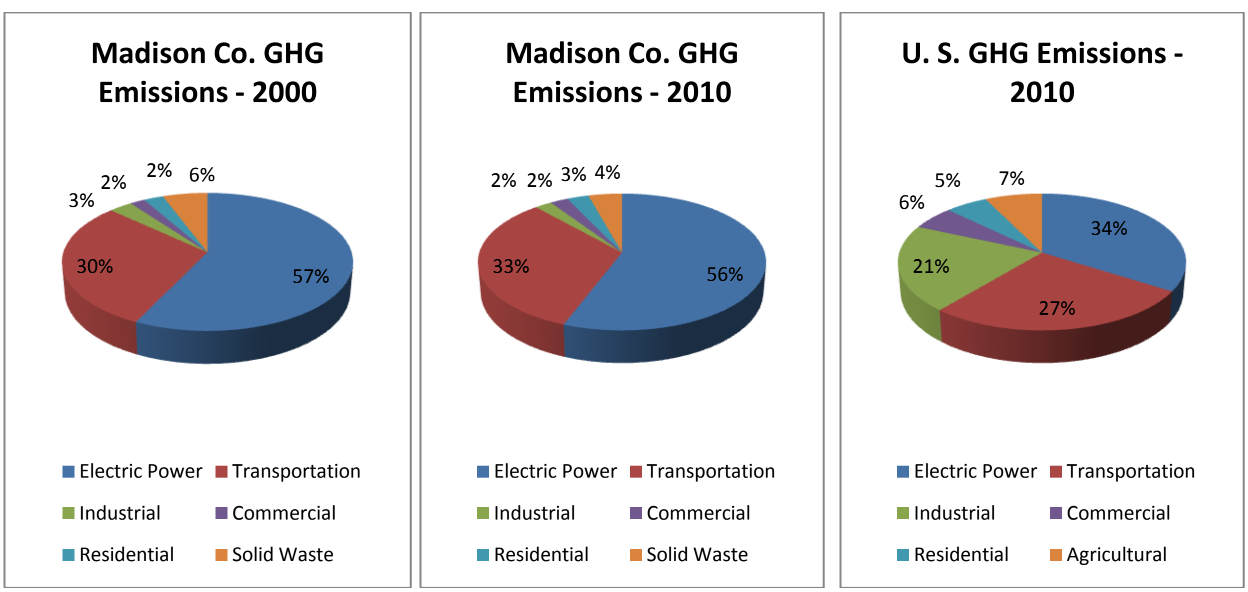
[46] See Footnote 7.

[47] If the agricultural sources are subtracted from the methane and nitrous oxide components of the national inventory for year 2010, and the fluorine compound emissions are also excluded, the percentages come much closer to those obtained in the Madison County inventory: carbon dioxide then accounts for 91.3 % nationally (versus 96.8 % locally), methane accounts for 7.4 % (versus 2.7 % locally), and nitrous oxide accounts for 1.3 % nationally (versus 0.5 % locally). If natural gas system losses of methane are also excluded from the national inventory, the national percentages become: CO_2 = 94.5 %; CH_4 = 4.1 %; and N_2O = 1.3 %.

Table 22 – Percent Contribution to Greenhouse Gas Emission Totals by Source Category in Madison County in Years 2000, 2005 and 2010. Corresponding Information from the 2010 U.S. National Inventory is shown for Comparison.

	2000	*2005*	*2010*	*2010 (U.S.)*
Electric Power	57.1	56.7	55.8	33.8
Transportation	29.7	31.2	32.6	26.9
Industrial	3.2	1.8	2.1	20.4
Commercial	1.9	2.1	2.4	5.6
Residential	2.5	2.8	2.8	5.4
Solid Waste Mgt.	5.7	5.4	4.3	Not a Separate Sector
Agricultural		Not Included		7.3
U.S. Territories		Not Applicable		0.7
TOTAL	100.1 %	100.0 %	100.0 %	100.1 %

Figure 5 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Source Category in Years 2000 and 2010. Analogous Information from the 2010 U.S. Inventory is shown for Comparison.



Part of the difference between the local and national emission contributions by economic sector can be explained by the scope of the inventories and differences in emissions allocation. As emphasized previously, the local inventory doesn't include agricultural emissions. The national inventory doesn't include solid waste management as an economic sector and allocates these greenhouse gas emissions among the other sectors. However, these considerations only explain a small portion of the differences. Nationally, electricity consumption is a much smaller contributor than it is in Madison County (33.8 % versus 55.8 %), while the industrial, commercial and residential sectors contribute substantially more to the national totals than they do locally. This suggests that a larger portion of total energy needs are provided by electricity in Madison County than nationally, and conversely that a larger portion of total energy needs are provided by fuel combustion in other parts of the country. This is probably true. As an example, electricity (heat pumps) is widely used for space heat in the southeastern U.S., whereas fossil fuel-fired furnaces are typically used in colder climates. The industrial contributions are certainly lower in Madison County than nationally because of the nature of local industry. For the most part, the types of industry located in Huntsville do not have large direct emissions of greenhouse gases and do not consume very large amounts of fossil fuels for process heat. (Examples of high greenhouse gas emitting industries are iron and steel production, cement kilns, nitric acid production, and petrochemical manufacturing). Thus, most of the differences in relative contribution by economic sector in the national and local inventories probably reflect reality and are not the result of differences in methodology or inventory scope.

Although electrical power generation is the single largest contributor to greenhouse gas emissions nationally, these emissions can be allocated among the other economic sectors based on their electricity consumption. Adding emissions from industrial fuel combustion to the emissions associated with electricity consumption by industrial users yields a total of 0.46 million tons CO_2 Eq. (7.9 % of the total) for Madison County in year 2010. Commercial sources contributed 1.47 million tons CO_2 Eq. emissions in year 2010 (24.9 % of the total). Finally, the residential CO_2 Eq. emissions were 1.78 million tons in year 2010 (30.3 % of the total). The percentage contributions by economic sector, including the emissions associated with electricity usage, are shown in Table 23 and in Figure 6. Analogous information from the 2010 U.S inventory is shown for comparison. Note that for previous inventory years (2000 and 2005), Huntsville Utilities grouped large commercial electric accounts with the industrial users, whereas in 2010 the categories of electric accounts were "industrial," "commercial," and "residential." The apparent large shift in percentages from 2000 to 2010 in Figure 6 is the result of this change in account classification.

Nationally, the industrial sector is the largest source of greenhouse gas emissions if electricity consumption is allocated among the economic sectors by usage, contributing 29.6 % of the total. In Madison County, the industrial sector contributes a much smaller percentage of the total, just under 8 % of the 2010 GHG emissions. This is not surprising because Madison County does not have industrial sources in the more energy intensive source categories. Largely because the industrial emissions constitute a much smaller fraction of the total locally, the other economic sectors contribute a higher percentage locally than nationally.

Table 23 – Percent Contribution to Greenhouse Gas Emission Totals by Economic Sector in Madison County in Years 2000, 2005 and 2010 with Emissions from Electricity Consumption Allocated Among the Sectors by Usage. Corresponding Information from the U.S. National Inventory for 2010 is shown for Comparison.

	2000	*2005*	*2010*	*2010 (U.S.)*
Industrial			7.9	29.6
Industrial & Large Commercial	30.8	28.5		
Transportation	29.7	31.2	32.6	26.9
Commercial			24.9	17.2
Small Commercial	5.5	6.0		
Residential	28.4	28.9	30.3	18.0
Solid Waste Mgt.	5.7	5.4	4.3	Not a Separate Sector
Agricultural	Not Included			7.6
U.S. Territories	Not Applicable			0.7
TOTAL	100.0 %	100.0 %	100.0 %	100.0 %

The commercial sector accounts for roughly 25 % of the 2010 greenhouse gas emissions in Madison County, as opposed to just over 17 % of the national total, and the residential sector contributes approximately 30 % of the local greenhouse gas emissions whereas this sector accounts for 18 % of the U.S. total. Finally, the transportation sector constituted about 27 % of the national emissions inventory in 2010, somewhat lower than the percentage for Madison County (just under 33 %). In addition to the increased relative importance of the residential, commercial and transportation sectors resulting from the much smaller industrial contributions to the Madison County inventory, differences between the scope of the local and national inventories are also reflected in the percentage contributions of the economic sectors represented in the respective inventories. E.g. agricultural emissions account for 7.6 % of the national emissions, but are not included in the Madison County inventory.[48] There are also differences between accounting methods used to allocate emissions among the economic sectors nationally and locally, e.g. emissions from solid waste management are allocated among the various

[48] Subtracting the agricultural and U.S Territory emissions from the national totals, and recalculating the percentages among the remaining economic sectors yields 31.9 % from industrial sources, 30.6 % from transportation, 18.6 % from the commercial sector and 18.9 % from residential sources.

economic sectors in the national inventory, but this has a relatively minor effect on the calculated percentages by sector.

Figure 6 shows the Madison County percentage of total greenhouse gas emissions by economic sector for the years 2000 and 2010. The percentages in the 2010 national inventory are shown for comparative purposes.

Figure 6 – Madison County Greenhouse Gas (CO_2 Eq.) Emissions by Economic Sector in Years 2000 and 2010, with Emissions from Electricity Consumption Allocated Based on Usage. Analogous Information from the 2010 U.S. Inventory is shown for Comparison.

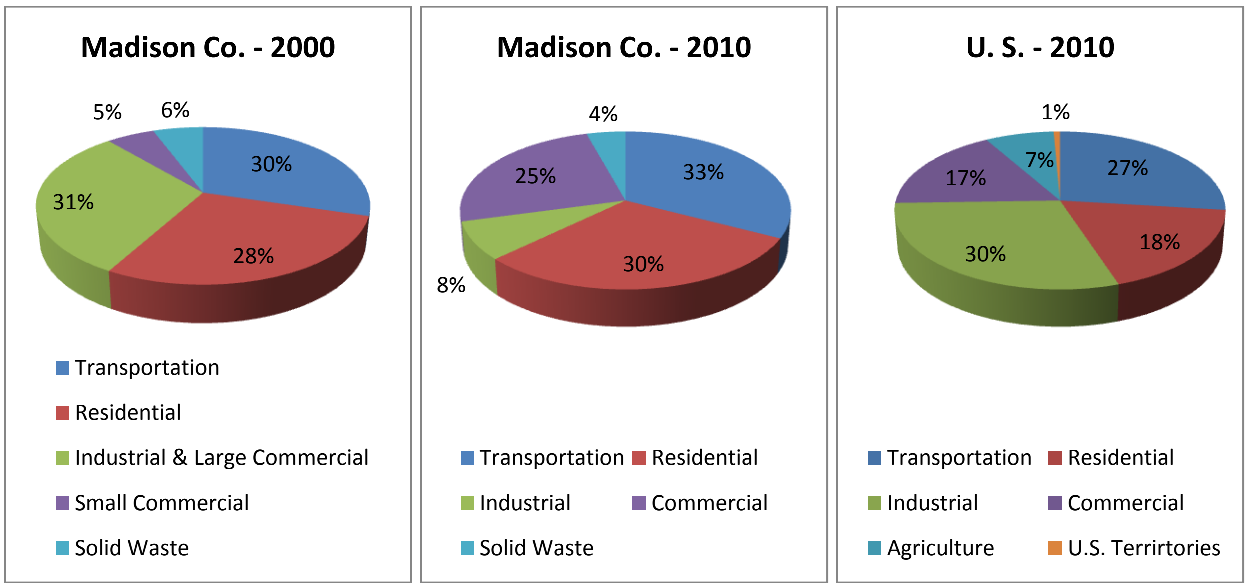
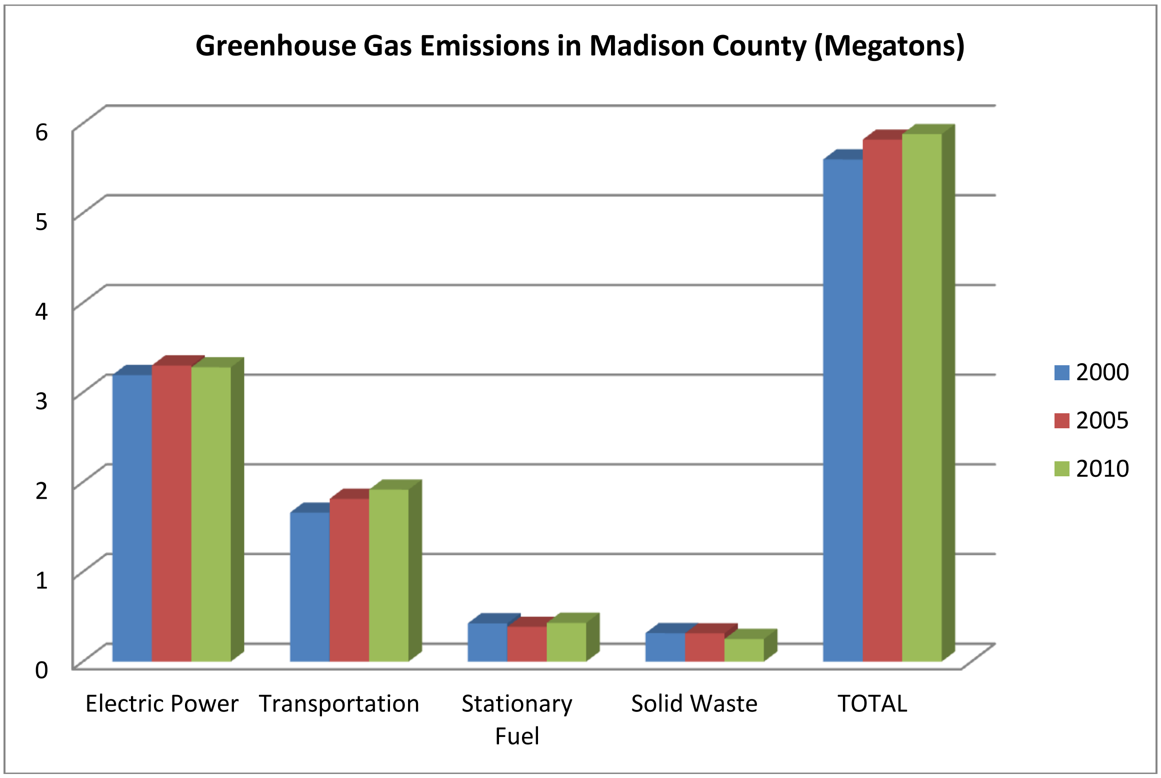


Figure 7 presents the emissions data for Madison County by source type in years 2000, 2005 and 2010 as a bar chart, making the changes with time more apparent. Overall, emissions increased by 5 % over the ten-year period, from 5.60 million tons in year 2000 to 5.88 million tons in 2010. In magnitude, the largest increase occurred in the transportation sector, from 1.66 million tons in year 2000 to 1.92 million tons in 2010, an increase of 15.5 %. In contrast, emissions associated with electricity usage, the largest component in the inventory, increased by only 2.7 % over the ten-year period, from 3.20 million tons in 2000 to 3.28 million tons in 2010. The emission associated with electricity consumption actually declined slightly from 2005 (3.30 million tons) to 2010 (3.28 million tons). Emissions from stationary fuel combustion, a much smaller component of the overall inventory, increased only slightly from the year 2000 (0.426 million tons) to year 2010 (0.432 million tons), an increase of only 1.4 %. Although there were increased emissions from residential and commercial natural gas combustion, these increases were largely offset by a decrease in emissions from industrial fuel combustion. Finally, emissions from solid waste management decreased over the ten-year period, from 0.317 million tons in 2000 to 0.252 million tons in 2010, a decline of just over 20 %. However, this "decrease" in emissions is primarily due to improvements in the method used to estimate methane emissions from the solid waste landfill rather than drastic changes in solid waste management practices.

Figure 7 – Madison County Greenhouse Gas Emissions in Years 2000, 2005 and 2010 (Megatons of CO_2 Eq.)



In addition to examining the types and sources of greenhouse gas emissions in the area, as well as their changes over time, it is helpful to express emissions in a form more amenable to comparison with other communities and that accounts for population growth. Once total emissions have been quantified, expression of those results in terms of per capita emissions is straightforward. To do this, population data for Madison County were obtained from the U. S. Census Bureau website.[49] Official census data are obtained from the decennial censuses, which were completed for years 2000 and 2010. In 2000, the population of Madison County was 276,972, and in 2010 the population was 334,811. Although official census data are not available for 2005, the U.S. Census Bureau does develop population estimates for years between

[49] http://www.census.gov/

the decennial censuses, and estimated the 2005 Madison County population at 299,409. Thus, per capita emissions for Madison County can readily be calculated as:

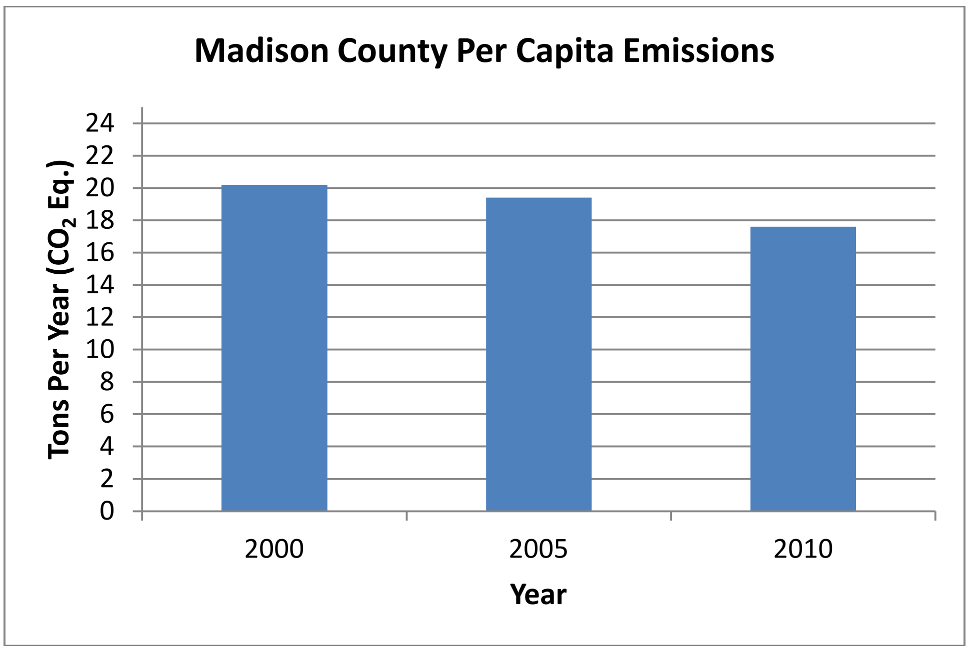
Year 2000 5,598,054 tons ÷ 276,972 persons = 20.2 tons/person

Year 2005 5,819,701 tons ÷ 299,409 persons = 19.4 tons/person

Year 2010 5,881,161 tons ÷ 334,811 persons = 17.6 tons/person

Consequently, although total greenhouse gas emissions increased by 5.0 % over the ten-year period, annual per capita emissions declined substantially, from 20.2 tons/person to 17.6 tons per person, a decrease of 13.1 %. Note that the population increase of 57,839 persons over the period from 2000 to 2010 constitutes a 20.9 % increase. Madison County per capita emissions in years 2000, 2005 and 2010 are shown in Figure 8.

Figure 8 – Madison County Greenhouse Gas Emissions Per Capita in Years 2000, 2005 and 2010 (Tons CO_2 Eq.)



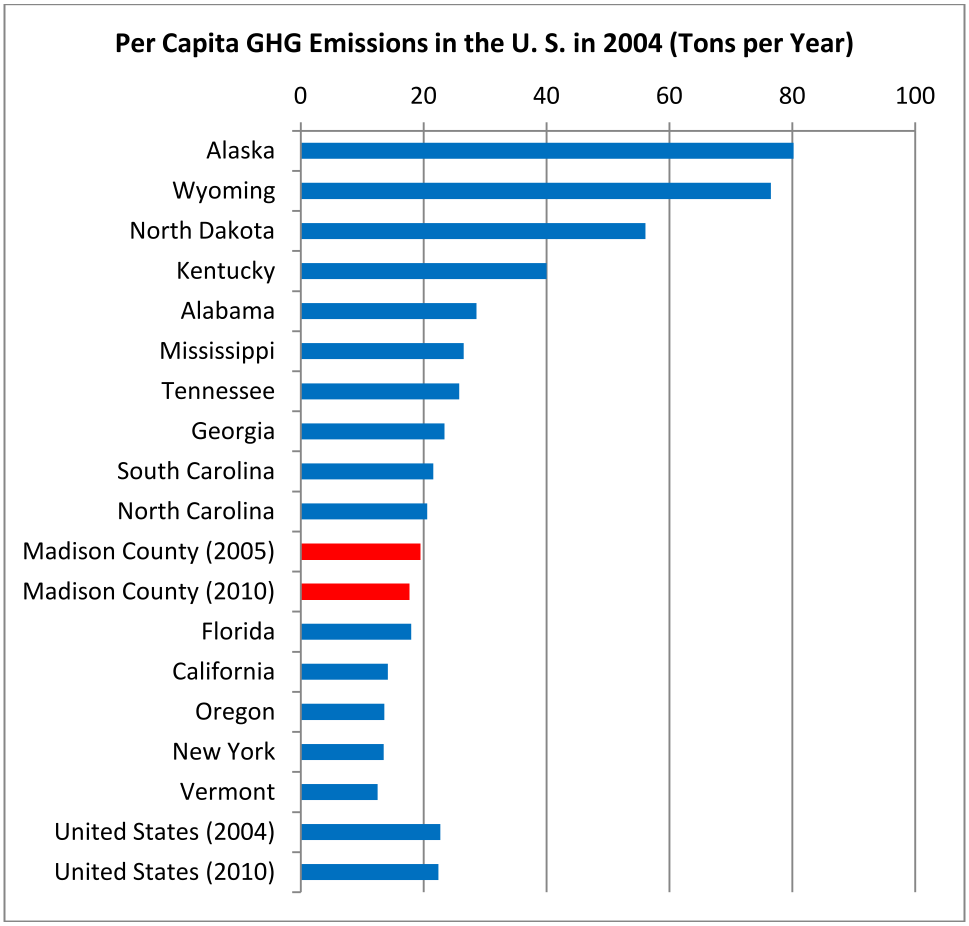
For purposes of comparison, per capita greenhouse gas emissions for a number of States are provided in Table 24 and shown in Figure 9. These totals were taken from a report prepared by Ecotrust for the Natural Resources Defense Council in 2009.[50] Although the data in the Ecotrust report are for year 2004, these per capita values are included for comparison because the

[50] Stanton, Elizabeth A., Frank Ackerman, and Kristen Sheeran; *Greenhouse Gases and the American Lifestyle: Understanding Interstate Differences in Emissions;* Ecotrust- Economics for Equity and the Environment, and Stockholm Environment Institute; May 2009.

Table 24 – Per Capita Greenhouse Gas Emissions for the United States, Selected States and Madison County, Alabama. All values are for Year 2004, except as shown. Values are included for the three States with the highest per capita emissions, the three States with the lowest per capita emissions, and for the States in the Southeastern U.S.

	Per capita Emissions (Tons per Year)
United States (2004)	22.7
United States (2010)	22.4
Vermont	12.5
New York	13.5
Oregon	13.6
California	14.2
Florida	18.0
Madison County, Alabama (2005)	***19.4***
Madison County, Alabama (2010)	***17.6***
North Carolina	20.6
South Carolina	21.6
Georgia	23.4
Tennessee	25.8
Mississippi	26.5
Alabama	28.6
Kentucky	40.0
North Dakota	56.1
Wyoming	76.5
Alaska	80.2

Figure 9 – Comparison of Per Capita Greenhouse Gas Emissions in Madison County, Selected States and the U.S. as a Whole (Tons CO_2 Eq. per Year). All Values are for Year 2004 unless Otherwise Shown.



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scope of the Ecotrust inventory is very similar to the scope of the Madison County inventory prepared by DNR. The greenhouse gases included (CO_2, CH_4 and N_2O) are the same in the two inventories, and the Ecotrust inventory includes adjusted State-by-State emissions to reflect interstate sales of electricity. More recent State-by-State comparisons do not share all of these commonalities with the Madison County inventory.

Per capita emissions in Madison County were equal to 19.4 tons per year in 2005, somewhat lower than the national average of 22.7 tons per year in year 2004. From the information in Table 24 and Figure 9, it should be evident that there are significant regional differences in per capita emissions. They tend to be lower for states on the West Coast and in the Northeast and higher for states in the West, Midwest and Southeast. A number of factors influence per capita emissions, including climatic differences, transportation patterns, the relative importance of energy intensive industries and the mix of electrical power generation facilities that serve a particular region. E.g. States in the Midwest and Southeast rely heavily on coal-fired power plants for electricity generation, which affects greenhouse gas emissions associated with electricity consumption. Per capita greenhouse emissions in Madison County are toward the lower end of the spectrum within the Southeast, with only the State of Florida having lower emissions (18.0 tons per person per year in 2004). State-wide, Alabama had per capita emissions of 28.6 tons per person per year in 2004, 47 % higher than the Madison County per capita emissions in 2005. The relatively low industrial emissions in Huntsville and Madison County are probably primarily responsible for the lower emissions locally than in Alabama as a whole and within the Southeast.

It should be noted that the substantial decrease in per capita greenhouse gas emissions in Madison County from 2000 to 2010 is primarily the result of changes in the power mix utilized by TVA to generate electricity. Over the ten-year period, the percentage of TVA-generated power provided by coal-fired power plants declined from 62 % in 2000 to 51 % in 2010. Conversely, the percentage of power generated by TVA's nuclear plants increased from 29 % in 2000 to 36 % in 2010. The TVA power mix in years 2000, 2005 and 2010 is summarized below:

	2000 [51]	***2005*** [52]	***2010***
Coal-fired	62 %	62 %	51 %
Nuclear	29 %	28 %	36 %
Hydroelectric	8 %	10 %	9 %
Gas & Oil-Fired	<1 %	<1 %	4 %
Renewables	<1%	<1 %	<1 %

The shift in TVA's power mix is reflected in the emission factors for electricity generation presented in the Methods section, decreasing from 1440 lb/MWh CO_2 Eq. in the year 2000 to 1185 lb/MWh CO_2 Eq. in the year 2010. Per capita electricity consumption in Madison County actually increased slightly from the year 2000 (16.0 MWh/year) to the year 2010 (16.5 MWh/year), so the large decrease in per capita emissions associated with electricity usage is not the result of reduced electricity consumption, but changes over the 10-year period in the relative importance of different types of electricity generating sources utilized by TVA to provide the power.

Smaller changes in per capita emissions are attributable to a decrease in per person transportation emissions. Again, this did not result from a decline in individual fuel usage (532 gallons/year in 2000 and 535 gallons/year in 2010), but a significant decrease in nitrous oxide emissions due to further penetration of vehicles that meet Tier 2 tail-pipe standards, which took effect with MY 2004, and a notable drop in aviation emissions.

In contrast to electricity consumption, which increased slightly from 2000 to 2010, per capita natural gas consumption did decline somewhat over the ten-year period, from 24.5 MSCF (thousand standard cubic feet) in 2000 to 21.0 MSCF in 2010. Interestingly, the slight decline in

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[51] TVA's power mix in 2000 is taken from eGRID. See Footnote 12.

[52] TVA's power mix for years 2005 and 2010 is taken from TVA's Annual Form 10-K reports filed with the SEC (Securities and Exchange Commission). TVA began filing these reports with the SEC in 2006. These reports can be accessed at the following web address: http://www.tva.com/finance/reports/

natural gas usage is almost entirely offset by the slight increase in per capita electricity consumption, on an equivalent energy basis, suggesting that a shift occurred in the percentage of buildings heated with natural gas to those heated with electricity. Thus, total per capita energy usage was virtually unchanged over the ten-year period. Of course, individual energy consumption in any given year is strongly impacted by annual variations in climatic conditions, and no effort was made in this inventory to consider differences in the number of HDD (Heating Degree Days) and CDD (Cooling Degree Days) in 2000 and 2010 when evaluating per capita energy consumption and per capita greenhouse gas emissions in Madison County for the two years.

Although comprehensive State-by-State comparisons of total per capita greenhouse gas emissions were not available for years more recent than 2004 at the time this inventory was prepared, data on per capita *carbon dioxide* emissions by State were available for the year 2010. This is probably because carbon dioxide emissions are more easily quantified than nitrous oxide or methane emissions. In compiling these State-by-State CO_2 emission totals, only emissions from fossil fuel combustion are included, including emissions from electricity generation, transportation sources and stationary source fuel combustion.[53] Thus, the scope of the CO_2 inventory is similar to that utilized in preparing the 2010 Madison County inventory update. It does not include agricultural emissions (which are primarily nitrous oxide and methane), emissions from natural gas distribution (methane), or fluorine compound emissions from electricity transmission systems, air conditioning system losses or industrial processes. Although the scope of the EPA State-by-State CO_2 inventory is similar to both the Madison County GHG inventory and the 2004 State-by-State comparisons presented above in terms of the sources included in the inventory, it differs in one key respect from the 2004 comparisons. The 2010 CO_2 totals do not adjust the emissions of CO_2 to reflect interstate transmission of electric power. In other words, unlike the 2004 totals, which reflect electricity *consumption* within each State, the 2010 totals are based on electricity *generation* within each State. This results in an increase in the per capita carbon dioxide emissions for those States that export electricity to neighboring States, and a depression of the per capita emissions for those States which import electricity from other States.

Table 25 shows the State-by-State per capita CO_2 emissions in 2010. This information is presented graphically in Figure 10.

The Madison County 2010 per capita carbon dioxide emissions of 17.0 tons per year are somewhat lower than the national average of 19.2 tons per year and toward the lower end of the range for the Southeastern United States. Generally, the per capita CO_2 emission in 2010 show a similar pattern to the 2004 per capita total greenhouse gas emissions, with States in the West, Midwest and Southeast having relatively higher per capita emissions and States on the West Coast and in the Northeast having lower per capita emissions. However, in some cases these regional differences are exaggerated when no adjustments are made for interstate electricity transmission.

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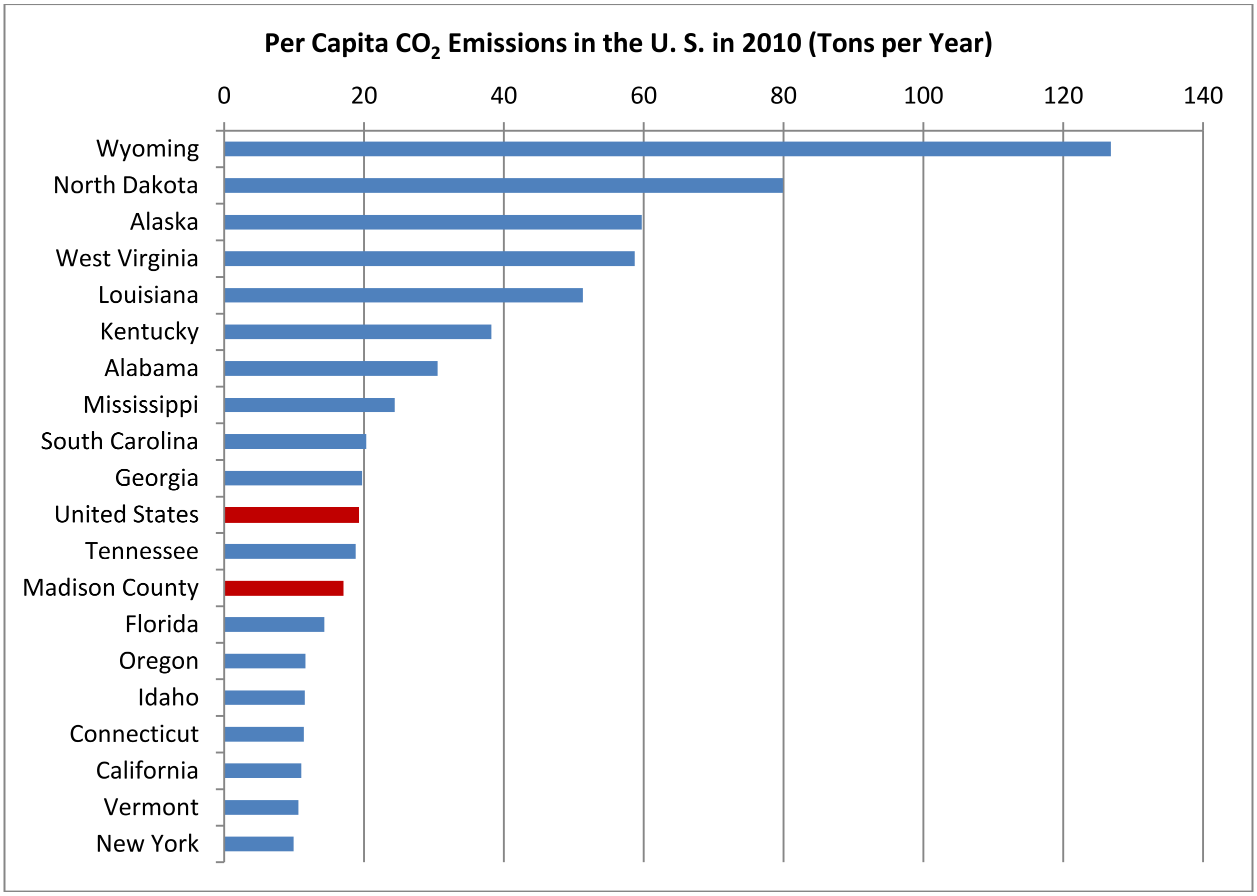
[53] EPA State-by-State carbon dioxide emissions for years 1990 through 2010 are available at the following web address: http://www.epa.gov/statelocalclimate/resources/state_energyco2inv.html

Table 25 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion for the United States, Selected States and Madison County, Alabama in the Year 2010. The five States with the highest per capita emissions, five States with the lowest per capita emissions and the Southeastern States are shown.

	Per capita Emissions (Tons per Year)
United States	19.2
New York	9.9
Vermont	10.6
California	11.0
Connecticut	11.4
Idaho	11.5
Florida	14.3
North Carolina	16.4
Madison County, Alabama (2010)	***17.0***
Tennessee	18.8
Georgia	19.7
South Carolina	20.3
Mississippi	24.4
Alabama	30.5
Kentucky	38.2
Louisiana	51.3
West Virginia	58.7
Alaska	59.7
North Dakota	79.9
Wyoming	126.8

Figure 10 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion for the United States, Selected States and Madison County, Alabama in the Year 2010. The five States with the highest per capita emissions, five States with the lowest per capita emissions and the Southeastern States are shown.



Note: No adjustments are made in these data for interstate electricity transmission, so States that export large amounts of electricity to neighboring States have proportionately higher per capita CO_2 emissions, while States that import large amounts of electricity have lower per capita emissions.

In Alabama, the 2010 per capita CO_2 emissions of 30.5 tons per year were 79 % higher than in Madison County. This large difference merits some discussion. Note that the 2010 per capita carbon dioxide emissions in Alabama are actually higher than the per capita total greenhouse gas emissions shown for 2004. This is largely because the 2010 data reflect emissions from electricity *generation* rather than electricity *consumption.* In other words there is no adjustment in per capita emissions for electricity that is generated within the State and exported to neighboring States as there is for the 2004 data. Consequently, for States such as Alabama that export significant amounts of electricity to neighboring States, the per capita emissions are somewhat inflated. The effect of this "inflation" of per capita emissions for electricity-exporting States is extreme in the case of Wyoming. This is because Wyoming, which has a relatively small population, generates most of its electricity from coal, and exports a large fraction of the electricity generated within the State to other States. [54] With respect to a comparison of Madison County per capita emissions to those in the State as a whole, it is also true that Alabama is home to a number of energy intensive industries, whereas Madison County is not.

[54] The Energy Information Administration compiles detailed State-by-State information on electricity generation and consumption. In 2010, Wyoming generated 48,119 million kWh of electricity (89.3 % from coal-fired plants) and exported 28,611 million kWh to other States (59 % of net generation). Alabama generated 152,151 million kWh of electricity (41.4 % from coal), and exported 49,454 million kWh to other States (33 % of net generation). Tables summarizing electricity generation and disposition data, by year and by State, is available on the EIA website: http://www.eia.gov/electricity/state/

Analysis and Discussion of Inventory Results – City of Huntsville Municipal Government

Greenhouse gas emissions from City of Huntsville municipal government operations in years 2000 and 2010 are summarized in Table 26 and depicted graphically for Years 2000, 2005 and 2010 in Figure 11. Percent contribution of electricity consumption, transportation fuel combustion and stationary source fuel combustion to total emissions is also shown in Table 26 and is depicted for years 2000, 2005 and 2010 in Figure 12.

Table 26 – Greenhouse Gas Emissions (Tons CO_2 Eq.) From City of Huntsville Municpal Government Operations in Years 2000 and 2010.

	2000		***2010***	
Electricity Consumption	25,253	(54.8 %)	23,125	(51.9 %)
Stationary Source Fuel Combustion	6,684	(14.5 %)	6,104	(13.7 %)
Transportation Fuel Combustion	14,125	(30.7 %)	15,316	(34.4 %)
TOTAL	46,062	(100.0 %)	44,545	(100.0 %)

Figure 11 – City of Huntsville Municipal Government Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005 and 2010.

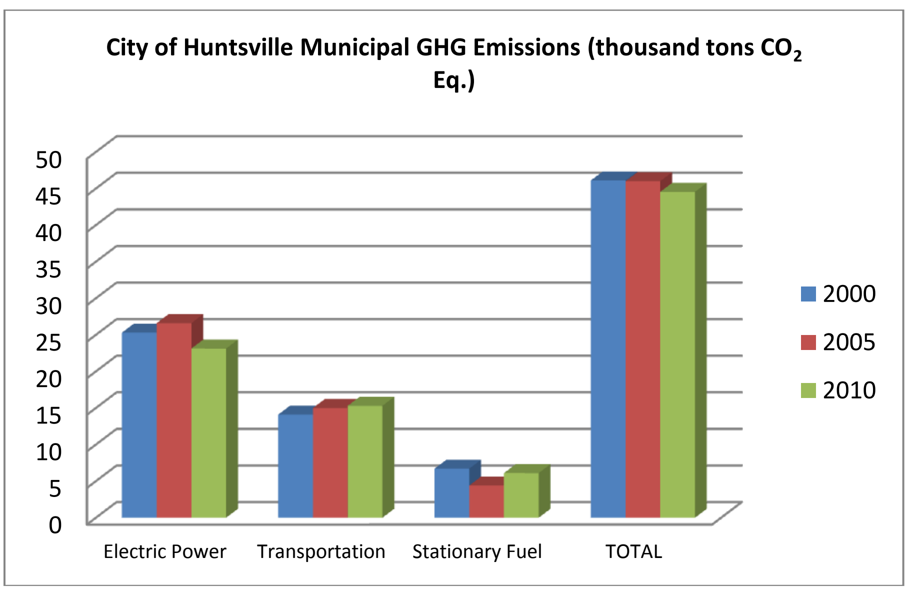
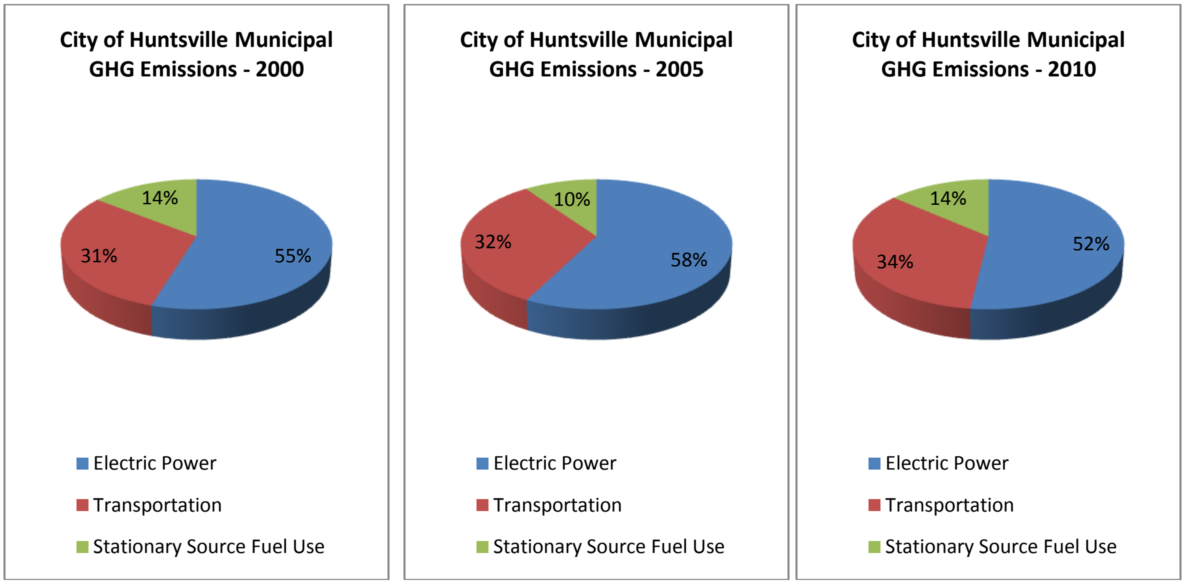


Figure 12 – City of Huntsville Municipal Operations Greenhouse Gas Emissions (CO_2 Eq.) by Source in Years 2000, 2005 and 2010.



Emissions from municipal operations were virtually unchanged from 2000 to 2005, equalling roughly 46 thousand tons in each of the two years, but then decreased to 44,545 tons in 2010, a reduction of roughly 3 %. There were substantial changes in the three emissions categories, i.e. electricity consumption, stationary fuel combustion and transportation. Emissions associated with electricity usage increased from 25.3 thousand tons in year 2000 to 26.6 thousand tons in 2005, an increase of 5.2 %, but then decreased to 23.1 thousand tons in 2010, a decline of roughly 13 % over the five-year period. The decrease over the ten-year period from 2000 to 2010 was 8.4 %. Emissions from natural gas combustion also declined dramatically from 2000 to 2010, dropping from roughly 6700 tons in 2000 to 6100 tons in 2010, a reduction of 8.7 %. Thus, there were substantial reductions in greenhouse gas emissions associated with City facilities over the ten-year period. However, there was a countervailing increase in emissions associated with operation of the City fleet over the same period of time. Emissions from gasoline and diesel fuel use in City vehicles increased from 14,125 tons in 2000 to 15,316 tons in 2010, an increase of 8.4 %. Consequently, despite the substantial decrease in GHG emissions associated with operation of municipal facilities, the overall reduction was only 3.3 %.

The reductions in emissions associated with electricity usage from 2005 (26,559 tons CO_2 Eq.) to 2010 (23,125 tons CO_2 Eq.), a decrease of 13 %, is due primarily to changes in the TVA power mix over the five-year period. The effect of the reduced reliance on coal-fired generation on GHG emissions was discussed previously in the context of Madison County per capita emissions associated with electricity usage. However, in that context Countywide electricity usage had increased substantially over the five-year period and per capita electricity consumption was essentially unchanged. Thus, the entire reduction in Countywide per capita emissions associated with electricity usage was the result of the changes in the TVA power mix. In contrast, City of Huntsville municipal electricity usage declined slightly from 2005 to 2010, from 39.8 GWh to 39.0 GWh, a decrease in usage of about 2 %. Therefore, the reduction in municipal GHG emissions attributable to electricity consumption resulted from a slight reduction in usage as well as the shift in TVA power generation from coal-fired generation to nuclear power. In the ten-year time period from 2000 to 2010, municipal GHG emissions associated with electricity consumption declined fairly dramatically, from just over 25 thousand tons to roughly 23.1 thousand tons (- 8.4 %), but electricity usage was 11 % higher in 2010 (39.0 GWh) than in 2000 (35.1 GWh), so the ten-year reduction in emissions is entirely the result of changes in the TVA power mix.

Natural gas combustion emissions from City facilities increased from 2005 to 2010 by about 36 % (from 4.5 thousand tons CO_2 Eq. to 6.1 thousand tons CO_2 Eq.). However, over the ten-year period from 2000 to 2010, emissions declined by 8.7 % (from 6684 tons in 2000 to 6104 tons in 2010). Natural gas usage follows the same pattern as the greenhouse gas emissions totals. Natural gas consumption dropped from 110.2 MM scf (million standard cubic feet) in 2000 to 74.1 MM scf in 2005, and then increased to 100.6 MM scf in 2010.

In contrast to greenhouse gas emissions associated with municipal fixed facility operations, which declined dramatically from 2000 to 2010, greenhouse gas emissions associated with municipal fleet operation steadily increased over the ten-year period. Emissions from gasoline and diesel fuel combustion increased from 14.1 thousand tons CO_2 Eq. in 2000 to 15.0 thousand tons CO_2 Eq. in 2005 (+ 6.1 %), and then increased further to 15.3 thousand tons in 2010 (+ 2.2 % from 2005 and + 8.4 % from 2000). Total fuel usage increased by 10.4 % over the ten-year period, but the increase was larger for gasoline (+ 13.7 %) than for diesel fuel (+ 5.7 %).

The relative contributions to overall emissions from City of Huntsville operations by the three usage sectors, i.e. electricity consumption, transportation fuel usage and natural gas combustion, were similar to those for the community as a whole, both in year 2000 and year 2005. However, in 2010 the proportion of municipal emissions associated with electricity usage (52 %) was somewhat lower than for the community as a whole (56 %), and the contribution from stationary source fuel combustion to total municipal greenhouse gas emissions (14 %) was notably higher than Countywide (7 %). Emissions from municipal fleet operations (34 %) constituted about the same proportion of the inventory as the transportation sector in the Countywide inventory (33 %).

Since electricity consumption and stationary source fuel combustion are both associated with the operation of City facilities, including the wastewater treatment plants and lift stations, roughly two-thirds of the total emissions from municipal operations are attributable to fixed facility operation (65.6 %) and about one-third of the total emissions are from operation of the City's motor vehicle fleet (34.4 %). The Countywide inventory is strikingly similar with 32.6 % of total greenhouse gas emissions attributable to the transportation sector and 67.4 % attributable to fixed facility operations (including solid waste disposal).

Appendix A

2010 GHG Emissions Summary Table

		CO2 (Tons)	Biogenic CO2 (tons)	CH4 (Tons)	CH4 (tons CO2 Eq.)	N2O (tons)	N2O (tons CO2 Eq.)	Total GHG (tons CO2 Eq.)
Electricity	*Residential*	1,613,084		19.28152561	404.9120377	22.48143837	6969.245893	1,620,458
	Commercial	1,321,841		15.80023004	331.8048309	18.42239588	5710.942723	1,327,883
	Industrial	330,685		3.952750297	83.00775624	4.608738644	1428.70898	332,197
	TOTAL	*3,265,610*		*39*	*820*	*46*	*14,109*	*3,280,539*
Natural Gas	*Residential*	161,149		3.1	64.5	2.9	911.3	162,125
	Commercial	138,536		2.6	55.5	2.5	783.4	139,375
	Industrial	124,377		2.4	49.8	2.3	703.4	125,130
	TOTAL	*424,062*		*8*	*170*	*8*	*2,398*	*426,630*
Coal & Coke	*Coal*	1,705		0.1825	3.83	0.02756	8.5436	1,718
	Coke	3,576		0.0689	1.45	0.02114	6.5534	3,584
	TOTAL	*5,282*	*0*	*0.25*	*5.3*	*0.05*	*15.10*	*5,302*
Transportation	*Gasoline*	1,622,125		219.3	4605.3	34.9	10819	1,637,549
	Diesel	156,478		4.7	98.7	0.5	155	156,732
	On-Road Mobile Sub-Total	1,778,603		224	4704	35.4	10974	1,794,281
	Aviation	120,884		14	284	5	1395	122,563
	TOTAL	*1,899,487*	*0*	*238*	*4,988*	*40*	*12,369*	*1,916,844*
Solid Waste	*Landfill*			7050	148,060			148,060
	Steam Plant	99,083	127,510	77	1,623	10	3,080	103,786
	TOTAL	*99,083*	*127,510*	*7,127*	*149,683*	*10*	*3,080*	*251,846*
	GRAND TOTAL	**5,693,524**	**127,510**	**7,412**	**155,665**	**103**	**31,972**	**5,881,161**
		0.968095271			0.026468467		0.005436262	

	2000	2005	% Change	2010	% Change (2005)	Overall % Change (2000)
Electricity Usage	3,195,192	3,302,271	3.35%	3,280,539	-0.66%	2.67%
Transportation	1,660,017	1,814,488	9.31%	1,916,844	5.64%	15.47%
Residential	141,210	160,949	13.98%	162,125	0.73%	14.81%
Industrial	177,467	106,745	-39.85%	130,433	22.19%	-26.50%
Commercial	107,255	119,836	11.73%	139,375	16.30%	29.95%
Stationary Fuel	425,932	387,530	-9.02%	431,933	11.46%	1.41%
Solid Waste	316,914	315,412	-0.47%	251,846	-20.15%	-20.53%
TOTAL	5,598,055	5,819,701	3.96%	5,881,162	1.06%	5.06%
Population	276,972	299,409	8.10%	334,811	11.82%	20.88%
Per Capita Emissions	20.21	19.44	-3.83%	17.57	-9.63%	-13.09%
Electricity Usage (GWh)	4439	4945	11.40%	5536.81	11.97%	24.73%
Per Capita Electricty Usage (MWh)	16.0268908	16.5158696	3.05%	16.5371209	0.13%	3.18%
Gas & Diesel Usage	147,324,896	163,671,063	11.10%	179,110,124	9.43%	21.57%
Per Capita Gas & Diesel Usage (gal)	532	547	2.77%	535	-2.14%	0.57%
Natural Gas Usage (MSCF)	6,786,452	6,298,584	-7.19%	7,032,545	11.65%	3.63%
Per Capita Natural Gas Usage (MSCF)	24.5	21.0	-14.14%	21.0	-0.15%	-14.28%
Per Capita NG Usage (BTU)	24,502,303	21,036,722		21,004,522		
Per Capita NG Usage (kWh)	7,180	6,165		6,155		
Per Capita NG Usage (MWh)	7.18	6.16		6.16		
Per Capita NG + Electricty (MWh)	23.21	22.68	-2.27%	22.69	0.05%	-2.22%

	2000	2005	% Change	2010	% Change (2005)	Overall % Change (2000)
Transportation	1,660,017	1,814,488	9.31%	1,916,844	5.64%	15.47%
Residential	1,589,448	1,684,201	5.96%	1,782,583	5.84%	12.15%
Industrial & Large Commercial	1,721,438	1,658,044	-3.68%			
Small Commercial	310,239	347,556	12.03%			
Industrial				462,629		
Commercial				1,467,258		
Industrial + Commercial	2,031,677	2,005,600	-1.28%	1,929,887	-3.78%	-5.01%
Solid Waste	316,914	315,412	-0.47%	251,846	-20.15%	-20.53%
TOTAL	5,598,056	5,819,701	3.96%	5,881,160	1.06%	5.06%
Population	276,972	299,409	8.10%	334,811	11.82%	20.88%
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Per Capita Natural Gas Usage (MSCF)	24.5	21.0	-14.14%	21.0	-0.15%	-14.28%
Per Capita NG Usage (BTU)	24,502,303	21,036,722		21,004,522		
Per Capita NG Usage (kWh)	7,180	6,165		6,155		
Per Capita NG Usage (MWh)	7.18	6.16		6.16		
Per Capita NG + Electricty (MWh)	23.21	22.68	-2.27%	22.69	0.05%	-2.22%

Per Capita 2010 CO_2 Emissions

	Million metric tons	Million tons CO2	Population (millions)	Per Capita (tons/year)	Per Capita (metric tons/year)	Rank
Alabama	132.1	145.6153241	4.779736	30.47	27.64	10
Madison County	5.165084232	5.693524	0.334811	17.01	15.43	
United States (Total)	5706.4	6290.221784	308.745538	20.37	18.48	
U.S. (Fossil Fuels)	5387.8	5939.025818	308.745538	19.24	17.45	
Florida	244.58	269.6029798	18.80269	14.34	13.01	40
Georgia	172.99	190.6886069	9.687653	19.68	17.86	27
Tennessee	108.25	119.3250575	6.346105	18.80	17.06	30
Mississippi	65.69	72.4107439	2.967297	24.40	22.14	19
Kentucky	150.22	165.5890082	4.339367	38.16	34.62	7
North Carolina	142.12	156.6602972	9.535483	16.43	14.90	33
South Carolina	85.21	93.9278351	4.625364	20.31	18.42	25
Alaska	38.45	42.3838195	0.710231	59.68	54.14	3
California	370.89	408.8357559	37.253956	10.97	9.96	48
Vermont	6.03	6.6469293	0.625741	10.62	9.64	49
New York	173.83	191.6145473	19.378102	9.89	8.97	50
Wyoming	64.81	71.4407111	0.563626	126.75	114.99	1
North Dakota	48.75	53.7376125	0.672591	79.90	72.48	2
Oregon	40.31	44.4341161	3.831074	11.60	10.52	45
Louisiana	210.98	232.5653638	4.533372	51.30	46.54	5
West Virginia	98.66	108.7539046	1.852994	58.69	53.24	4
Connecticut	37.03	40.8185393	3.574097	11.42	10.36	47
Idaho	16.32	17.9896992	1.567582	11.48	10.41	46

Per Capita 2010 GHG Emissions (Minus Agriculture and Fluorine Compounds)

United States	6251.1	6890.650041	308.745538	22.32	20.25
U.S. (Total)	6821.7	7519.628127	308.745538	24.36	22.09

Total GHG Emissions Madison County 2010

	Tons (CO2 Eq.)	Percent	Percent
By GHG			
Carbon Dioxide	5,693,524	96.81	96.8
Methane	155,665	2.65	2.7
Nitrous Oxide	31,972	0.54	0.5
TOTAL	5,881,161	100.00	100.00
By Source			
Electricty Generation	3,280,539	55.7804658	55.8
Industrial	130,432	2.217793391	2.2
Commercial	139,375	2.369855204	2.4
Residential	162,125	2.756683587	2.8
Transportation	1,916,844	32.59295231	32.6
Solid Waste	251,846	4.282249712	4.3
TOTAL	5,881,161	100.00	100.1
By Sector			
Residential	1,782,583	30.31005788	30.3
Commercial	1,467,258	24.94844554	24.9
Industrial	462,629	7.866288283	7.9
Transportation	1,916,844	32.59295785	32.6
Solid Waste	251,846	4.28225044	4.3
Total	5,881,160	100.00	100.0

2010 GHG Emissions From Electricity Usage

	GWh	CO2 (tons)	CH4 (tons)	CH4 (tons CO2 Eq)	N2O (tons)	N2O (tons CO2 Eq)	Total GHG (CO2 Eq)	
Residential	2734.968171	1,613,084	19.28152561	404.9120377	22.48143837	6969.245893	1,620,458	1620458.385
Commercial	2241.167382	1,321,841	15.80023004	331.8048309	18.42239588	5710.942723	1,327,883	1327883.269
Industrial	560.673801	330,685	3.952750297	83.00775624	4.608738644	1428.70898	332,197	332197.1246
	5,536.81	3,265,610.16	39.03	819.72	45.51	14,108.90	3,280,539	3,280,539

1179600
296.1
5096.4

1184992.5

592.49625

Natural Gas Data

	Transported Gas	Huntsville Utilities (MSCF)	N AL Gas MSCF)	Total (MSCF)	CO2 (tons)	CH4 (tons)	CH4 (tons CO2 Eq)	N2O (tons)	N2O (tons CO2 Eq)	GHG (Tons CO2 Eq)
natural gas residential county		425,824	518,722							
natural gas residential city		1,727,914								
residential natural gas usage	0	2,153,738	518,722	2,672,459.6	161,149.3	3.1	64.5	2.9	911.3087236	162,125.2
natural gas commercial county		244,452	214,733							
natural gas commercial city		1,838,256								
commercial natural gas usage	0	2,082,708	214,733	2,297,440.7	138,535.7	2.6	55.5	2.5	783.4272787	139,374.6
natural gas industrial county		141,349								
natural gas industrial city	1,376,124	545,172								
industrial natural gas usage	1,376,124	686,520	0	2,062,644.2	124,377.4	2.4	49.8	2.3	703.3616722	125,130.6
TOTAL				7,032,545	424,062.4	8.1	169.8	7.7	2398.097675	426,630.4
Residential (Hsv Utilities)		2,153,738	0	2,153,737.6	129,870.4	2.5	52.0	2.4	734.4245216	130,656.8
Residential (N Al Gas)		518,722	0	518,722.0	31,278.9	0.6	12.5	0.6	176.884202	31,468.3
Commercial (Hsv Utilities)		2,082,708	0	2,082,707.7	125,587.3	2.4	50.3	2.3	710.2033257	126,347.8
Commercial (N Al Gas)		214,733	0	214,733.0	12,948.4	0.2	5.2	0.2	73.223953	13,026.8

						2010 eia co2 em fact		
			kg CO2/MM BTU	lb/kg		120.3694742	lb/1000 scf	
2000 and 2005 emission factors	120.6	2010 EIA emission factors	53.06		2.20462			120.37
	0.682		1029 BTU/scf					0.238198168
	0.0483		5 g CH4/MM BTU					0.070325173
						2010 methane factor		
			0.005			0.01134277	lb/1000 scf	
	121.3303		0.1 g N2O/MM Btu			11.3427699	lb/MM scf	120.6785233
			0.0001			2010 N2O factor		
						0.000226855	lb/1000 scf	
						0.226855398	lb/MM scf	

2010 Coal & Coke GHG Emissions

	Tons	CO_2 (Tons)	CH_4 (Tons)	CH_4 (tons CO_2 Eq.)	N_2O (tons)	N_2O (tons CO_2 Eq.)	Total GHG (tons CO_2 Eq.)
Coal	689	1705.275	0.182585	3.834285	0.02756	8.5436	1717.652885
Coke	1057	3576.3595	0.0689	1.4469	0.02114	6.5534	3584.3598
TOTAL		5281.6345	0.251485	5.281185	0.0487	15.097	5302.012685

		CO_2 Eq. (Metric Tons)	*Values in short tons*	*GWP*	*TPY CO_2 Eq*
Conversion factor	1.10231131				
MSWLF					
Methane (metric tons)	6396.08	134,318	7050.471324	21	148,060
Steam Plant					
Biogenic CO_2 (metric tons)	115675	115675	127509.8608	1	127,510
CO_2 (metric tons)	89887	89887	99083.45672	1	99,083
Methane (metric tons)	70.12	1472.52	77.29406906	21	1,623
N_2O (metric tons)	9.012	2793.72	9.934029526	310	3,080
Steam Plant Sub-Total		209,828			231,296
Steam Plant - Non-Biogenic		94,153			103,786
Solid Waste TOTAL		344,146			379,356
Solid Waste Total - Non- Biogenic		228,471			251,846

Municipal GHG Emissions and Energy Usage

	2000	2005	% Change	2010	% Change (2005)	Overall % Change (2000)
Electricity	25,253	26,559	5.17%	23,125	-12.93%	-8.43%
Natural Gas	6,684	4,493	-32.78%	6,104	35.86%	-8.68%
Motor Fuel	14,125	14,986	6.10%	15,316	2.20%	8.43%
TOTAL	46,062	46,038	-0.05%	44,545	-3.24%	-3.29%
Electricity Usage (GWh)	35.08	39.77	13.37%	39.03	-1.86%	11.26%
Natural Gas Usage (MSCF)	110,211	74,077	-32.79%	100,646	35.87%	-8.68%
Gasoline Usage (gal)	786,818	794,029	0.92%	894,691	12.68%	13.71%
Diesel Usage (gal)	544,100	620,228	13.99%	575,125	-7.27%	5.70%
Motor Fuel (gal)	1,330,918	1,414,257	6.26%	1,469,816	3.93%	10.44%
NG Usage (BTU)	110,211,000,000	74,077,000,000		100,646,000,000		
NG Usage (kWh)	32,297,210	21,708,182		29,494,198		
NG Usage (GWh)	32.30	21.71		29.49		
NG + Electricty (GWh)	67.38	61.48	-8.76%	68.52	11.46%	1.70%

Appendix B

On-road Mobile Source GHG Emission Summary - 2010

	VMT	Fuel (gal)	CO2 (tons)	CH4 (tons)	CH4 (tons CO2 Eq)	N2O (tons)	N2O (tons CO2 Eq)	GHG (tons CO2 Eq)
Gasoline	3,214,482,833	165,126,981	1,622,125	219.3	4605.3	35	10819	1,637,549
Diesel	141,866,860	13,983,143	156,478	4.7	98.7	1	155	156,732
TOTAL	3,356,349,693	179,110,124	1,778,603	224	4704	35	10974	1,794,281

City Gasoline and Diesel GHG Emissions

	VMT	Fuel (gal)	CO2 (tons)	CH4 (tons)	CH4 (tons CO2 Eq)	N2O (tons)	N2O (tons CO2 Eq)	GHG (tons CO2 Eq)
Gasoline	17,414,825	894,691	8,789	1.1880826	24.9497346	0.1890747	58.61315847	8,873
Diesel	4,195,638	575,125	6,436	0.139000036	2.919000749	0.0147872	4.584043729	6,443
TOTAL	21,610,463	1,469,816	15,225	1.33	27.87	0.20	63.20	15,316

Gasoline	Methane (lb/mi)	0.000136445	2376.1652	1.1880826	24.9497346
	Nitrous Oxide (lb/mi)	2.17142E-05	378.1494095	0.189074705	58.61315847
Diesel	Methane (lb/mi)	6.62593E-05	278.0000713	0.139000036	2.919000749
	Nitrous Oxide (lb/mi)	7.04886E-06	29.57447567	0.014787238	4.584043729

Includes both taxed and untaxed fuel in fuel total
All fuel economy values taken from FHWA OHPI (Office of Highway Policy Information) Table VM-1 for 2010
Percent diesel vs gasoline engines in each vehicle class taken from MOVES database

MOVES Class	Description	% of Fleet	% Gas	% Diesel	mpg		VMT	VMT (gas)	VMT (diesel)	Gasoline (gallons)	Diesel (Gallons)
11	Motorcycles	0.0266	1	0	43.4	1.15444	3,356,349,693	89,278,902	0	2,057,118	0
20	Passenger Cars	0.3748	0.9962	0.0038	23.3	8.73284		1,253,179,618	4,780,247	53,784,533	205,161
31	Light Trucks	0.4524	0.9768	0.0232	17.2	7.78128		1,483,185,429	35,227,172	86,231,711	2,048,091
32	Light Trucks (Comm)	0.1276	0.8947	0.1053	17.2	2.19472		383,173,367	45,096,854	22,277,521	2,621,910
40	Buses	0.0002	0	1	7.2	0.00144		0	671,270	0	93,232
51	Refuse	0.0022	0.04	0.96	7.3	0.01606		295,359	7,088,611	40,460	971,043
52	Short Haul S-Unit Trucks	0.0018	0.3	0.7	7.3	0.01314		1,812,429	4,229,001	248,278	579,315
53	Long Haul S-Unit Trucks	0.0002	0.3	0.7	7.3	0.00146		201,381	469,889	27,586	64,368
54	Motor Homes	0.002	0.5	0.5	7.3	0.0146		3,356,350	3,356,350	459,774	459,774
61	Short Haul Semi's	0.0093	0	1	5.9	0.05487		0	31,214,052	0	5,290,517
62	Long Haul Semi's	0.0029	0	1	5.9	0.01711		0	9,733,414	0	1,649,731
		1				19.98196		3,214,482,833	141,866,860	165,126,981	13,983,143
								3,356,349,693		179,110,124	
								18.73902836			

FHWA mpg values	vehicle fraction	vehicle fraction/mpg	
	0.0266	0.000612903	
	0.3748	0.016085837	
	0.4524	0.026302326	
	0.1276	0.007418605	
	0.0002	2.77778E-05	
	0.0022	0.00030137	
	0.0018	0.000246575	
	0.0002	2.73973E-05	
	0.002	0.000273973	
	0.0093	0.001576271	
	0.0029	0.000491525	
179,110,124	1	0.05336456	3,356,349,693

Note: VMT = Total Fuel ÷ Σ (vehicle fraction/mpg)

Madison Co.			Mobile	Adjusted Madison County		MOVES Fleet % by Vehicle Class	MOVES VMT by Vehicle Class	VMT	# Vehicles
Passenger Cars	249971	0.703226496	0.3428	0.374787029	Moves 20	0.374787029	1,257,916,331	1,257,916,331	133223
Passenger Trucks	89346	0.251351055							
Commercial Trucks	75	0.000210992	0.5305	0.580001514	Moves 31	0.452401181	1,518,416,565		206169
					Moves 32	0.127600333	428,271,339	1,946,687,904	
TOTAL	355463	0.954788543	0.8733	0.954788543		0.954788543			
					Moves 41	5.62646E-05	188,844		
					Moves 42	4.50117E-05	151,075		
					Moves 43	7.87705E-05	264,381	604,300	64
					Moves 51	0.002211201	7,421,562		
					Moves 52	0.001856733	6,231,846		
					Moves 53	0.000177234	594,858		
					Moves 54	0.002011461	6,751,167	20,999,434	2224
					Moves 61	0.009261161	31,083,694		
					Moves 62	0.002897629	9,725,457	40,809,151	4322
					MC	0.026615991	89,332,573	89,332,573	9461
						1			355463
									(# Mad Co Vehicles)
					Total VMT	3356349693	3356349693	3,356,349,693	355463
							ADVMT	9,195,479	

Vehicle Class	VMT (GAS)	VMT (DIESEL)	VMT (TOTAL)	Gasoline (gal)	Diesel Fuel (gal)	Diesel + Gas (gal)
Motorcycles	89,278,902	0	89,278,902	2,057,118	0	2,057,118
Passenger cars	1,253,179,618	4,780,247	1,257,959,865	53,784,533	205,161	53,989,694
LD Trucks (passenger)	1,483,185,429	35,227,172	1,518,412,601	86,231,711	2,048,091	88,279,802
LD Trucks (Commercial)	383,173,367	45,096,854	428,270,221	22,277,521	2,621,910	24,899,431
Buses	0	671,270	671,270	0	93,232	93,232
Refuse Trucks	295,359	7,088,611	7,383,970	40,460	971,043	1,011,503
Short Haul S-Unit Trucks	1,812,429	4,229,001	6,041,430	248,278	579,315	827,593
Long Haul S-Unit Trucks	201,381	469,889	671,270	27,586	64,368	91,954
Motor Homes	3,356,350	3,356,350	6,712,700	459,774	459,774	919,548
Short Haul Semi Trucks	0	31,214,052	31,214,052	0	5,290,517	5,290,517
Long Haul Semi Trucks	0	9,733,414	9,733,414	0	1,649,731	1,649,731
	3,214,482,835	141,866,860	3,356,349,695	165,126,981	13,983,142	179,110,123
			3,356,349,693			179,110,124

Appendix C

MOVESRunID	HeaderItem	HeaderItemValue
0	Report Description	Summary Report
0	Report Date/Time	2013-3-12 6:54:41
0	MOVES Output Database	march2010_out
0	Emission Process	All
1	Run Date/Time	2013-03-11 16:58:28.0
1	Run Specification	march2010
1	Run Spec File Date/Time	2013-03-11 16:58:10.0
1	Run Spec Description	Madison County Mobile Source Emissions Inventory - 2010
1	Mass Units	ton
1	Energy Units	MMBTU
1	Distance Units	km
1	Time Units	year

MOVES - 2013 Run (Madison Co)

County	CO2	CO2_Equiv	CO	CH4	N2O	NMHC	NOx	Total_PM25	Brake_PM25	ElementC_PM25
1089	2057730	2073342	64295	224	35	5853	8366	204	22	81

OrganicC_PM25	Sulfate_PM25	Tire_PM25	TotalEnergy	TotalHC	VOC	Distance
122	1	6	24564118	6076	6003	5509663744

HPMSVtyp	HPMSVtypeName
10	Motorcycles
20	Passenger Cars
30	Other 2 axle-4 tire vehicles
40	Buses
50	Single Unit Trucks
60	Combination Trucks

yearID	sourceTyp	sourceTypePopulation
2010	11	9461
2010	21	249971
2010	31	89346
2010	32	75
2010	41	20
2010	42	16
2010	43	28
2010	51	786
2010	52	660
2010	53	63
2010	54	715
2010	61	3292
2010	62	1030

355463

HPMSVtyp	yearID	HPMSBaseY·	baseYearOffNetVMT
10	2010	89332573	0
20	2010	1257916331	0
30	2010	1946687904	0
40	2010	604300	0
50	2010	209999434	0
60	2010	40809151	0
		3545349693	

MOVES Mobile Source Run 3/12/13
Data Output Analysis

		CO2	CO2 eq	CH4	N2O	Total Energy	Gallons Fuel	No. Vehicles	Annual VMT (Miles)	ADVMT (Miles)
Gasoline	*(Tons)*	1,825,798	1,841,163	219.3246	34.89799	21,844,666	169,338,496	341,187	3,251,538,913	8,908,326
Diesel		231,933	232,179	4.688034	0.478449	2,719,450	23,647,391	13,520	172,003,697	471,243
Totals from 3/12/13 Model Run		**2,057,731**	**2,073,342**	**224.01263**	**35.37644**	**24,564,116**	**192,985,887**	354,707	3,423,542,610	9,379,569
Actual							*179,110,124*	355,463	*3,356,349,693*	*9,195,479*

Appendix D

Community Greenhouse Gas Emissions in 2010
Detailed Report

Scope 1 + Scope 2

	CO_2 (tons)	N_2O (lbs)	CH_4 (lbs)	Equiv CO_2 (tons)	Bio CO_2 (tons)	Energy (MMBtu)
Residential						
Huntsville, Alabama						
Untitled						
Electricity	1,613,103	44,854	38,290	1,620,457	0	9,334,471
Natural Gas	160,564	606	30,284	160,976	0	2,747,289
Subtotal Untitled	1,773,667	45,460	68,574	1,781,433	0	12,081,760
Subtotal Residential	1,773,667	45,460	68,574	1,781,433	0	12,081,760
Commercial						
Huntsville, Alabama						
Untitled						
Electricity	1,321,742	36,752	31,374	1,327,768	0	7,648,464
Natural Gas	138,033	521	26,034	138,387	0	2,361,769
Subtotal Untitled	1,459,774	37,273	57,408	1,466,154	0	10,010,234
Subtotal Commercial	1,459,774	37,273	57,408	1,466,154	0	10,010,234
Industrial						
Huntsville, Alabama						
Untitled						
Electricity	330,878	9,200	7,854	332,386	0	1,914,676
Commercial Coal	3,922	132	906	3,952	0	37,347
Natural Gas	123,926	467	4,675	124,047	0	2,120,398
Subtotal Untitled	458,725	9,800	13,434	460,385	0	4,072,421
Subtotal Industrial	458,725	9,800	13,434	460,385	0	4,072,421

Community Greenhouse Gas Emissions in 2010
Detailed Report

Scope 1 + Scope 2

	CO_2 (tons)	N_2O (lbs)	CH_4 (lbs)	Equiv CO_2 (tons)	Bio CO_2 (tons)	Energy (MMBtu)
Transportation						
Huntsville, Alabama						
Untitled						
Diesel	157,375	898	834	157,523	0	1,930,797
Gasoline	1,598,147	216,361	173,036	1,633,500	0	20,638,647
OFF ROAD Aviation Gasoline	971	0	0	971	0	12,718
OFF ROAD Jet Fuel	196,317	0	0	196,317	0	2,512,054
Subtotal Untitled	1,952,810	217,259	173,870	1,988,311	0	25,094,215
Subtotal Transportation	1,952,810	217,259	173,870	1,988,311	0	25,094,215

TOTAL GREENHOUSE GAS EMISSIONS

	DNR GHG EI	CACP Results	
Electricity			
Residential	1,620,458	1,620,457	0.0001%
Commercial	1,327,883	1,327,768	0.0087%
Industrial	332,197	332,386	-0.0569%
Electricity Total	3,280,538	3,280,611	-0.0022%
Fuel Combustion			
Residential	162,125	160,976	0.7087%
Commercial	139,375	138,387	0.7089%
Industrial Gas	125,130	124,047	0.8655%
Industrial Coal & Coke	5,302	3,952	25.4621%
Fuel Combustion Total	431,932	427,362	1.0580%
Transportation			
Gasoline	1,637,549	1,633,500	0.2473%
Diesel	156,732	157,523	-0.5047%
Aviation	122,563	197,288	-60.9686%
Transportation Total	1,916,844	1,988,311	-3.7284%
Solid Waste			
Landfill	148,060		100.0000%
Steam Plant	103,786		100.0000%
Solid Waste Total	251,846	0	100.0000%
GRAND TOTAL	**5,629,314**	**5,696,284**	-1.1897%

CARBON DIOXIDE EMISSIONS

	DNR GHG EI	CACP Results	
Electricity			
Residential	1,613,084	1,613,103	-0.0012%
Commercial	1,321,841	1,321,742	0.0075%
Industrial	330,685	330,878	-0.0584%
Electricity Total	3,265,610	3,265,723	-0.0035%
Fuel Combustion			
Residential	161,149	160,564	0.3630%
Commercial	138,536	138,033	0.3631%
Industrial Gas	124,377	123,926	0.3626%
Industrial Coal & Coke	5,282	3,922	25.7478%
Fuel Combustion Total	429,344	426,445	0.6752%
Transportation			
Gasoline	1,622,125	1,598,147	1.4782%
Diesel	156,478	157,375	-0.5732%
Aviation	120,884	197,288	-63.2044%
Transportation Total	1,899,487	1,952,810	-2.8072%
Solid Waste			
Landfill	0		#DIV/0!
Steam Plant	99,083		100.0000%
Solid Waste Total	99,083	0	100.0000%
GRAND TOTAL	5,594,441	5,644,978	-0.9033%

NITROUS OXIDE EMISSIONS

	DNR GHG EI	CACP Results	
Electricity			
Residential	22.48	22.43	0.2224%
Commercial	18.42	18.38	0.2172%
Industrial	4.61	4.60	0.2169%
Electricity Total	45.51	45.41	0.2197%
Fuel Combustion			
Residential	2.90	0.30	89.6552%
Commercial	2.50	0.26	89.6000%
Industrial Gas	2.30	0.23	90.0000%
Industrial Coal & Coke	0.05	0.07	-40.0000%
Fuel Combustion Total	7.75	0.86	88.9032%
Transportation			
Gasoline	34.90	108.18	-209.9713%
Diesel	0.50	0.45	10.0000%
Aviation	5.00	0.00	100.0000%
Transportation Total	40.40	108.63	-168.8861%
Solid Waste			
Landfill	0.00		#DIV/0!
Steam Plant	10.00		100.0000%
Solid Waste Total	10.00	0.00	100.0000%
GRAND TOTAL	**93.66**	**154.90**	-65.3854%

METHANE EMISSIONS

	DNR GHG EI	CACP Results	
Electricity			
Residential	19.28	19.15	0.6743%
Commercial	15.80	15.69	0.6962%
Industrial	3.95	3.93	0.5063%
Electricity Total	39.03	38.77	0.6662%
Fuel Combustion			
Residential	3.10	15.14	-388.3871%
Commercial	2.60	13.02	-400.7692%
Industrial Gas	2.40	2.34	2.5000%
Industrial Coal & Coke	0.25	0.45	-80.0000%
Fuel Combustion Total	8.35	30.95	-270.6587%
Transportation			
Gasoline	219.30	86.52	60.5472%
Diesel	4.70	0.42	91.0638%
Aviation	14.00	0.00	100.0000%
Transportation Total	238.00	86.94	63.4706%
Solid Waste			
Landfill	7,050.00		100.0000%
Steam Plant	77.00		100.0000%
Solid Waste Total	7,127.00	0.00	100.0000%
GRAND TOTAL	**285.38**	**156.66**	45.1048%