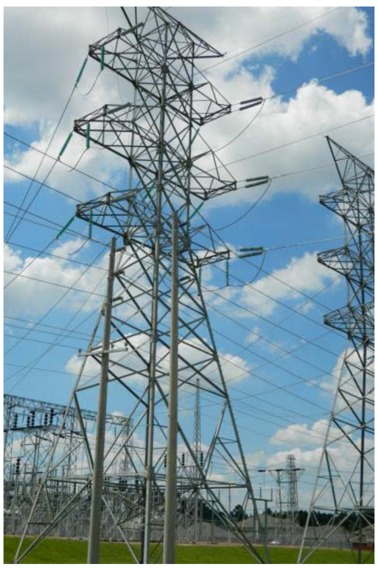
Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama

2015



The City of Huntsville
Division of Natural Resources and Environmental Management

DNR AQEI/03-17

Acknowledgement

The Division of Natural Resources is pleased to recognize the contributions to preparation of this report by Ms. Caroline Cloud, a student intern working for the Division during the summer of 2016. With general direction from DNR staff, Ms. Cloud gathered much of the information necessary for preparing this update to the Greenhouse Gas Emissions Inventory to include emissions in 2015. Ms. Cloud 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. Caroline's dedication, enthusiasm for this project, and hard work greatly accelerated the preparation of this updated greenhouse gas emissions inventory for the Huntsville area.

Table of Contents

Page

Tables

Page

Page

Figures

Executive Summary

The City of Huntsville Division of Natural Resources & Environmental Management developed the first greenhouse gas (GHG) 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. The first such update was completed in 2013 and covered the year 2010. This report constitutes the second update and focuses on the year 2015. Although data for the years 2000, 2005 and 2010 are included for comparative purposes, exhaustive detail regarding information sources, sample calculations, etc. is only provided for year 2015 in this report. Wherever there are significant differences in the methodology employed in the 2015 update relative to the previous inventories, those differences are discussed and explained, but it is otherwise deemed unnecessary to repeat all of the details of prior year inventory development in this report. For those interested in reviewing the methodology utilized in development of the previous inventory in greater detail, the 2013 report, entitled *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Year 2010* (DNR AQEI/05-13; May 2013) is available on the City of Huntsville website at the following address: http://www.huntsvilleal.gov/wp-content/uploads/2016/08/Madison_County_AL_GHG_2010_Inventory.pdf

The 2015 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 previous GHG 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.

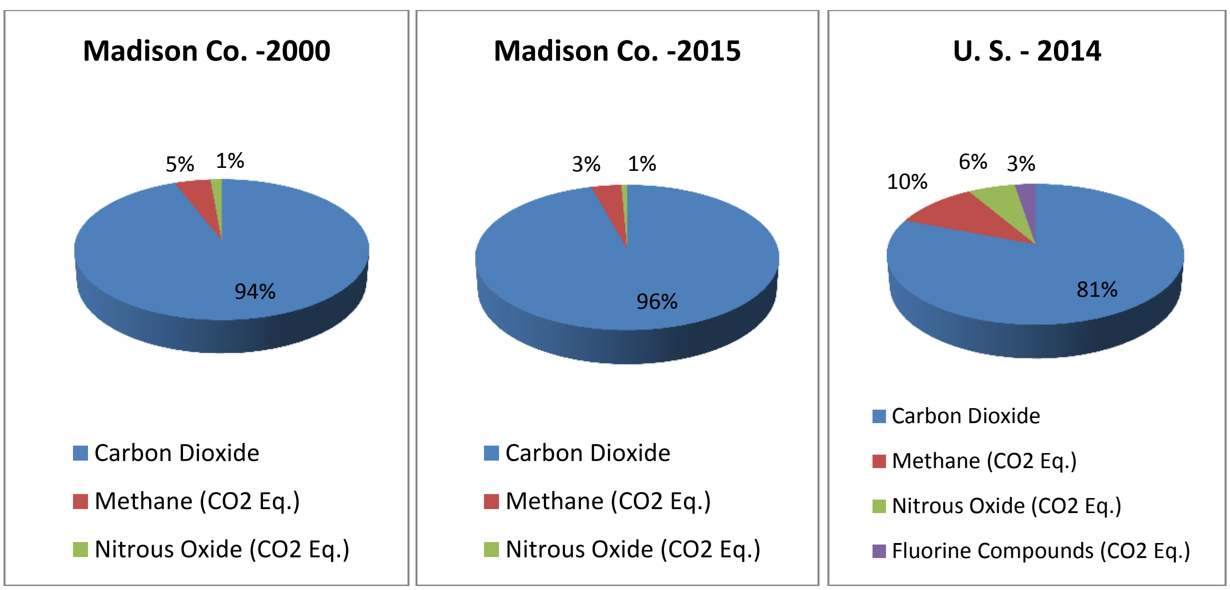
CO_2 is the most important greenhouse gas and is emitted in far larger quantities than any of the other greenhouse gases. However, an equivalent weight of methane, nitrous oxide or the fluorine compounds has a greater "Global Warming Potential" (GWP) than CO_2, and it is therefore conventional practice 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 2015. The relative importance of the different greenhouse gases in the 2014 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 2015, carbon dioxide emissions constituted roughly 96 % of total greenhouse gas emissions in Madison County, compared with roughly 81 % 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 2015. Percentage Contributions are Shown in Parentheses. Percentages from the National Inventory are Included for Comparative Purposes.

	2000		***2015***		***2014 (U.S.)***
CO_2	5,265,982	(94.1 %)	5,081,588	(95.7 %)	80.9 %
CH_4 (CO_2 Eq.)	252,463	(4.5 %)	193,353	(3.6 %)	10.6 %
N_2O (CO_2 Eq.)	79,609	(1.4 %)	36,608	(0.7 %)	5.9 %
Fluorine Compounds		Not Included			2.6 %
TOTAL (CO_2 Eq.)	5,598,054	(100.0 %)	5,311,549	(100.0 %)	100.0 %

Figure ES-1 – Madison County Principal Greenhouse Gas Emissions in Years 2000 and 2015 (Percent). Analogous Information from the 2014 U.S. Inventory is Shown for Comparison.



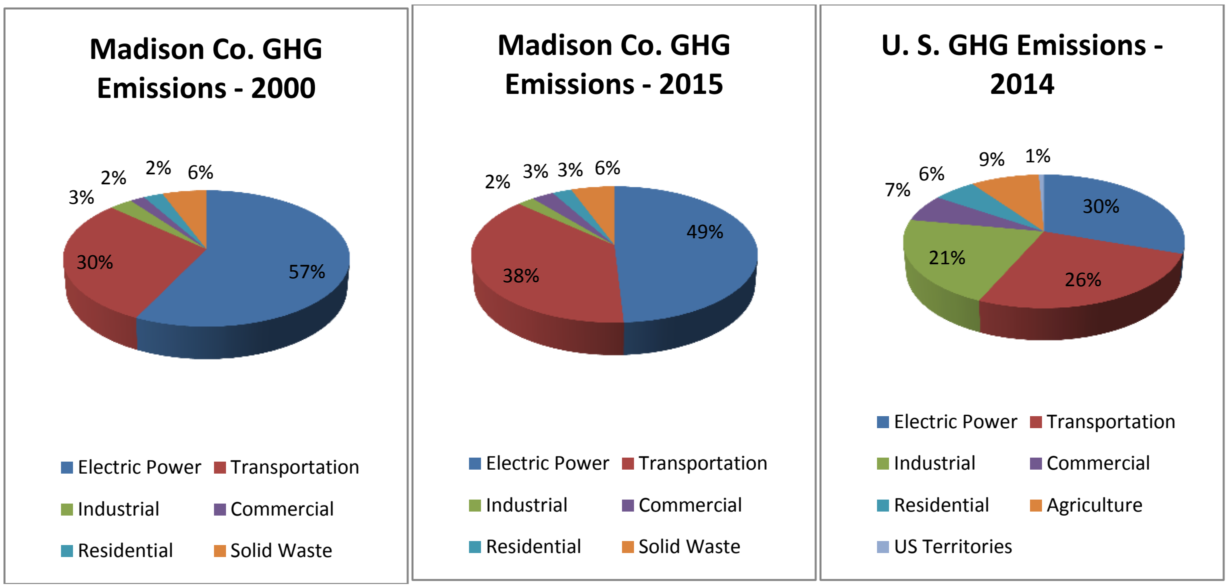
The majority of greenhouse gas emissions are attributable to combustion of fossil fuels (coal, natural gas, gasoline, diesel fuel, etc.). Fuel usage at electric power generating facilities, primarily coal-fired power plants, is responsible for a substantial fraction of national greenhouse gas emissions. 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 just under half of total emissions in Madison County (roughly 49 % in 2015), compared with approximately 30 % 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 38 % of total emissions in 2015. Nationally, transportation contributed roughly 26 % of total emissions.

Table ES-2 shows emission totals by source type for years 2000 and 2015 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 2015. Percentage Contributions are Shown in Parentheses. Percentages from the National Inventory are Included for Comparative Purposes.

	2000		***2015***		***2014 (U.S.)***
Electric Power	3,195,192	(57.1 %)	2,608,720	(49.1 %)	(30.3 %)
Transportation	1,660,017	(29.7 %)	2,004,420	(37.7 %)	(26.3 %)
Stationary Source Fuel Use	425,931	(7.6 %)	401,522	(7.6 %)	
Stationary Fuel Use + Solid Waste Mgt.					(33.6 %)
Solid Waste Management	316,914	(5.7 %)	296,887	(5.6 %)	----
Agricultural	Not Included				(9.1 %)
U.S. Territories	Not Applicable				(0.7 %)
Total	***5,598,054***	***(100.1 %)***	***5,311,549***	***(100.0 %)***	***(100.0 %)***

Figure ES-2 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Source Category in Years 2000 and 2015. Analogous Information from the 2010 U.S. Inventory is Shown for Comparison.



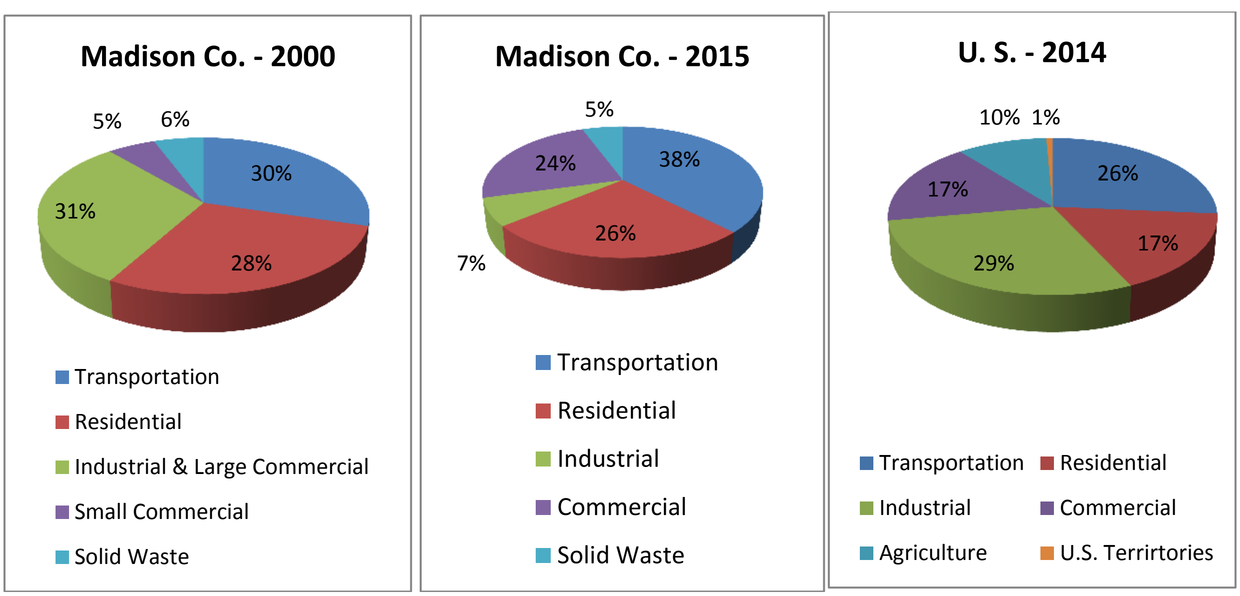
In addition to delineating emissions by the type of source, emissions can be allocated to the different economic sectors. In other words, emissions associated with electric power generation can be assigned to the end users in the residential, commercial and industrial sectors based on their usage. Similarly, 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 2014 U.S. inventory is shown for comparative purposes.

The largest sector nationally is the industrial sector, contributing roughly 29 % of total U.S. greenhouse gas emissions in 2014. In Madison County, industrial facilities constitute a much smaller fraction of the overall inventory, comprising a little less than 7 % 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 early 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 2015.

Table ES-3 – Contribution to Greenhouse Gas Emission Totals (Tons CO_2 Eq.) by Economic Sector in Madison County in Years 2000 and 2015 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 2014 U.S. National Inventory.

	<u>*2000*</u>	<u>*2015*</u>	<u>*2014 (U.S.)*</u>
Industrial		361,180 (6.8 %)	29.2 %
Industrial & Large Commercial	1,721,438 (30.7 %)		
Transportation	1,660,017 (29.7 %)	2,004,720 (37.7 %)	26.4 %
Commercial		1,259,371 (23.7 %)	17.1 %
Small Commercial	310,239 (5.5 %)		
Residential	1,589,448 (28.4 %)	1,389,691 (26.2 %)	16.6 %
Solid Waste Mgt.	316,914 (5.7 %)	296,887 (5.6 %)	Not a Separate Sector
Agricultural	Not Included		10.0 %
U.S. Territories	Not Applicable		0.7 %
Total	***5,598,054 (100 %)***	***5,311,549 (100 %)***	***100 %***

Figure ES-3 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Economic Sector in Years 2000 and 2015, with Emissions from Electricity Consumption Allocated Based on Usage. Analogous Information from the 2014 U.S. Inventory is Shown for Comparison



The transportation sector was the largest contributor to total emissions in the 2015 Madison County inventory, constituting approximately 38 % of the total. In the U.S. as a whole, transportation is responsible for a somewhat lower amount (26 % of total emissions). In contrast, the residential sector contributes a much higher percentage locally than nationally, with residential emissions equal to roughly 26 % of the Madison County inventory in 2015, compared with approximately 17 % nationally. Similarly, commercial emissions are of relatively greater importance locally, constituting a little less than 24 % of the Madison County inventory compared with roughly 17 % nationally. Emissions attributable to solid waste management were just under 6 % of the Madison County total in 2015, 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 10 % 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, 2010, and 2015 as a bar chart, making the changes with time more apparent. As shown in the Figure, Madison County total greenhouse gas emissions increased over the time period from 2000 to 2010. More specifically, 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. However, total emissions then decreased to 5.33 million tons in 2015, a reduction of over 9 % over the five-year period and a reduction of nearly 5 % relative to the year 2000. The overall reduction is due almost entirely to a dramatic change in the emissions associated with electricity usage. This decrease is attributable to changes in the TVA power generation mix, most notably including an increased reliance on natural gas and corresponding reduction in the use of coal in their power plants. Over the five-year period from 2010 to 2015, transportation emissions continued to increase, while fuel usage at stationary facilities decreased slightly and emissions associated with solid waste disposal increased slightly.

Although overall emissions decreased by 5 % in Madison County from 2000 to 2015, the reduction in per capita emissions is actually far greater because the population increased substantially over the same 15-year period. The population increased by 27.5 %, from 276,972 persons in the year 2000 to a 2015 population of 353,089. Per capita emissions in Madison County were 20.2 tons in year 2000, decreasing to 19.4 tons in 2005, then to 17.6 tons in 2010, and more recently to 15.0 tons in 2015. Table ES-4 and Figure ES-5 compare Madison County 2015 per capita emissions with per capita emissions in selected cities and in the U.S. as a whole. Although there are slight differences in the methodology utilized by the various cities in preparing their greenhouse gas inventories, the scope is generally quite similar to that utilized in preparing the Madison County inventory. For purposes of comparing per capita emissions, agricultural emissions and emissions of fluorinated compounds were subtracted from the national inventory to more closely align the scope with that employed locally.

The cities selected for inclusion in Table ES-4 and Figure ES-5 were limited by the availability of greenhouse gas emissions inventories. For many U.S. cities, local greenhouse gas emissions inventories have either not been prepared or are not readily available to the public. However, more comprehensive comparisons of carbon dioxide emissions by state are available. Carbon dioxide is the principal 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

Figure ES-4 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005, 2010 and 2015 by Source. Values are in millions of tons.

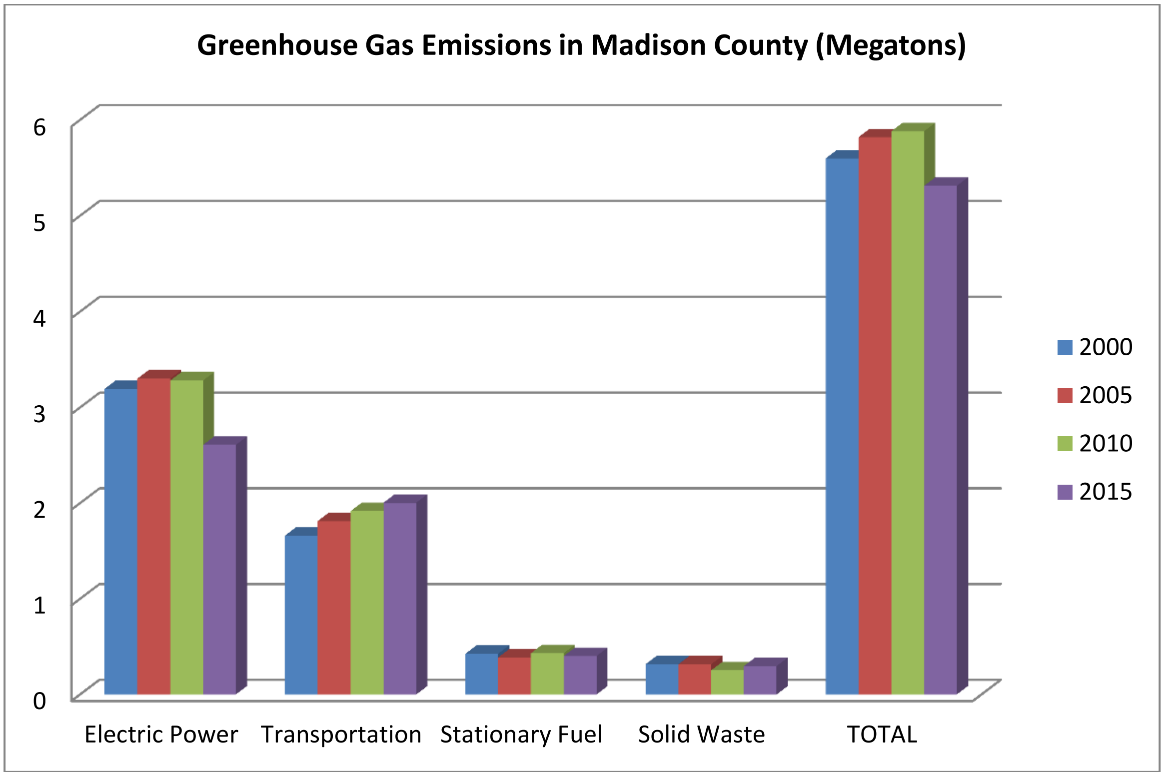


Table ES-4 – Per Capita Greenhouse Gas Emissions for the United States, Selected Cities and Madison County, Alabama. All values are for Year 2014 unless otherwise shown.

	Per capita Emissions (Tons per Year)
Atlanta, GA	22.9
Nashville, TN	22.2
Detroit, MI (2012)	21.1
United States	***21.0***
Madison County, Alabama (2015)	***15.0***
Las Vegas, NV	14.8
Minneapolis, MN (2010)	14.8
Raleigh, NC (2010)	14.7
Boston, MA (2011)	13.7
Baltimore, MD (2010)	13.5
Washington, DC (2013)	13.1
New York, NY	6.4
Seattle, WA	5.7

Figure ES-5 – Comparison of per Capita Greenhouse Gas Emissions in Madison Co., Alabama, Selected Cities and in the United States as a Whole (Tons/Year CO_2 Eq.). All values are for 2014 unless otherwise shown.

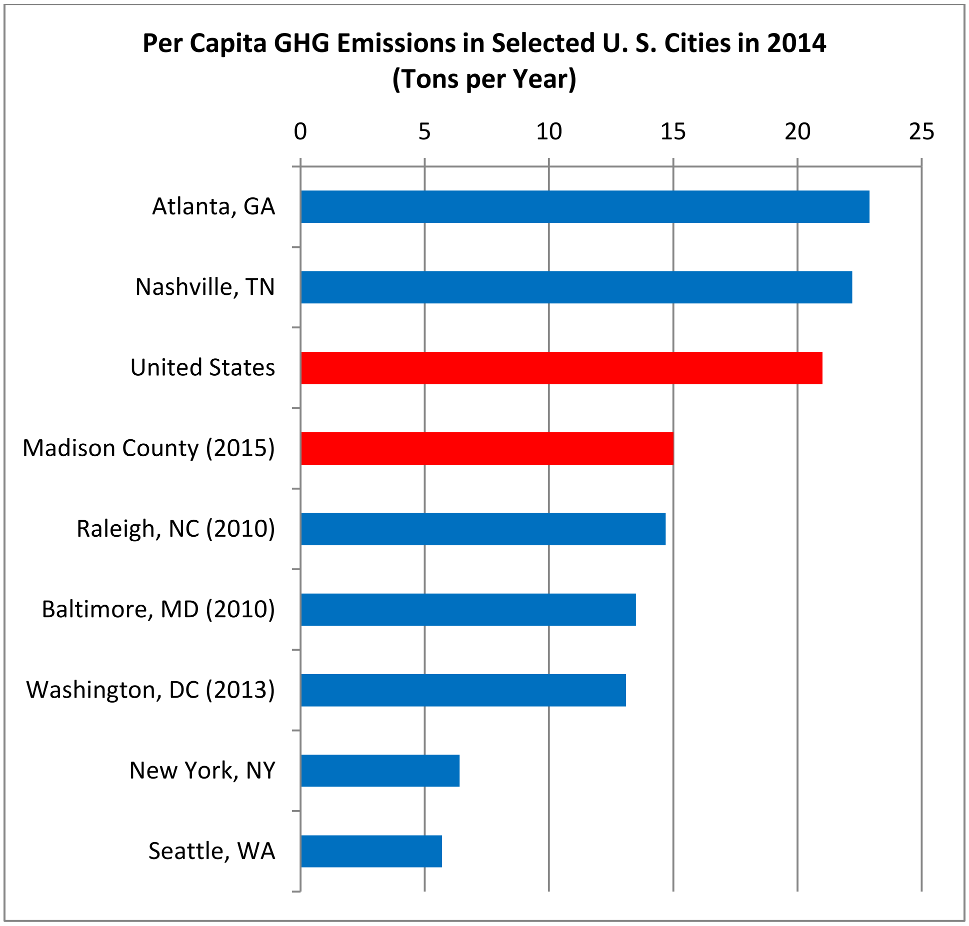
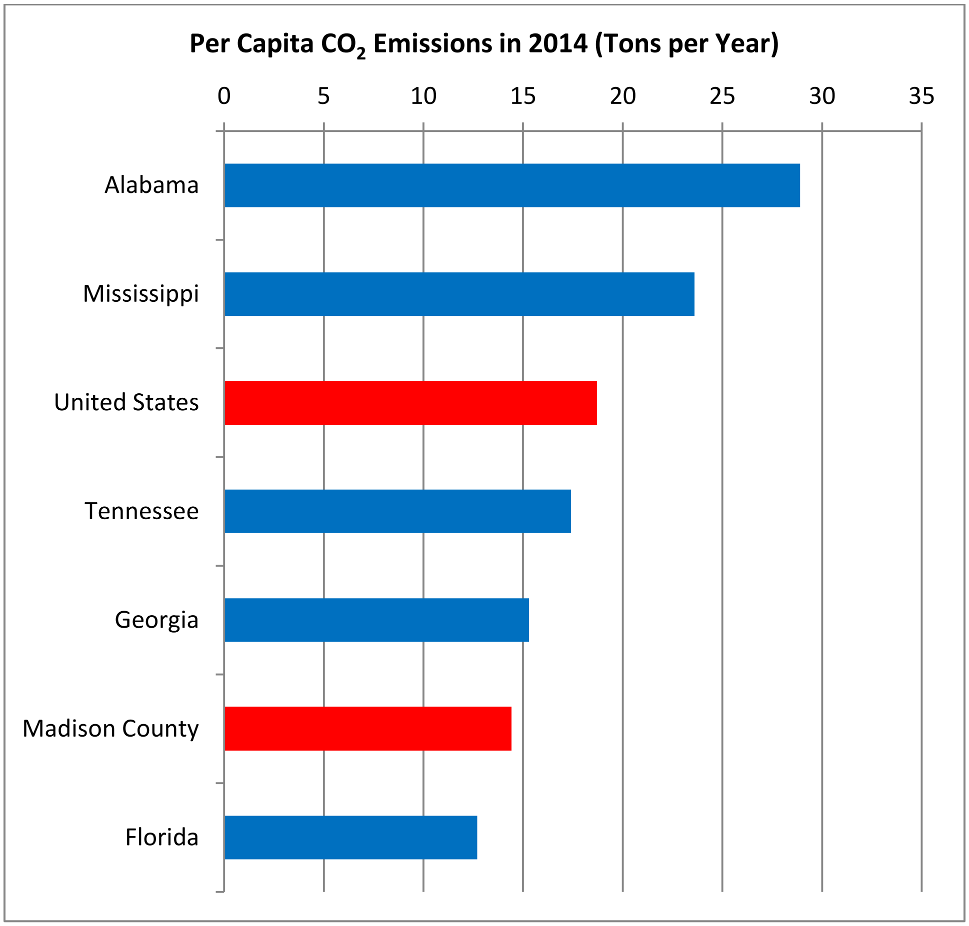


Table ES-5 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion in 2014 for the United States and Selected States and in 2015 for Madison County, Alabama.

	Per capita Emissions (Tons per Year)
Alabama	28.0
Mississippi	23.6
United States	18.7
Tennessee	17.4
Georgia	15.3
Madison County, Alabama	***14.4***
Florida	12.7

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 2014 (Tons/Year).



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, which are based on electricity usage, 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 2015 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 fairly current and all States are included in the analysis allowing a comparison of the Madison County per capita emissions with the State of Alabama as a whole, and with neighboring States. Therefore, they are useful for presentation with the 2015 update to the Madison County inventory. In general, 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 2015 (15.0 tons/year) were lower than the 2014 national average of 21.0 tons per person, and are on the lower end of the range for cities in the Southeastern United States. The 2014 per capita carbon dioxide emissions shown in Table ES-5 exhibit a similar pattern. The Madison County per capita CO_2 emissions of 14.4 tons per year were 23 % lower than the national average of 18.7 tons per year and toward the lower end of the range for the Southeastern United States. In Alabama, per capita emissions of 28.0 tons per year were 94 % higher than in Madison County. This difference is partly because the 2014 State-by-state CO_2 emissions 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. 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 2015. Per capita emissions have declined from 20.2 tons in 2000 to 19.4 tons in 2005 (a decrease of 4 %), from 19.4 tons in 2005 to 17.6 tons in 2010 (a decrease of over 9 %), and from 17.6 tons in 2010 to 15.0 tons in 2015 (a decrease of nearly 15 %). Overall, per capita GHG emissions decreased by roughly 26 % from the year 2000 to the year 2015. However, this reduction in per capita greenhouse gas emissions is not primarily associated with a decrease in per capita energy usage, although both electricity usage and natural gas consumption were lower in 2015 than in 2010, presumably as a result of differences in heating and cooling requirements in the two years. Rather, it largely resulted from a change in the power mix utilized by TVA, which relied less heavily on coal-fired electricity generation in 2015, 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, 2010 and 2015. This information is summarized for years 2000 and 2015 in Table ES-6 and depicted graphically for all four 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 2015) and is depicted graphically for years 2000, 2010 and 2015 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 %. A more significant reduction in total emissions is reflected in the 2015 inventory, dropping to 41,380 tons. This is a redeuction of roughly 7 % from the 2010 total and a reduction of just over 10 % relative to total emissions in the year 2000. There were reductions in each of the three categories from 2010 to 2015, i.e. in the emissions associated with electricity usage, fuel usage at fixed facilities and fuel usage by the City fleet. Similar to the County-wide inventory, there was a notable reduction in total greenhouse gas emissions associated with electricty usage, with total emissions dropping by nearly 8 % from 2010 to 2015 and a reduction of over 15 % relative to the year 2000. However, for City of Huntsville municipal operations, there was an even more dramatic decrease in emissions from fuel usage at fixed facilities, equating to a nearly 18 % reduction from 2010 to 2015 and an almost 25 % reeduction relative to the year 2000. This dramatic reduction in fuel usage is attributable in part to the replacement by the Water Pollution Control Department of the aeration blowers powered by natural gas-fueled engines to electric blowers at the Vermont Road Watewater Treatment Plant. Energy conservation measures implemented by the General Services Department at City buildings also played a role in the decreased natural gas usage and associated greenhouse gas emissions. There was also a decrease in greenhouse gas emissions from municipal fleet operations from 2010 to 2015, but this decrease was much smaller (a little less than 2 %). 2015 emissions from fleet fuel usage were roughly 7 % higher in 2015 than in the year 2000.

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 2015. In 2000, roughly 55 % of municipal government emissions resulted from electricity

Table ES-6 – Greenhouse Gas Emissions (Tons CO_2 Eq.) From City of Huntsville Municipal Government Operations in Years 2000 and 2015.

	2000		***2015***	
Electricity Consumption	25,253	(54.8 %)	21,314	(51.5 %)
Stationary Source Fuel Combustion	6,684	(14.5 %)	5,022	(12.1 %)
Transportation Fuel Combustion	14,125	(30.7 %)	15,044	(36.4 %)
Total	46,062	(100.0 %)	41,380	(100.0 %)

Figure ES-7 – City of Huntsville Municipal Government Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005, 2010 and 2015.

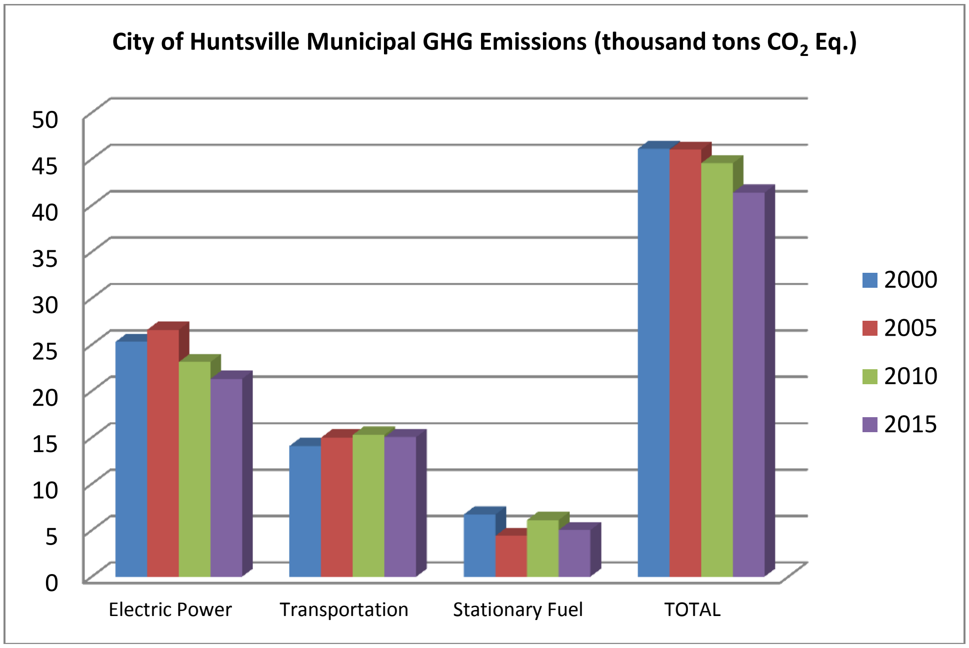
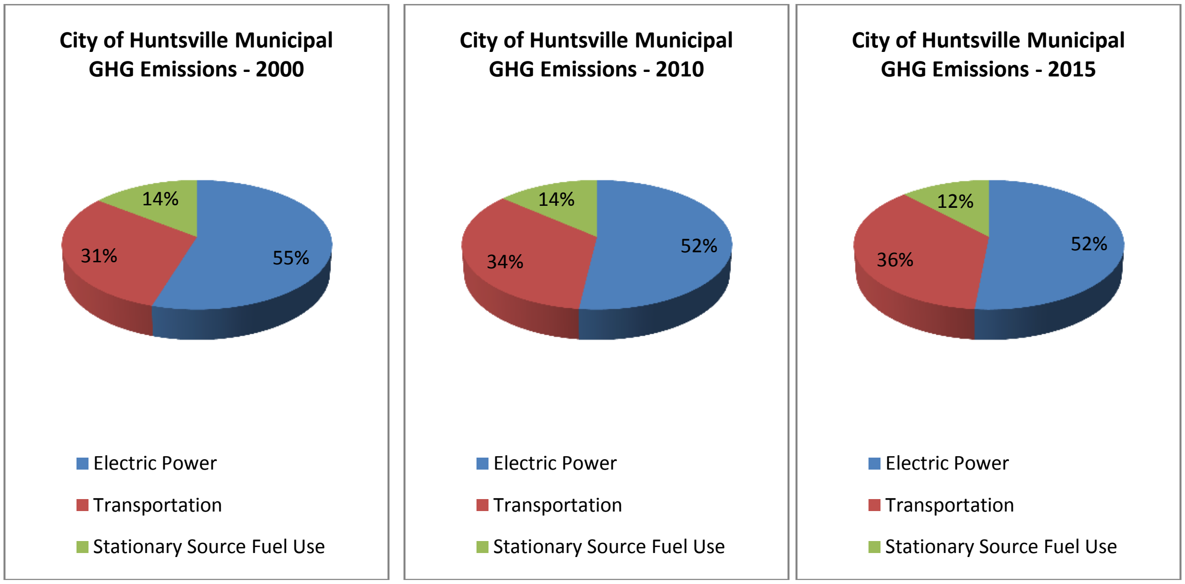


Figure ES-8 – City of Huntsville Municipal Operations Greenhouse Gas Emissions (CO_2 Eq.) by Source in Years 2000, 2010 and 2015.



consumption, compared with a corresponding value of 57 % County-wide. Electricity usage accounted for roughly 52 % of municipal operation emissions in 2015, whereas emissions from electricity use contributed approximately 49 % 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 2015, these percentages are fairly similar as well, with roughly 36 % of total emissions from municipal operations attributed to motor vehicles and 38 % 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 2015, the relative contribution of natural gas combustion to total greenhouse gas emissions for City of Huntsville government declined somewhat to roughly 12 % of the total, but were about the same for the community as a whole, contributing a little less than 8 % 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, a little less than two-thirds of the total emissions from municipal operations are attributable to fixed facility operations (64 %) and roughly one-third of the total emissions are from operation of the City's motor vehicle fleet (36 %).

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. At the time the initial inventory was compiled, periodic updates were envisioned and the first such update focused on the year 2010. This document presents the results of the second update and focuses on the year 2015.[5]

Although data for the years 2000, 2005 and 2010 are included for comparative purposes, exhaustive detail regarding information sources, sample calculations, etc. is only provided for year 2015 in this report. Wherever there are significant differences in the methodology employed in the 2015 update relative to the 2010 inventory, those differences are discussed and explained, but it is otherwise deemed unnecessary to repeat all of the details of previous inventory development in this report. For those interested in reviewing the methodology utilized

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[1] The most recent Air Quality Reports can be accessed on the City's website: http://www.huntsvilleal.gov/wp-content/uploads/2015/06/AQ_Report2015.pdf

[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. The scope of the permitting requirements for major sources of GHG was subsequently narrowed by a U.S. Supreme Court decision. Since the initial mobile source GHG and CAFE standards were promulgated, EPA and DOT have established standards for medium and heavy duty engines and vehicles (September 2011 and October 2016), and EPA and DOT extended the GHG and CAFE standards for passenger vehicles to cover MY 2017-2025 (October 2012). In August 2015, EPA finalized the Clean Power Plan, which limits GHG emissions from power plants, but implementation has been stayed by the U.S. Supreme Court pending legal challenges.

[5] This report, *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Year 2010* (DNR AQEI 05-13), May 2013, can be accessed on the City's website: http://www.huntsvilleal.gov/wp-content/uploads/2016/08/Madison_County_AL_GHG_2010_Inventory.pdf

in development of the previous inventory in greater detail, the 2013 report, entitled *Greenhouse Gas Emissions Inventory for the City of Huntsville and Madison County, Alabama: Year 2010* (DNR AQEI/05-13; May 2013) is available on the City of Huntsville website at the following address:
http://www.huntsvilleal.gov/wp-content/uploads/2016/08/Madison_County_AL_GHG_2010_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 fluorine 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

[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: https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2014

[8] See preceding footnote.

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 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 previous greenhouse gas emissions inventories 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 2015 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

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[9] Under EPA's "Tailoring Rule," a new "major source" of greenhouse gas emissions was 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 was 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. However, in 2014 the U.S. Supreme Court limited the scope of GHG major source permitting requirements to stationary sources that are otherwise subject to major source permitting requirements, i.e. are major for one or more pollutants other than GHG (so-called "anyway" sources). There are currently no industrial sources of GHG emissions subject to these requirements in Huntsville.

[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).

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, 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 2015 Madison County had the highest cotton and corn production of any county in Alabama, and was second in the State in soybean production.[11] Based on USDA (United States Department of Agriculture) estimates, Madison County had 19,000 head of cattle at the start of 2015 (1.5 % 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. 2015 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 the initial inventory years the large commercial accounts were categorized with the industrial customers. Total electricity sales by account type for the years 2000, 2005, 2010, and 2015 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, 2010 and 2015. (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 and 2015, the categories are "residential," "commercial," and "industrial."

Account Type	*Year 2000 (GWh)*	*Year 2005 (GWh)*	*Year 2010 (GWh)*	*Year 2015(GWh)*
Industrial			561	487
Industrial & Lrg Commercial	2145	2323		
Small Commercial	282	341		
Commercial			2241	2190
Residential	2012	2281	2735	2488
TOTAL	4439	4945	5537	5165

(Emissions & Generation Resources Integrated Database)[12] for the years 2000 and 2005. For 2015, 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 2012 were used for nitrous oxide and methane. Although use of these e-GRID emission factors for 2012 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 2012 to 2015, 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 2015. 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) Fourth Assessment Report.[14] The GWP for nitrous oxide, based on a 100-year time horizon, is 298. For methane, the GWP = 25, again for a 100- year time horizon. Using these values for GWP, the carbon dioxide equivalent emission factor for TVA electricity generation in 2015 is calculated as follows:

(1005.08 lb/MWh ÷ 2000 lb/ton * 1000 MWh/GWh) + (15.78 lb/GWh * 298 ÷ 2000 lb/ton) + (14.82 lb/GWh * 25 ÷ 2000 lb/ton) = 505.1 tons CO_2 Eq./GWh in Year 2015

Finally, multiplying the electricity consumption for Madison County (see Table 1) by these emissions factors yields the greenhouse gas emissions from electricity use in 2015, 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, 2005 and 2010 are included for comparison. Figure 1 depicts the relative contribution to total emissions from electricity consumption by economic sector.

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[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 2012. Data for 1996 through 2011 has been archived, but is still accessible using previous versions of eGRID. The eGRID web address is: https://www.epa.gov/energy/egrid

[13] Provided in e-mail communications from Donald Kachelman, Tennessee Valley Authority, to Caroline Cloud, Division of Natural Resources, dated June 21, 2016. Also see TVA's website for emissions information: https://www.tva.gov/Environment/Environmental-Stewardship/Air-Quality

[14] GWP values from the IPCC Fourth Assessment are used in EPA's most recent national inventory of GHG. In previous inventories prepared by DNR, GWP values from the IPCC Second Assessment Report were utilized, consistent with the convention employed by EPA at the time those inventories were prepared. The GWP values used in previous DNR inventories, taken from the Second Assessment Report, were 21 for methane and 310 for nitrous oxide.

The updated GWP values included in the IPCC Fifth Assessment Report are 28 for methane and 265 for nitrous oxide.

Table 2 – Net Power Generation and Greenhouse Gas Emissions Data for TVA in 2000, 2005, 2010, and 2015. (Taken from EPA's eGRID and TVA).

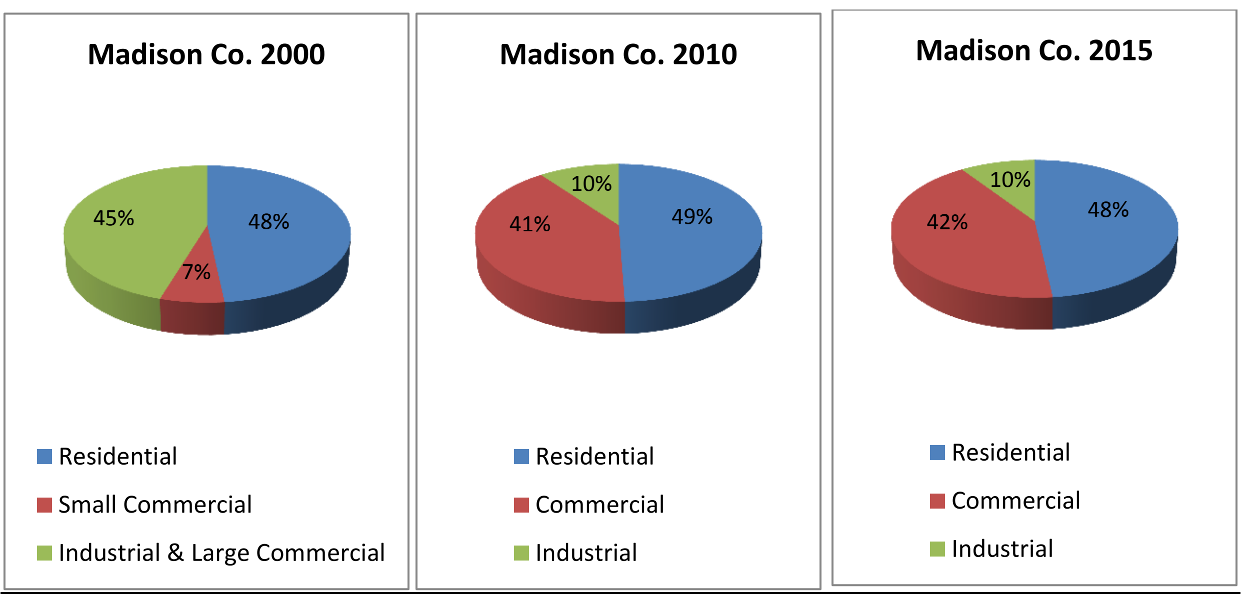
	2000	***2005***	***2010***	***2015***
Net Power Generation(MWh)	153,393,767	158,320,339	146,835,592	139,507,348
CO_2 Emissions (Tons)	109,556,428	105,144,715	86,603,474	70,108,023
CO_2 Emissions (lb/MWh)	1,428.4	1328.3	1179.6	1,005.1
NO_x Emissions (Tons)	285,034.4	190,282.90	70,980	43,682
N_2O Emissions (Pounds)	--	3,570,316	--	2,671,370
N_2O Emissions (lb/GWh)	--	22.55	16.44	15.78
CH_4 Emissions (Pounds)	--	2,427,139	--	2,508,158
CH_4 Emissions (lb/GWh)	--	15.33	14.10	14.82

Note: For 2015, N_2O and CH_4 emission factors are taken from eGRID 2012 and are based on 2012 data. Power generation, CO_2 and NO_x emissions data were provided by TVA for 2015.

Table 3 – Madison County Greenhouse Gas Emissions (Tons CO_2 Eq.) from Electricity Consumption in 2000, 2005, 2010, and 2015 by Economic Sector. Note that large commercial users were grouped with the industrial facilities in 2000 and 2005, but not in 2010 and 2015.

	2000	*2005*	*2010*	*2015*
Industrial	1,543,971	1,551,299	332,197	245,972
Commercial	202,984	227,720	1,327,883	1,106,118
Residential	1,448,238	1,523,252	1,620,458	1,256,630
TOTAL	3,195,192	3,302,271	3,280,539	2,608,720

Figure 1 – Greenhouse Gas Emissions from Electricity Consumption by Economic Sector in Years 2000, 2010 and 2015 in Madison County.



Note: Huntsville Utilities categorized electricity sales as "residential," "small commercial," and "industrial and large commercial" in 2000 and 2005. In 2010 and 2015, 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 2015. Recall that this emission factor is 505.1 tons CO_2 Eq./GWh for 2015. This compares with factors of 719.8 tons CO_2 Eq./GWh in year 2000, 667.8 tons CO_2 Eq./GWh in year 2005, and 592.5 tons CO_2 Eq./GWh for 2010. Greenhouse gas emissions associated with electricity usage by the City of Huntsville in 2015 are presented in Table 5.

Table 4 – Electricity Usage (GWh) by City of Huntsville Municipal Government in Years 2000, 2005, 2010, and 2015. (Data provided by the City of Huntsville General Services and Water Pollution Control Departments).

	2000	2005	2010	2015
General Services	19.57	23.16	23.84	22.87
Water Pollution Control	15.52	16.62	15.19	19.33
TOTAL	35.08	39.77	39.03	42.20

Table 5 – Greenhouse Gas Emissions (Tons CO_2 Eq.) Associated with Electricity Usage by City of Huntsville Municipal Government in Years 2000, 2005, 2010, and 2015.

	2000	***2005***	***2010***	***2015***
General Services	14,084	15,463	14,126	11,551
Water Pollution Control	11,169	11,096	8,999	9,763
TOTAL	25,253	26,559	23,125	21,314

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 years 2010 and 2015, 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 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. For 2015, Huntsville Utilities provided the volume of transported gas for the calendar year.[16]

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)[17] 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 2015. 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.[18] Emission factors for methane (2.3 lb/1,000,000 scf) and for nitrous oxide (2.2

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

[16] E-mail communication from Chris Key, Huntsville Utilities, to Caroline Cloud, Natural Resources, dated July 11, 2016.

[17] 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}).

[18] The Energy Information Administration website has a table of carbon dioxide emission factors for various fuels, which can be accessed at: https://www.eia.gov/survey/form/eia_1605/emission_factors.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: https://www.eia.gov/oiaf/1605/January2007_1605bTechnicalGuidelines.pdf lb/1,000,000 scf) were taken from AP-42.[19] 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

$$(2.2\ \text{lb}/10^6\ \text{ft}^3) \div (1000) * 298 = 0.66\ \text{lb}\ CO_2\ \text{Eq.}/1000\ \text{ft}^3\ \text{for}\ N_2O$$

and

$$(2.3\ \text{lb}/10^6\ \text{ft}^3) \div (1000) *25 = 0.06\ \text{lb}\ CO_2\ \text{Eq.}/1000\ \text{ft}^3\ \text{for}\ CH_4$$

Table 6 – Madison County Natural Gas Combustion in Years 2000, 2005, 2010, and 2015 in Thousands of Standard Cubic Feet. (Based on information from Huntsville Utilities, and North Alabama Gas District).

	2000	***2005***	***2010***	***2015***
Huntsville Utilities				
Residential (1000 ft^3)	1,785,169	1,984,915	2,153,738	1,825,010
Commercial (1000 ft^3)	1,768,423	1,975,869	2,082,708	2,168,687
Industrial (1000 ft^3)	2,689,759	620,013	686,520	332,633
Transported Gas (1000 ft^3)		1,048,965	1,376,124	1,504,418
Adjusted Industrial(1000 ft^3)	2,689,759	1,668,978	2,062,644	1,837,051
North Alabama Gas District				
Residential(1000 ft^3)	543,101 (2001)	668,822	518,722	368,715
Commercial(1000 ft^3)			214,733	357,895
TOTAL (1000 ft^3)	6,786,452	6,298,584	7,032,545	6,557,358

* Adjusted Industrial Usage was obtained by adding the volume of transported natural gas in 2005, 2010 and 2015 to the natural gas sold to industrial users by Huntsville Utilities.

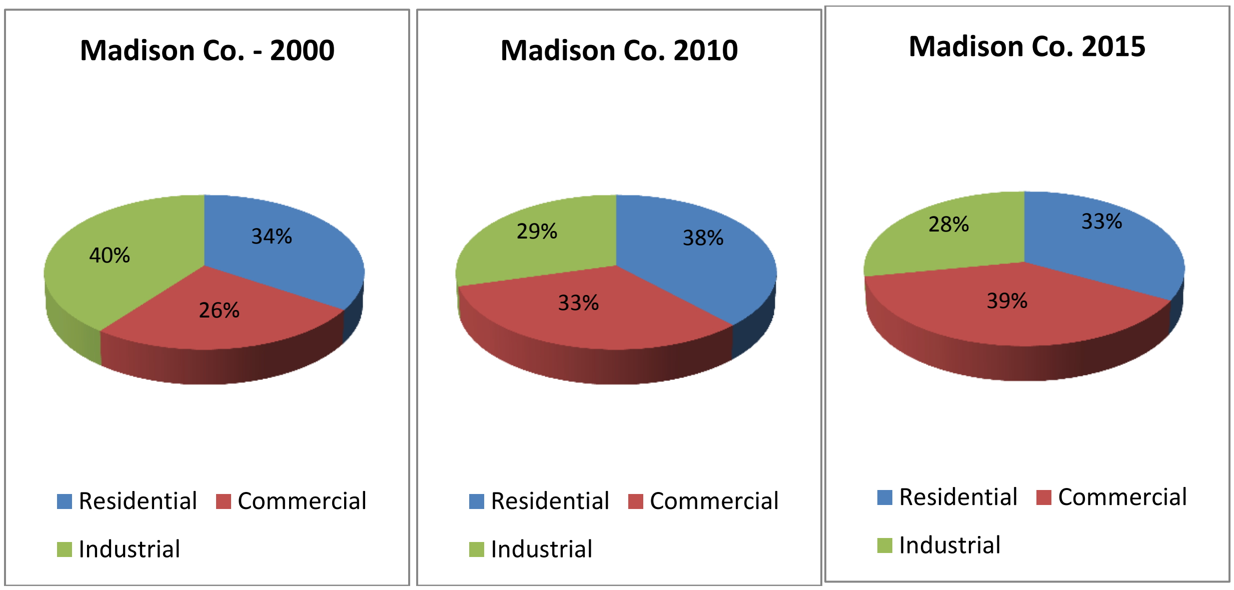
19 *Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Supplement D;* Office of Air Quality Planning and Standards, USEPA; July 1998. Table 1.4-2: "Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion." AP-42 can be accessed at the following web address: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

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 7 – Madison County Greenhouse Gas Emissions (Tons CO_2 Eq.) from Natural Gas Combustion by Economic Sector in Years 2000, 2005, 2010 and 2015.

	2000	***2005***	***2010***	***2015***
Huntsville Utilities				
Residential	108,271	120,385	130,657	110,699
Commercial	107,255	119,836	126,348	131,545
Industrial	163,134	101,224	125,131	111,429
North Alabama Gas District				
Residential	32,939	40,564	31,468	22,365
Commercial			13,027	21,709
TOTAL	411,598	382,009	426,630	397,747

Figure 2 – Madison County Greenhouse Gas Emissions from Natural Gas Consumption by Economic Sector in Years 2000, 2005, 2010 and 2015.



Emissions from Natural Gas Combustion by City of Huntsville Municipal Government

Total natural gas consumption for the year 2015 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.[20] Since the digester gas is burned in a boiler 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 currently produced as 31,000 ft^3/day, with a methane content of 65 % by volume. The equivalent volume of natural gas is thus:

$$(31{,}000\ ft^3/day)*(365\ days/year) * (0.65) = 7{,}354{,}750\ ft^3/year$$

[20] 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.

Note that prior to 2012, digester gas and natural gas were used to fuel industrial engines that drove the aeration blowers at the Vermont Road Treatment Plant. These engines and blowers were replaced with electric blowers, which explains the dramatic reduction in natural gas usage by Water Pollution Control in 2015 relative to 2010. It also partially explains the increased electricity usage over that same time frame. Natural gas volumes combusted in municipal operations in 2015 are shown in Table 8. Usage in the years 2000, 2005 and 2010 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, 2010, and 2015 (data from City of Huntsville General Services and Water Pollution Control Departments).

	2000	***2005***	***2010***	***2015***
General Services Department (1000 ft^3)	65,327	53,280	71,980	72,622
Water Pollution Control Dept. (1000 ft^3)	39,190	15,103	22,972	2,818
Equivalent Volume of Digester Gas (1000 ft^3)	5,694	5,694	5,694	7,355
TOTAL (1000 ft^3)	110,211	74,077	100,646	82,795

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, 2010, and 2015.

	2000	***2005***	***2010***	***2015***
General Services Department	3,962	3,231	4,366	4,405
Water Pollution Control Dept.	2,377	916	1,393	171
Digester Gas	345	345	345	446
TOTAL	6,684	4,493	6,104	5,022

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 2015. Emission factors for bituminous coal and petroleum coke were obtained from the Energy Information Administration and EPA.[21] For bituminous coal, the factor is 5,126 pounds CO_2/ton of coal burned, and for petroleum coke the factor is 6,773 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 EPA. These factors are 0.60 lb CH_4 and 0.09 lb N_2O per ton of coal burned, and 2.12 lb CH_4 and 0.28 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.

5,126 lb/ton + (0.60 lb/ton * 25) + (0.09 lb/ton * 298) = 5,168 lb CO_2 Eq./ton of coal

and

6,773 lb/ton + (2.12 lb/ton * 25) + (0.28 lb/ton * 298) = 6,909 lb CO_2 Eq./ton of coke

Note that these emission factors have been updated and are somewhat higher than those used in previous GHG inventories. Table 10 shows the quantities of coal and petroleum coke burned in 2000, 2005, 2010 and 2015 and the greenhouse gas emissions associated with combustion of these fuels.

[21] See footnote 18. EPA fuel combustion GHG emission factors can be found at the following web address: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

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***	***2015***
Coal Burned (tons)	4262	830	689	560
Petroleum Coke Burned (tons)	1119	1023	1057	675
GHG Emissions from Coal (tons CO_2 Eq.)	10,538	2052	1718	1447
GHG Emissions from Coke (tons CO_2 Eq.)	3795	3469	3584	2332
TOTAL (tons CO_2 Eq.)	14,333	5521	5302	3779

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[22]. 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 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

[22] Reference footnote 7.

private companies was not readily available.[23] 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[24]. Fuel tax revenue data for year 2015 was obtained from the Madison County Commission 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 2015, county fuel tax revenue was $5,309,040 which equates to fuel sales of 176,968,000 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.[25] The fuel consumption values for 2000, 2005 and 2010 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 determine the fraction of the total that consists of diesel, and the fraction that consists of gasoline.

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[23] 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).

[24] *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/

[25] 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, 2010, and 2015.

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
Year 2015			
Taxed Fuel	176,968,000		
City of Huntsville		899,230	544,011
Madison County		395,944	442,272
Madison County Schools		28,612	362,837
Huntsville Utilities		213,009	301,998
Redstone Arsenal		4,398,347	134,801

In preparing past GHG inventories for Madison County, vehicle registration data from the Madison County Tax Assessor's Office was used to allocate VMT (Vehicle Miles Travelled) and fuel usage among the various vehicle classes. This approach had the advantage of using local data, which reflects the actual fleet composition based on vehicle registration. However, it also had a few disadvantages. First, it failed to account for vehicles that travel through Madison County but are registered elsewhere. Second, it relied on the assumption that the number of vehicles in each class was directly proportional to the VMT actually driven by vehicles in that class, i.e. the number of miles travelled by a passenger car was the same as the number of miles travelled by a heavy duty diesel vehicle. Both of these limitations would tend to understate the volume of diesel fuel consumed and overstate the volume of gasoline consumed.

A different approach was taken in the preparation of the 2015 inventory. Rather than using local vehicle registration data, national data from the Federal Highway Administration on urban VMT by vehicle class was used as the starting point for allocating total fuel usage among the gasoline-fueled and diesel-fueled vehicles.[26] Because this method relies on VMT rather than vehicle registration data, it avoids both of the limitations inherent in the approach used in previous inventories. However, it injects another limitation, i.e. it relies on national data which may not reflect the actual VMT distribution among the various vehicle classes in Madison County. Because Madison County contains an interstate spur, but there is no major north-south interstate nor major east-west interstate that traverses the County, the proportion of Madison County VMT attributable to long-distance combination trucks may well be lower than in most urban areas of the nation. If so, the use of national urban VMT to allocate diesel and gasoline usage would tend to overstate the volume of diesel consumed and understate the volume of gasoline consumed.

In addition to VMT distribution by vehicle class, information on fuel economy is needed for each vehicle class to apportion total fuel consumption between diesel and gasoline fueled vehicles, as is information on the fraction of vehicles in each class that use diesel fuel versus gasoline. Average fuel economy for each vehicle class was taken from FHWA data, as was the VMT distribution data.[27] The composition of the fleet by vehicle class and fuel type was taken from U.S. Department of Transportation data.[28] The information on urban VMT distribution by vehicle class, the fraction of each vehicle class that is diesel-fueled versus gasoline-fueled, and the average fuel economy by vehicle class is summarized in Table 12.

For each vehicle class, the relationship between VMT and fuel economy 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)

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[26] Highway statistics for 2015 can be found at the Federal Highway Administration web address: https://www.fhwa.dot.gov/policyinformation/statistics/2015/
Table vm-1 (2014) was used as the source of the urban VMT distribution utilized in this report. This Table can be accessed at: https://www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm

[27] See footnote 26. Reference Table VM-1.

[28] US DOT Fact Sheet available at the following website:
https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/bts_fact_sheets/oct_2015/html/figure_01_text.html

Table 12 – Urban Area VMT (Vehicle Miles Travelled), by Vehicle Class, Fuel Type, and Average Fuel Efficiency in 2015.

Year 2015

Vehicle Class	***Fraction of Urban VMT***	***Fraction of Class Gasoline-Fueled***	***Fraction of Class Diesel-Fueled***	***Avg. Fuel Eff. Fleet (mpg)***
Motorcycles	0.0063	1	0	43.5
Light-Duty Vehicles (Short Wheel-base)	0.7191	0.9912	0.0088	23.2
Light Duty Vehicles (Long Wheel Base)	0.1998	0.9975	0.0025	17.1
Buses	0.0050	0	1	7.2
Single-Unit Trucks	0.0317	0.1951	0.8049	7.3
Combination Trucks	0.0382	0	1	5.8

Note that the equation on the preceding page is for each vehicle class. Thus there are six equations, each with two unknowns (total Vehicles Miles Travelled), and (total fuel usage by vehicles in the class). For example, short wheel-base Light Duty Vehicles accounted for 71.91 % of the total urban VMT in 2015 based on 2014 FHWA VMT data, and the average fuel economy for this vehicle class was 23.2 miles per gallon. The equation for passenger cars is thus:

(0.7191)*(Total VMT) ÷ 23.2 mpg = (Fuel used by short wheel-base light duty vehicles)

This equation can be rewritten as:

(0.0310 gal/mile) * (Total VMT) = (Fuel used by short wheel-base light duty vehicles)

None of these individual equations are amenable to solution because each equation has two unknown quantities. However, if all six 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 2015 yields:

(0.054436 gallons/mile) * (Total VMT) = 184,689,061 gallons of fuel

Thus, Total VMT for year 2015 = 3,392,802,930 miles. This equates to an overall fuel efficiency of 18.37 miles/gal.

Each vehicle class was then allocated a fraction of total VMT based on the fraction of VMT attributed to that vehicle class. E.g. for the year 2015, 71.91 % of total VMT was attributed to short wheel-base light duty vehicles. For this vehicle class, 99.12 % were gasoline-fueled and only 0.88 % were diesel-fueled. Therefore, the gasoline and diesel fuel used by short wheel-base light duty vehicles in 2015 are calculated as:

(0.7191)* (0.9912)*(3,392,802,930 miles) ÷ (23.2 mpg) = 104,231,152 gallons of gasoline

And

(0.7191)* (0.0088)*(3,392,802,930 miles) ÷ (23.2 mpg) = 930,635 gallons of diesel fuel

The results of these calculations for each vehicle class in year 2015 are presented in Table 13. As shown in the Table, summing the values for all vehicle classes yields total gasoline consumption of 147,135,375 gallons and total diesel consumption of 37,553,686 gallons.

Table 13 – Distribution of VMT (Vehicle Miles Travelled) and Fuel Consumption (gallons) by Vehicle Class in Madison County, Alabama in 2015.

Year 2015

Vehicle Class	***VMT (miles)***	***Gasoline Usage (gallons)***	***Diesel Fuel Usage. (gallons)***
Motorcycles	21,312,135	489,934	-0-
Light Duty Vehicles (Short Wheel-base)	2,439,753,456	104,231,152	930,635
Light Duty Vehicles (Long Wheel-base)	677,900,314	39,542,930	100,363
Buses	16,858,204	-0-	2,341,417
Single Unit Trucks	107,424,703	2,871,359	11,844,354
Combination Trucks	129,554,118	-0-	22,336,917
TOTALS	3,392,802,930	147,135,375	37,553,686

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.

[29] Reference footnote 18. The emission factors are 19.643 lb CO_2/gallon gasoline and 22.377 lb CO_2/gallon diesel fuel. These differ slightly from the factors used in the previous GHG emissions inventory.

(gasoline) = 19.643 lbs/ gal x 147,135,375 gals ÷ 2000 lb/ton = 1,445,090 tons CO_2

(diesel) = 22.377 lbs/ gal x 37,553,686 gals ÷ 2000 lbs/ ton = 420,169 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. The EPA has published tables of weighted average emission factors for methane and nitrous oxide by vehicle class and model year.[30] Very similar emission factors are included in the EIA tabulated emission factors for various fuels.[31] 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. 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.[32] In preparing the 2015 inventory, tabulated emission factors by vehicle class and model year were used, along with the VMT apportioned to each vehicle class, as was done previously. However, information on vehicle age distribution by vehicle class was taken from tabulated data in the MOVES 2014a User Manual (using national age distribution data) rather than being derived from Madison County vehicle registration data.[33] The spreadsheet that incorporates the CH_4 and N_2O emission factors for different vehicle types and model years, the VMT by fuel type and vehicle class, and the fleet age distribution by vehicle class is included in Appendix B. The calculation of total CH_4 and N_2O on-road emissions and the CO_2 Eq. emissions is also shown in the spreadsheet.

These calculations yielded total on-road emissions of methane = 78.6 tons in 2015 (77.3 tons from gasoline combustion and 1.3 tons from diesel combustion) and total on-road nitrous oxide emissions = 60.2 tons in 2015 (58.9 tons from gasoline combustion and 1.3 tons from diesel combustion).

[30] *Greenhouse Gas Inventory Guidance: Direct Emissions from Mobile Combustion Sources*; USEPA Center for Corporate Climate Leadership; January 2016. Emission factors were taken from Tables B-1 and B-2. 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 (diesel-fueled short wheel-base light duty vehicles) and highest for heavy duty gasoline vehicles (gasoline-fueled single-unit trucks). This EPA document can be accessed at: http://www.epa.gov/climateleaders/documents/resources/mobilesource_guidance.pdf

[31] See footnote 18.

[32] MOVES (Motor Vehicle Emissions Simulator) 2014a 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

[33] See the preceding footnote.

Applying the Global Warming Potentials to the on-road mobile source emissions of methane and nitrous oxide in 2015 yields the following:

(78.6 tons CH_4) * (25) = 1,965 tons CO_2 Eq. for methane

And

(60.15 tons N_2O) * (298) = 17,925 tons CO_2 Eq. for nitrous oxide

Greenhouse gas emissions for on-road mobile sources in Madison County are summarized in Table 14. Totals for previous inventory years are shown for comparative purposes. The large reduction in methane emissions can be explained, at least in part, by the larger fraction of vehicles which met EPA Tier 2 tailpipe standards, which took effect in MY 2004 for passenger cars and in 2005 for light duty trucks. However, the Tier 2 tailpipe standards also resulted in dramatic reductions in nitrogen oxide emissions, so on-road N_2O emissions would also be expected to be considerably lower in 2015 than in 2010.

Table 14 – Greenhouse Gas Emissions from Gasoline and Diesel Transportation Fuel Usage in Madison County, Alabama in Years 2000, 2005, 2010 and 2015. All values are in Tons Per Year.

	2000	***2005***	***2010***	***2015***
CO_2	1,458,386	1,617,570	1,778,603	1,865,260
CH_4	255	196	224	79
N_2O	167	150	35	60
TOTAL (CO_2 Eq.)	1,515,509	1,668,532	1,794,281	1,885,149

Greenhouse Gas Emissions from Aviation in Madison County

Nationally, aviation is the second largest source of greenhouse gas emissions within the transportation sector.[34] The Huntsville International Airport is the largest of three area airports and the only airport providing commercial airline service. Although two smaller airports are

[34] See Footnote 7.

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.[35] As noted previously, emission estimates can be based on aviation landing and take-off operations (LTOs)[36] which occur near the airport at altitudes of less than 3000 feet. LTO data was obtained from the Huntsville International Airport for the year 2015. The emission estimates are made by multiplying the LTO data by default emission 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 [37]. 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 2015:

(39,823 LTO) * (5908 lb/LTO) ÷ (2000 lb/ton) = 117,637 tons CO_2
(39,823 LTO) * (0.66 lb/LTO) ÷ (2000 lb/ton) = 13.1 tons CH_4 = 329 tons CO_2 Eq.
(39,823 LTO) * (0.22 lb/LTO) ÷ (2000 lb/ton) = 4.4 tons N_2O = 1,305 tons CO_2 Eq.

Table 15 – Madison County Greenhouse Gas Emissions (Tons) from Aviation in Years 2000, 2005, 2010 and 2015.

	2000	***2005***	***2010***	***2015***
LTO cycles	48,250	48,729	40,922	39,823
CO_2	142,531	143,945	120,884	117,637
CH_4	16	16	14	13.1
CH_4 (CO_2 Eq.)	334	338	284	329
N_2O	5	5	5	4.4
N_2O (CO_2 Eq.)	1,643	1,674	1,395	1,305
Total GHG Emissions (CO_2Eq.)	144,508	145,957	122,563	119,271

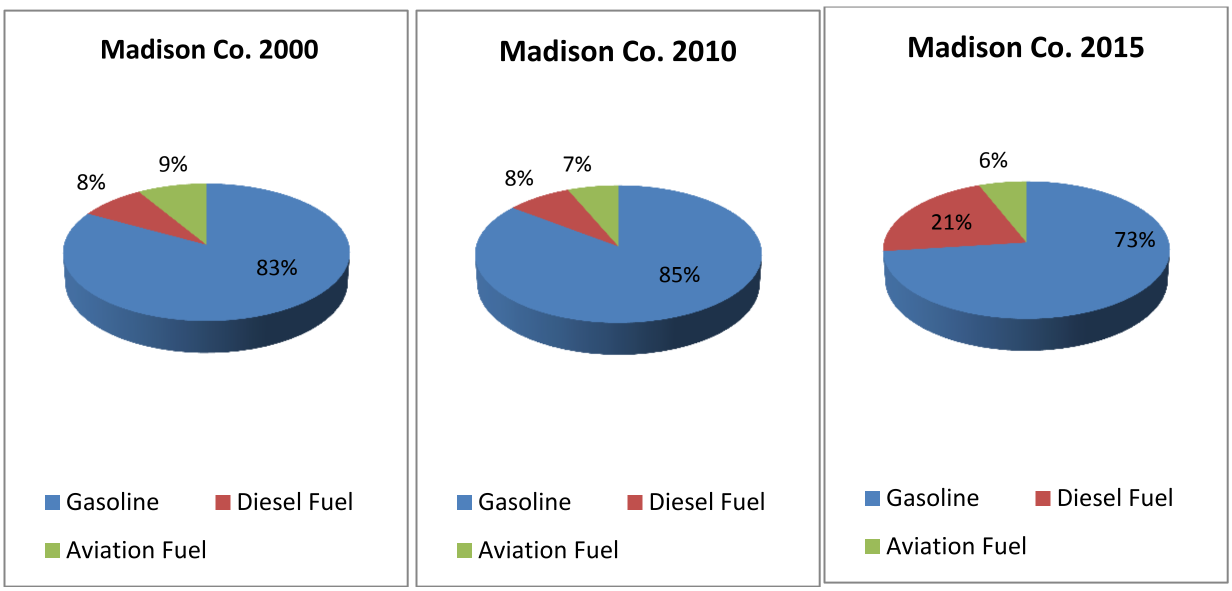
[35] *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories Background Paper: Aircraft Emissions;* Intergovernmental Panel on Climate Change; 2000. This document can be accessed at the following website: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_5_Aircraft.pdf

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

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

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

Figure 3 – Greenhouse Gas Emissions from Gasoline, Diesel and Aviation Transportation Fuel Combustion in Years 2000, 2010 and 2015.



Emissions from Transportation Fuel Consumption by City of Huntsville Municipal Government

Fuel usage data by the City of Huntsville fleet in 2015 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 2015:

(gasoline) = 19.643 lbs/gal x 899,230 gal ÷ 2000 lb/ton = 8832 tons CO_2

(diesel) = 22.377 lbs/gal x 544,011 gal ÷ 2000 lbs/ ton = 6087 tons CO_2

Estimation of nitrous oxide and methane emissions from the City of Huntsville mobile source fleet was done based on VMT for each vehicle class, similar to the method used for Madison County on-road emissions. VMT was in turn calculated from total gasoline and diesel usage, FHWA data on urban VMT by vehicle class, 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 is the assumption that VMT by the City fleet mirrors the national urban VMT by vehicle class, with a few obvious exceptions (e.g. the City fleet includes no tractor-trailer trucks). 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 2015, 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.

(0.046287 gallons/mile) * (Total Gasoline VMT) = 899,230 gallons of gasoline

AND

(0.137244 gallons/mile) * (Total Diesel VMT) = 544,011 gallons of diesel fuel

Thus, Total Gasoline VMT for year 2015 = 19,427,271 miles. This equates to an overall fuel efficiency of 21.6 miles/gal for gasoline fueled vehicles. Similarly, Total Diesel VMT for year 2015 = 3,963,812 miles. This equates to an overall diesel fuel efficiency of 7.29 miles/gal.

Total VMT for gasoline-fueled vehicles was then apportioned among the gasoline vehicle classes and total VMT for diesel-fueled vehicles was apportioned among the diesel vehicle classes. The age distribution information from the MOVES model was then used to apportion the VMT associated with each vehicle class by Model Year. Finally, the appropriate methane and nitrous oxide emission factors were multiplied by the VMT that had thus been determined for each vehicle class by Model Year. This is the same procedure that was used to develop the County-wide on-road methane and nitrous oxide emissions. These calculations are shown in a spreadsheet included in the Appendix and yielded methane emissions = 0.49 TPY (12.2 TPY CO_2 Eq.) and nitrous oxide emissions = 0.38 TPY (112.8 TPY CO_2 Eq.). City of Huntsville transportation related emissions are summarized in Table 17.

Table 16 – City of Huntsville Municipal Fleet VMT, by Vehicle Class, Type of Fuel, and Average Fuel Efficiency in Year 2015

	Year 2015		
Vehicle Class	***Fraction of Gasoline VMT***	***Fraction of Diesel VMT***	***Avg. Fuel Eff. (mpg)***
Motorcycles	0.0068	-0-	43.5
SWB Light-Duty Vehicles	0.7772	-0-	23.2
LWB Light-Duty Vehicles	0.2160	-0-	17.1
Buses	-0-	0.1357	7.2
S-Unit Trucks	-0-	0.8643	7.3

Table 17 – Greenhouse Gas Emissions From City of Huntsville Municipal Fleet Operations in Years 2000, 2005, 2010 and 2015. All values are in Tons Per Year.

	2000	***2005***	***2010***	***2015***
CO_2	13,787	14,709	15,225	14,918
CH_4	1.5	1.3	1.2	0.5
N_2O	< 1	< 1	< 1	0.4
TOTAL (CO_2 Eq.)	14,125	14,986	15,316	15,044

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,[38] 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

[38] 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).

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 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.[39] 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.[40] 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 2015 are actually lower than this default percentage, constituting roughly 53 % of the total). The national default was used to separate biogenic and non-biogenic emissions in the early 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,[41] reported values for methane, nitrous oxide, biogenic carbon dioxide and non-biogenic carbon dioxide are utilized in the 2010 and 2015 GHG inventories. 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 initial 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 19) to

[39] 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).

[40] *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.

[41] 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.

estimate GHG emissions from the WTE facility. However, this wasn't necessary in 2010 and 2015 since this facility is subject to the Mandatory Greenhouse Gas Reporting Rule. For 2015, emissions from the facility were taken from the annual report submitted by the SWDA pursuant to these reporting requirements.[42]

Reported greenhouse gas emissions for the WTE in 2015 are 117,212 tons biogenic CO_2, 103,943 tons non-biogenic CO_2, 78 tons CH_4 (1,951 tons CO_2 Eq.), and 10.2 tons N_2O (3052 tons CO_2 Eq.). Total GHG emissions from the facility were 226,157 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 108,945 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 the initial 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.[43] Mass emissions of methane were then calculated from these volumetric data using the ideal gas law and molecular weight of methane.[44] For 2010 and 2015, these calculations were not necessary because the MSWLF is now subject to the Mandatory Greenhouse Gas Reporting Rule. Consequently,

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

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

[44] 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 $atm \cdot ft^3 \cdot lb\text{-}mol^{-1} \cdot R^{-1}$. There are 16 pounds of methane per lb mol.

methane emissions were taken from the report submitted by the SWDA pursuant to these reporting requirements.[45]

In 2015, reported methane emissions from the landfill were 7,518 tons (187,942 tons CO_2 Eq.). Note that the methane emissions reported for 2010 and 2015 are based on the estimation protocol prescribed by the Mandatory Greenhouse Gas Reporting Rule, which yields lower estimates than 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, 2010 and 2015.

	2000	**2005**	**2010**	**2015**
Waste-to-Energy Facility				
Biogenic CO_2	132,250	140,749	127,510	117,212
Non-biogenic CO_2	71,212	75,788	99,083	103,943
CH_4			77	78
CH_4 (CO_2 Eq.)			1,623	1,951
N_2O			10	10
N_2O (CO_2 Eq.)			3,080	3052
Municipal Solid Waste Landfill				
CH_4	11,700	11,411	7,050	7,518
CH_4 (CO_2 Eq.)	245,702	239,624	148,060	187,942
TOTAL (CO_2 Eq.)	449,164	456,161	379,356	414,100
TOTAL (Excluding Biogenic CO_2)	316,914	315,412	251,846	296,887

[45] See Footnote 42.

Analysis and Discussion of Inventory Results – Madison County

The results of greenhouse gas emissions inventory development for Madison County are summarized in Table 19.

Table 19 – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005, 2010 and 2015.

	2000	***2005***	***2010***	***2015***
Electricity Usage				
CO_2	3,170,334	3,284,222	3,265,610	2,595,619
CH_4 (CO_2 Eq.)	888	791	820	957
N_2O (CO_2 Eq.)	23,970	17,258	14,109	12,144
TOTAL (CO_2 Eq.)	3,195,192	3,302,271	3,280,539	2,608,720
Stationary Fuel Combustion				
Natural Gas				
CO_2	409,223	379,805	424,062	395,409
CH_4 (CO_2 Eq.)	169	157	170	189
N_2O (CO_2 Eq.)	2,206	2,047	2,398	2,150
TOTAL (CO_2 Eq.)	411,598	382,009	426,630	397,747
Coal and Coke				
CO_2	14,296	5,509	5,282	3,721
CH_4 (CO_2 Eq.)	4	1	5	22
N_2O (CO_2 Eq.)	33	11	15	36
TOTAL (CO_2 Eq.)	14,333	5,521	5,302	3,779
Totals for Stationary Fuel Combustion				
CO_2	423,519	385,314	429,344	399,130
CH_4 (CO_2 Eq.)	173	158	175	211
N_2O (CO_2 Eq.)	2,239	2,058	2,413	2,182
TOTAL (CO_2 Eq.)	425,931	387,530	431,932	401,522

Table 19 (Continued) – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005, 2010 and 2015.

	2000	***2005***	***2010***	***2015***
Transportation Fuels				
Gasoline				
CO_2	1,321,431	1,486,280	1,622,125	1,445,090
CH_4 (CO_2 Eq.)	5,357	4,126	4,605	1,931
N_2O (CO_2 Eq.)	51,633	46,654	10,819	17,549
TOTAL (CO_2 Eq.)	1,378,421	1,537,060	1,637,549	1,464,571
Diesel Fuel				
CO_2	136,955	131,290	156,478	420,169
CH_4 (CO_2 Eq.)	9	12	99	33
N_2O (CO_2 Eq.)	124	169	155	375
TOTAL (CO_2 Eq.)	137,088	131,471	156,732	420,578
Aviation Fuels				
CO_2	142,531	143,945	120,884	117,637
CH_4 (CO_2 Eq.)	334	338	284	329
N_2O (CO_2 Eq.)	1,643	1,674	1,395	1,305
TOTAL (CO_2 Eq.)	144,508	145,957	122,563	119,271
Totals for Transportation Fuels				
CO_2	1,600,917	1,761,515	1,899,487	1,982,897
CH_4 (CO_2 Eq.)	5,700	4,476	4,988	2,293
N_2O (CO_2 Eq.)	53,400	48,497	12,369	19,230
TOTAL (CO_2 Eq.)	1,660,017	1,814,488	1,916,844	2,004,420

Table 19 (Continued) – Summary of Greenhouse Gas Emissions (Tons CO_2 Eq.) in Madison County, Alabama in Years 2000, 2005, 2010 and 2015.

	2000	***2005***	***2010***	***2015***
Solid Waste Management				
Municipal Waste Combustion				
"Biogenic" CO_2	132,250	140,749	127,510	117,212
"Non-biogenic" CO_2	71,212	75,788	99,083	103,943
CH_4 (CO_2 Eq.)			1,623	1,951
N_2O (CO_2 Eq.)			3,080	3,052
Municipal Solid Waste Landfill				
CH_4 (CO_2 Eq.)	245,702	239,624	148,060	187,942
Totals for Solid Waste Management				
CO_2	71,212	75,788	99,083	103,943
CH_4 (CO_2 Eq.)	245,702	239,624	149,683	189,892
N_2O (CO_2 Eq.)			3,080	3,052
TOTAL (CO_2 Eq.)	316,914	315,412	251,846	296,887
GRAND TOTALS				
CO_2	5,265,982	5,507,993	5,693,524	5,081,588
CH_4 (CO_2 Eq.)	252,463	245,049	155,665	193,353
N_2O (CO_2 Eq.)	79,609	67,813	31,972	36,608
TOTAL (CO_2 Eq.)	5,598,054	5,819,701	5,881,161	5,311,549

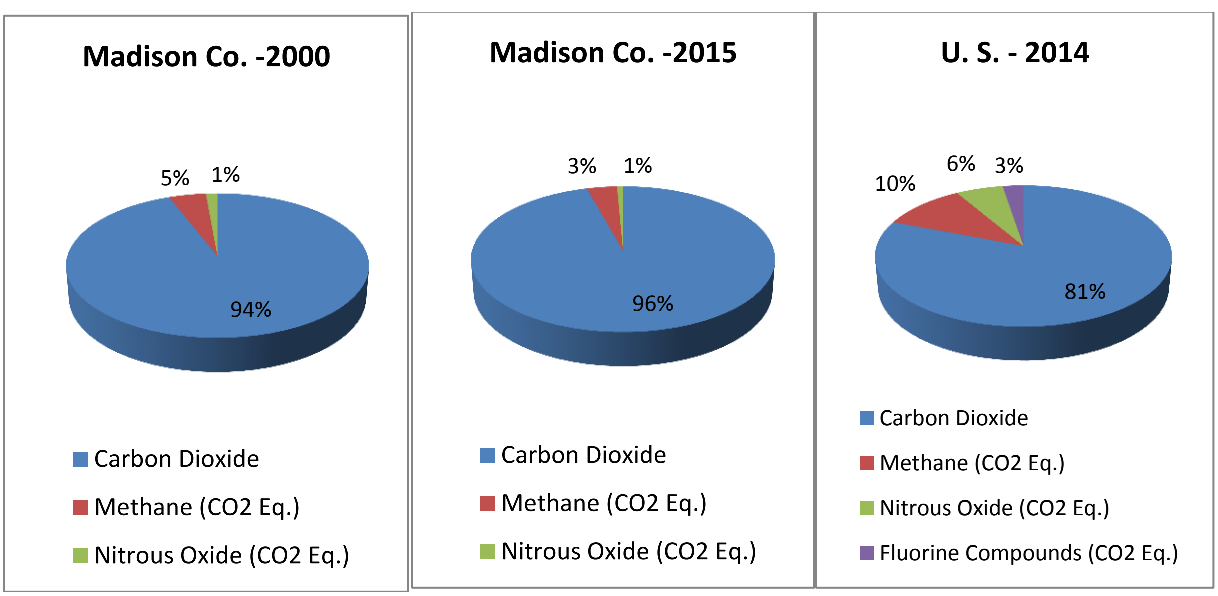
The inventory results show that the overall anthropogenic greenhouse gas emissions for sources evaluated in Madison County were 5.60 million tons CO_2 Eq. in 2000, and 5.82 million tons CO_2 Eq. in 2005, a 4.0 % increase from 2000. In 2010, total GHG emissions were 5.88 million tons, an increase of 1.1 % from the year 2005 and an increase of 5.1 % over the ten-year period from 2000 to 2010. The upward trend in total emissions was reversed in 2015, with total GHG emissions decreasing to 5.31 million tons CO_2 Eq., a decrease of 9.7 % relative to 2010 and a decrease of 5.1 % since the year 2000.

Carbon dioxide is by far the predominant greenhouse gas in the inventory, constituting roughly 96 % of the total in year 2015 on a CO_2 Eq. basis, which is slightly lower than in 2010 (97 %), but slightly higher than in earlier inventory years (94 % in 2000 and 95 % in 2005). Methane emissions were 3.6 % of the total in 2015 on a CO_2 Eq. basis, while nitrous oxide emissions were only 0.7 % of the 2015 total. The contributions of the three principal greenhouse gases to the year 2000, year 2005, year 2010 and year 2015 inventories are shown in Table 21, and are depicted graphically for years 2000 and 2015 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 2014.

Table 20 – Percent Contributions of the Principal Greenhouse Gases to Total Greenhouse Gas Emissions in Madison County, Alabama in Years 2000, 2005, 2010, and 2015 on a CO_2 Eq. Basis. Corresponding Information from the U.S. National Inventory for 2014 is Shown for Comparison.

	2000	***2005***	***2010***	***2015***	***2014 (U.S.)***
CO_2	94.1	94.6	96.8	95.7	80.9
CH_4	4.5	4.2	2.7	3.6	10.6
N_2O	1.4	1.2	0.5	0.7	5.9
Fluorine Compounds		Not Included			2.6
TOTAL	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Figure 4 – Madison County Principal Greenhouse Gas Emissions for Years 2000 and 2015. Analogous Information from the 2014 U.S. Inventory is Shown for Comparison.



Nationally, the relative contributions of the various greenhouse gases to the overall 2014 inventory were 80.9 % CO_2, 10.6 % CH_4, 5.9 % N_2O and 2.6 % fluorine compounds.[46] The lower percentage of methane in the local inventory (3.6 % versus 10.6 % 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 49.1 % of the total in year 2015, a somewhat lower percentage than in previous inventory years. Combustion of transportation fuels is the second largest contributor, constituting 37.7 % of the total emissions in the 2015 inventory, a somewhat higher percentage than in previous inventory years. Following these two dominant source categories is stationary source fuel combustion with 7.6 % of the 2015 total, and solid waste management, which makes up the remainder (5.6 % in 2015). The contributions to total emissions from stationary source fuel combustion can be further broken down into the industrial, residential and commercial components. In 2015, industrial fuel combustion was 2.2 % of total greenhouse gas emissions, residential was 2.5 % and commercial was 2.9 %. Contributions by source category are summarized for years 2000, 2005, 2010 and 2015 in Table 21 and are shown graphically for years 2000 and 2015 in Figure 5, along with comparable data from the 2014 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 30.3 % of total U.S. greenhouse gas emissions in 2014 compared with 49.1 % of the total in Madison County. Transportation was the second largest contributor to U.S. emissions and to local emissions, but again the relative contribution is substantially higher locally than nationally, with transportation accounting for 26.3 % of total U.S. emissions compared with 37.7 % of the Madison County emissions. Industrial emissions contribute far more to the national inventory than to the Madison County inventory, with the 2014 industrial contribution equal to 21.3 % of the total, while locally that contribution was only 2.2 % in 2015. For the commercial sector, the contribution was 6.6 % nationally and 2.9 % locally, while the residential sector contributed 5.7 % nationally and only 2.5 % locally.

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[46] See Footnote 7.

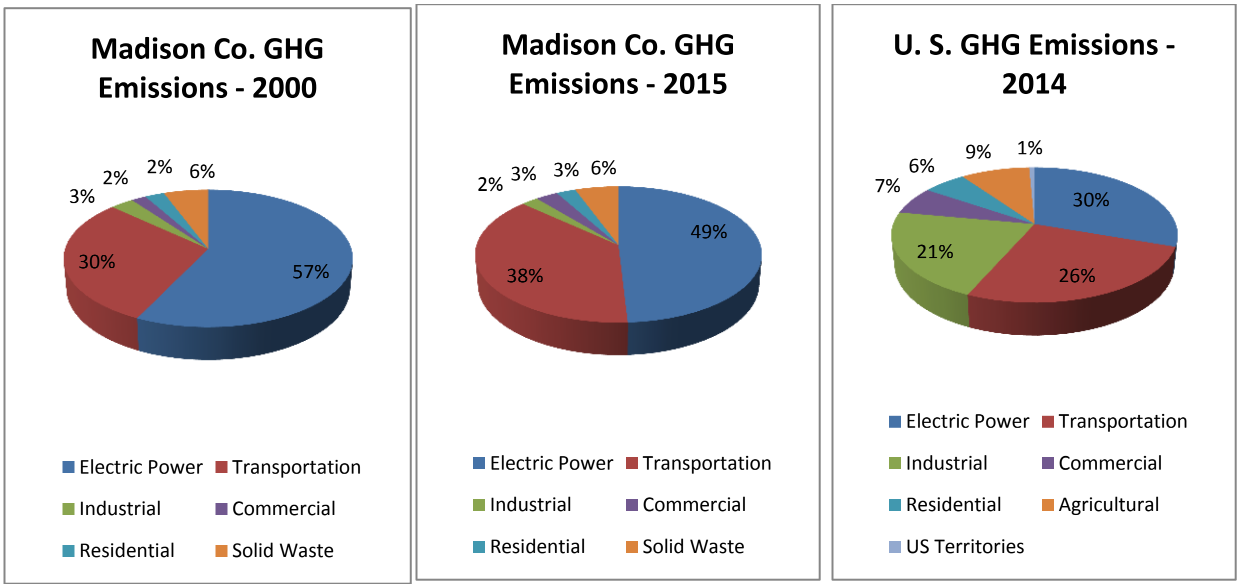
[47] If the agricultural sources are subtracted from the methane and nitrous oxide components of the national inventory for year 2014, and the fluorine compound emissions are also excluded, the percentages come much closer to those obtained in the Madison County inventory: carbon dioxide then accounts for 90.7 % nationally (versus 95.7 % locally), methane accounts for 8.2 % (versus 3.6 % locally), and nitrous oxide accounts for 1.1 % nationally (versus 0.7 % locally). If natural gas system losses of methane are also excluded from the national inventory, the national percentages become: CO_2 = 93.3 %; CH_4 = 5.5 %; and N_2O = 1.1 %.

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 (30.3 % versus 49.1 %), 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.

Table 21 – Percent Contribution to Greenhouse Gas Emission Totals by Source Category in Madison County in Years 2000, 2005, 2010 and 2015. Corresponding Information from the 2014 U.S. National Inventory is shown for Comparison.

	2000	2005	2010	2015	2014 (U.S.)
Electric Power	57.1	56.7	55.8	49.1	30.3
Transportation	29.7	31.2	32.6	37.7	26.3
Industrial	3.2	1.8	2.1	2.2	21.3
Commercial	1.9	2.1	2.4	2.9	6.6
Residential	2.5	2.8	2.8	2.5	5.7
Solid Waste Mgt.	5.7	5.4	4.3	5.6	Not a Separate Sector
Agricultural		Not Included			9.1
U.S. Territories		Not Applicable			0.7
TOTAL	100.1 %	100.0 %	100.0 %	100.0 %	100.0 %

Figure 5 – Madison County Greenhouse Gas Emissions (CO_2 Eq.) by Source Category in Years 2000 and 2015. Analogous Information from the 2014 U.S. Inventory is shown for Comparison.



(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 0.36 million tons CO_2 Eq. (6.8 % of the total) for Madison County in year 2015. Commercial sources contributed 1.26 million tons CO_2 Eq. emissions in year 2015 (23.7 % of the total). Finally, the residential CO_2 Eq. emissions were 1.39 million tons in year 2015 (26.2 % 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 2014 U.S inventory is shown for comparison. Note that for the early inventory years (2000 and 2005), Huntsville Utilities grouped large commercial electric accounts with the industrial users, whereas in 2010 and 2015 the categories of electric accounts were "industrial," "commercial," and "residential." The apparent large shift in percentages from 2000 to 2015 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 29.2 % of the total. In Madison County, the industrial sector contributes a much smaller percentage of the total, just under 7 % of the 2015 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 22 – Percent Contribution to Greenhouse Gas Emission Totals by Economic Sector in Madison County in Years 2000, 2005, 2010 and 2015 with Emissions from Electricity Consumption Allocated Among the Sectors by Usage. Corresponding Information from the U.S. National Inventory for 2014 is shown for Comparison.

	2000	***2005***	***2010***	***2015***	***2014 (U.S.)***
Industrial			7.9	6.8	29.2
Industrial & Large Commercial	30.8	28.5			
Transportation	29.7	31.2	32.6	37.7	26.4
Commercial			24.9	23.7	17.1
Small Commercial	5.5	6.0			
Residential	28.4	28.9	30.3	26.2	16.6
Solid Waste Mgt.	5.7	5.4	4.3	5.6	Not a Separate Sector
Agricultural		Not Included			10.0
U.S. Territories		Not Applicable			0.7
TOTAL	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

The commercial sector accounts for roughly 24 % of the 2015 greenhouse gas emissions in Madison County, as opposed to just over 17 % of the national total, and the residential sector contributes approximately 26 % of the local greenhouse gas emissions whereas this sector accounts for a little less than 17 % of the U.S. total. Finally, the transportation sector constituted about 26 % of the national emissions inventory in 2014, substantially lower than the percentage for Madison County (just under 38 %). 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 10.0 % 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 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 2015. The percentages in the 2014 national inventory are shown for comparative purposes.

Figure 6 – Madison County Greenhouse Gas (CO_2 Eq.) Emissions by Economic Sector in Years 2000 and 2015, with Emissions from Electricity Consumption Allocated Based on Usage. Analogous Information from the 2014 U.S. Inventory is shown for Comparison.

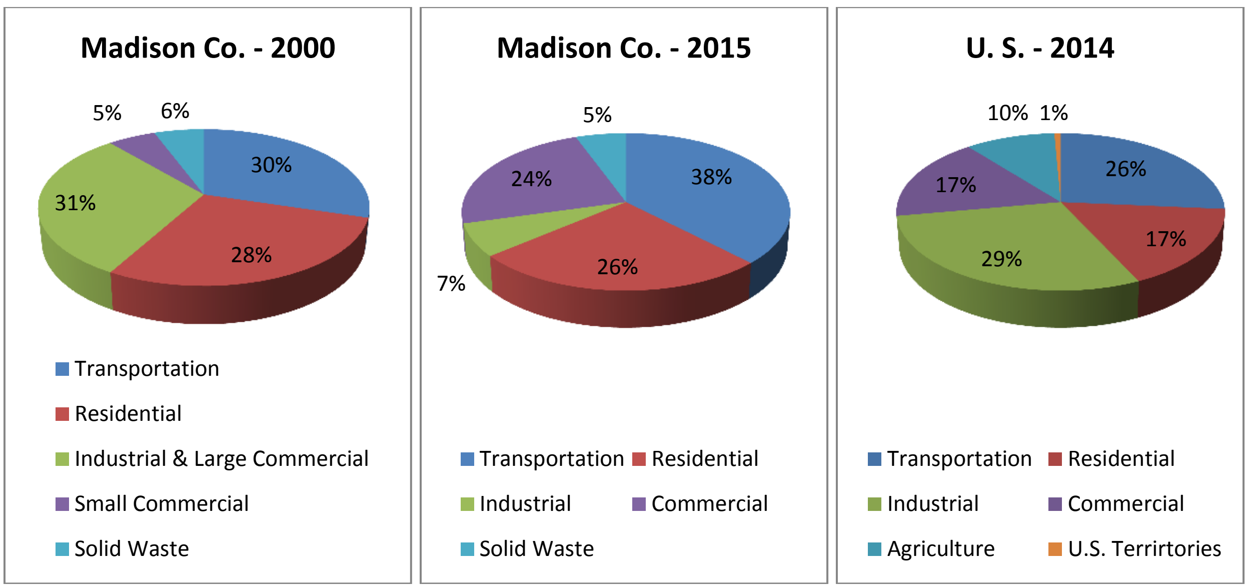


Figure 7 presents the emissions data for Madison County by source type in years 2000, 2005, 2010 and 2015 as a bar chart, making the changes with time more apparent. Overall, emissions increased by 5 % over the ten-year period from 2000 to 2010 (5.60 million tons in year 2000 to 5.88 million tons in 2010). However, total emissions declined significantly from 2010 to

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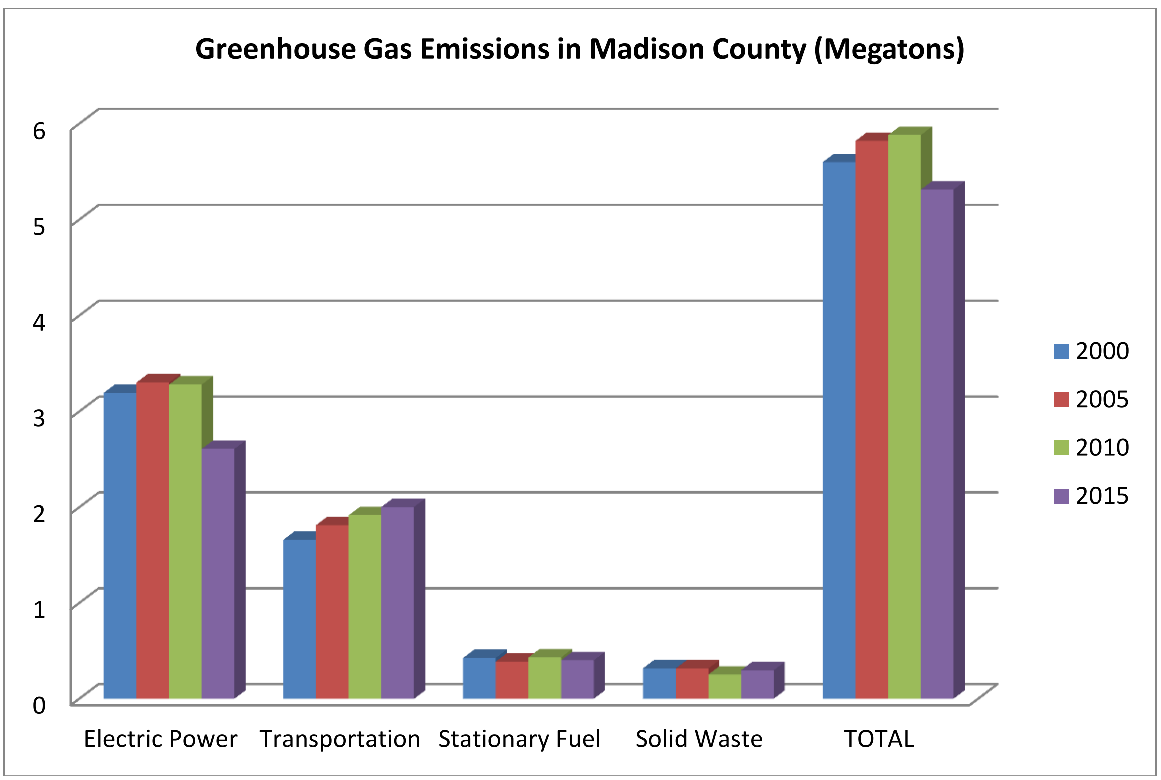
[48] Subtracting the agricultural and U.S Territory emissions from the national totals, and recalculating the percentages among the remaining economic sectors yields 31.9 % from industrial sources, 30.6 % from transportation, 18.6 % from the commercial sector and 18.9 % from residential sources.

2015, dropping to 5.31 million tons (a 9.7 % decrease over the five-year period). In magnitude, the largest decrease occurred in the electric power sector, from 3.28 million tons in year 2010 to 2.61 million tons in 2015, a decrease of 20.5 %. In contrast, emissions associated with transportation fuel usage increased by 4.6 % over the five-year period, from 1.92 million tons in 2010 to 2.00 million tons in 2015. Emissions from stationary fuel combustion, a much smaller component of the overall inventory, decreased by 7.0 % from the year 2010 (0.432 million tons) to year 2015 (0.402 million tons). Although there were increased emissions from commercial natural gas combustion, these increases were more than offset by decreases in emissions from residential and industrial fuel combustion. Finally, emissions from solid waste management increased somewhat over the five-year period, from 0.252 million tons in 2010 to 0.297 million tons in 2015, an increase of roughly 18 %. Although the percentage increase is fairly large, note that emissions from solid waste disposal are a relatively small component of the overall inventory so the actual magnitude of the increase is fairly small.

Figure 7 – Madison County Greenhouse Gas Emissions in Years 2000, 2005, 2010 and 2015 (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 or 2015, the U.S. Census Bureau does develop population estimates for years between the decennial censuses, and estimated the 2005 Madison County population at 299,409. The 2015 Madison County population estimate is 353,089. 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

Year 2015 5,311,549 tons ÷ 353,089 persons = 15.0 tons/person

Consequently, although total greenhouse gas emissions decreased by 9.7 % over the five-year period from 2010 to 2015, annual per capita emissions declined even more dramatically, from 17.6 tons/person to 15.0 tons per person, a decrease of 14.8 %. From the year 2000 to the year 2015, per capita emission declined from 20.2 tons/year to 15.0 tons/ year, a decline of just over 25 %. Madison County per capita emissions in years 2000, 2005, 2010 and 2015 are shown in Figure 8.

For purposes of comparison, per capita greenhouse gas emissions for a number of U.S. Cities are provided in Table 24 and shown in Figure 9. The cities for which comparative data are available is somewhat limited because not all areas have prepared local greenhouse gas emissions inventories or made them readily available to the public.[50] Nevertheless, the

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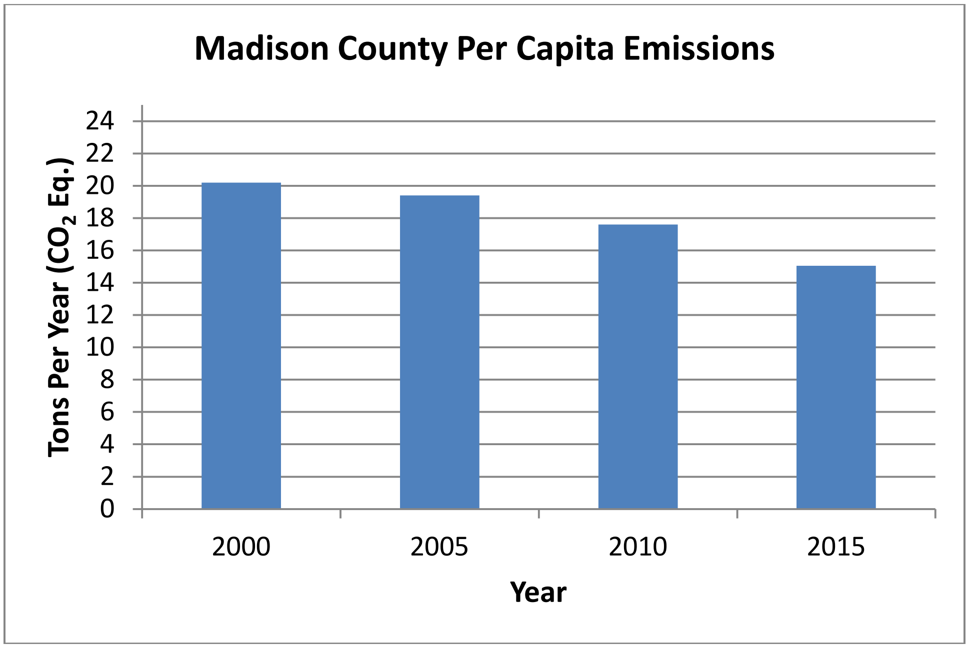
[49] http://www.census.gov/

[50] Greenhouse Gas Emissions Inventories for select cities are available at the following web addresses:
Atlanta (2014): http://p2catl.com/wp-content/uploads/CoA-2014_GHG_Inventory_07-28-2016.pdf
Baltimore (2010): http://www.baltimoresustainability.org/wp-content/uploads/2015/12/BaltimoreClimateActionPlan.pdf
Boston (2011): http://www.cityofboston.gov/images_documents/updatedversionghg1_tcm3-38142.pdf
Detroit (2012): http://css.snre.umich.edu/sites/default/files/css_doc/CSS14-21.pdf
Las Vegas (2014): http://www.clarkcountynv.gov/comprehensive-planning/eco-county/Documents/RegionalGHG.pdf
Los Angeles (2013): https://www.lamayor.org/sites/g/files/wph446/f/landing_pages/files/pLAn%20Climate%20Action-final-highres.pdf
Minneapolis (2010):
http://www.minneapolismn.gov/www/groups/public/@citycoordinator/documents/webcontent/wcms1p-092812.pdf
Nashville (2014): summarized in a newspaper article in *The Tennessean* published on February 7, 2017:
http://www.tennessean.com/story/news/2017/02/07/nashvilles-greenhouse-gas-emissions-vehicles-waste-rise/97598948/
New York (2014): http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC_GHG_Inventory_2014.pdf
Raleigh (2010): https://www.raleighnc.gov/environment/content/AdminServSustain/Articles/SustainabilityReport.html
Seattle (2014): https://www.seattle.gov/Documents/Departments/OSE/ClimateDocs/2014GHG%20inventorySept2016.pdf
Washington, DC (2013): https://doee.dc.gov/service/greenhouse-gas-inventories

Figure 8 – Madison County Greenhouse Gas Emissions Per Capita in Years 2000, 2005, 2010 and 2015 (Tons CO_2 Eq.)



information in Table 24 and Figure 9 is useful for purposes of comparison with the Madison County inventory results.

Per capita emissions in Madison County were equal to 15.0 tons per year in 2015, somewhat lower than the national average of 21.0 tons per year in year 2014. Note that the value for national per capita emissions of 21.0 tons per year was obtained by subtracting the agricultural emissions and the emissions of fluorinated compounds from the national inventory emissions total, and then dividing the adjusted emissions by the U.S. population in 2014. This adjusted total is closer, but still not identical, in scope to the Madison County greenhouse gas emissions inventory. 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 in states on the West Coast and in the Northeast and higher in 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

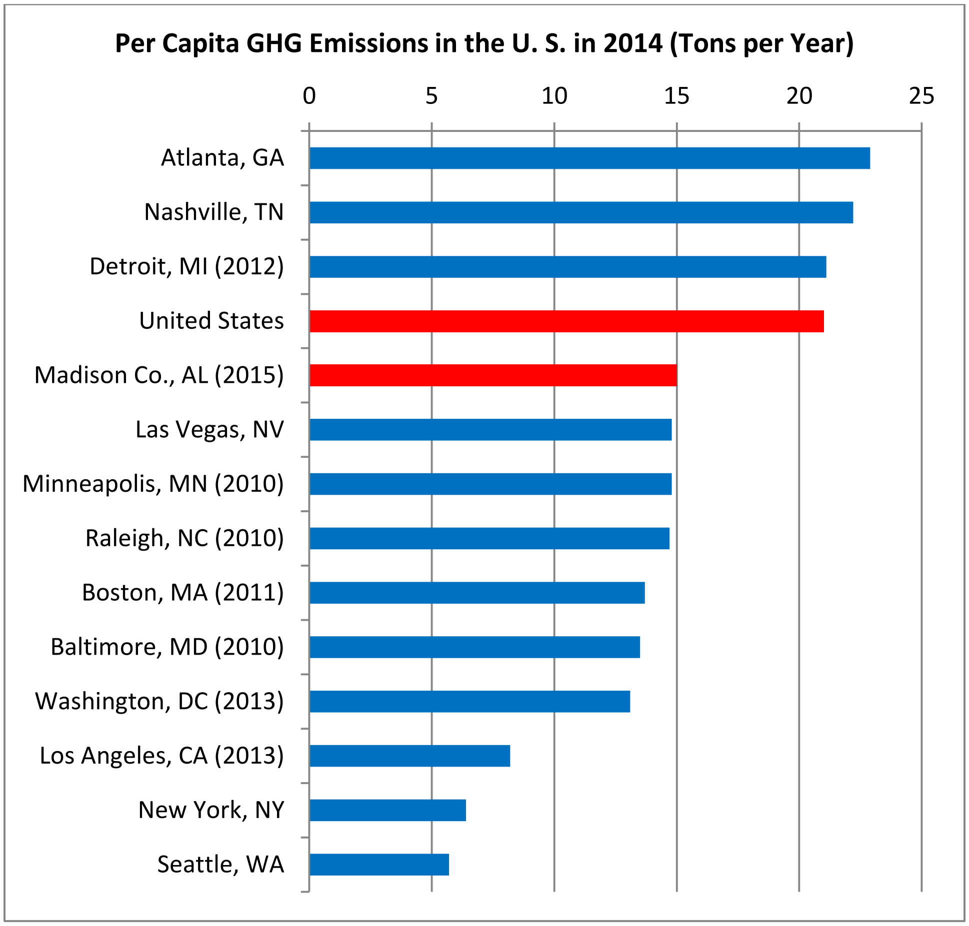
Table 23 – Per Capita Greenhouse Gas Emissions for the United States, Selected Cities and Madison County, Alabama. All values are for Year 2014, except as shown. Note that the per capita emissions shown for the U.S. do not include agricultural emissions or emissions of fluorinated compounds.

	Per capita Emissions (Tons per Year)
Atlanta, GA	22.9
Nashville, TN	22.2
Detroit, MI (2012)	21.2
United States	21.0
Madison County, Alabama (2015)	***15.0***
Las Vegas, NV	14.8
Minneapolis, MN (2010)	14.8
Raleigh, NC (2010)	14.7
Boston, MA (2011)	13.7
Baltimore, MD (2010)	13.5
Washington, D.C. (2013)	13.1
Los Angeles, CA (2013)	8.2
New York, NY	6.4
Seattle, WA	5.7

County are toward the lower end of the spectrum within the Southeast. The relatively low industrial emissions in Huntsville and Madison County are probably primarily responsible for the lower emissions locally than within the Southeast generally.

It should be noted that the substantial decrease in per capita greenhouse gas emissions in Madison County from 2000 to 2015 is largely the result of changes in the power mix utilized by TVA to generate electricity. Over the 15-year period, the percentage of TVA-generated power provided by coal-fired power plants declined from 62 % in 2000 to 38 % in 2015. Conversely, the percentage of power generated by TVA's nuclear plants increased from 29 % in 2000 to 38

Figure 9 – Comparison of Per Capita Greenhouse Gas Emissions in Madison County, Selected Cities and the U.S. as a Whole (Tons CO_2 Eq. per Year). All Values are for Year 2014 unless Otherwise Shown.



% in 2015, and the percentage of electricity generated by natural gas-fired power plants increased from 4% in the year 2000 to 14 % in 2015. The TVA power mix in years 2000, 2005, 2010 and 2015 is summarized below:

	2000 [51]	2005 [52]	2010	2015 [53]
Coal-fired	62 %	62 %	51 %	38 %
Nuclear	29 %	28 %	36 %	37 %
Hydroelectric	8 %	10 %	9 %	9 %
Gas & Oil-Fired	<1 %	<1 %	4 %	14 %
Renewables	<1%	<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 1010 lb/MWh CO_2 Eq. in the year 2015. However, per capita electricity consumption in Madison County actually decreased somewhat from the year 2000 (16.0 MWh/year) to the year 2015 (14.6 MWh/year), so the large decrease in per capita emissions associated with electricity usage is also the result of reduced electricity consumption, probably due in part to the mild winter in 2015.[54] 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 2015 when evaluating per capita energy consumption and per capita greenhouse gas emissions in Madison County for the two years.

Smaller changes in per capita emissions are attributable to a decrease in per person natural gas consumption and in per capita motor fuel consumption. Natural gas usage declined from 24.5 Mscf (thousand standard cubic feet) per person in 2000 to 18.6 Mscf per person in 2015. Although the percentage change in per capita natural gas usage is large (roughly 24 %), stationary source fuel combustion is a much smaller contributor to total greenhouse gas emissions than electricity usage or transportation fuel usage, so the impact on total emissions is smaller. Per capita transportation fuel usage also decreased slightly from the year 2000 (532 gallons) to the year 2015 (523 gallons), a decrease of just under 2 %.

[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.snl.com/irw/Doc/4063363/Index?did=34600175

[53] TVA's power mix for 2015 is taken from TVA's *Budget Proposal and Management Agenda (Performance Report) dated February 2016.* This Report can be accessed at the following web address: https://www.tva.gov/file_source/TVA/Site%20Content/About%20TVA/Guidelines%20and%20Reports/FY17%20Performance%20Report%20-%20FINAL.pdf

[54] A review of the 2000 and 2015 editions of the National Weather Service *Annual Climatological Data – Annual Summary with Comparative Data: Huntsville, Alabama* Reports showed that the Heating Degree Days and Cooling Degree Days in 2000 were: HDD = 3176 and CDD = 2040; for 2015, HDD = 2548 and CDD = 2299.

Although comprehensive State-by-State greenhouse gas emissions comparisons are not available for recent years, and such information is only available for some cities in the U.S., data on per capita *carbon dioxide* emissions by State are available for the year 2014 from the Energy Information Administration. 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.[55] Thus, the scope of the CO_2 inventory is similar to that utilized in preparing the 2015 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 EIA State-by-State CO_2 inventory is similar to both the Madison County GHG inventory and the 2014 City comparisons presented above in terms of the sources included in the inventory, it differs in one key respect. The 2014 CO_2 totals do not adjust the emissions of CO_2 to reflect interstate transmission of electric power. In other words, unlike the Madison County inventory (and other local inventories used for comparative purposes), which reflect electricity *consumption* within each City, the 2014 CO_2 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 24 shows the State-by-State per capita CO_2 emissions in 2014. This information is presented graphically in Figure 10.

The Madison County 2015 per capita carbon dioxide emissions of 14.4 tons per year are somewhat lower than the national average of 18.7 tons per year and toward the lower end of the range for the Southeastern United States. Generally, the per capita CO_2 emission in 2014 show a similar pattern to the 2014 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.

In Alabama, the 2014 per capita CO_2 emissions of 28.0 tons per year were 94 % higher than in Madison County. This large difference merits some discussion. As noted above, the 2014 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. 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

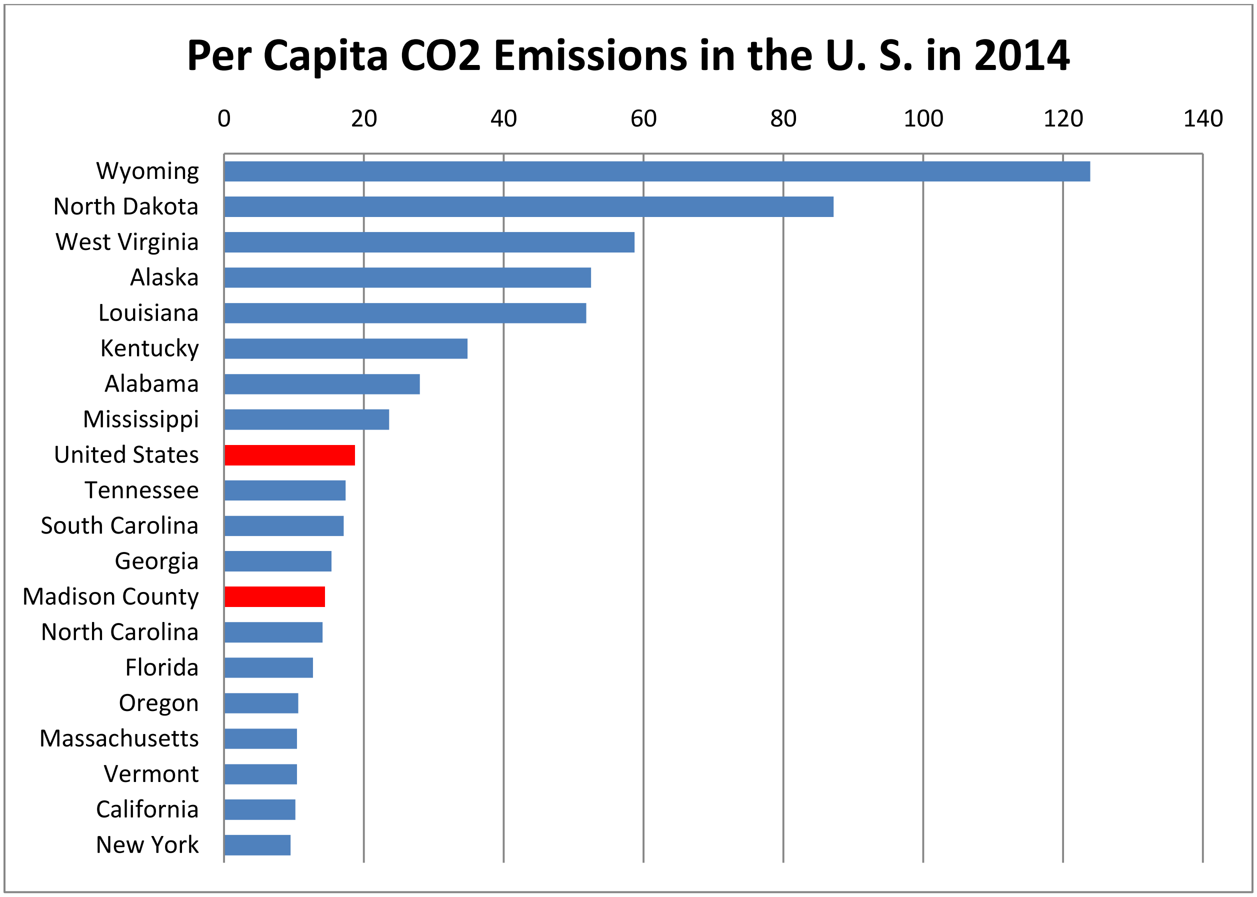
[55] EIA State-by-State carbon dioxide emissions for years 1990 through 2014 are available at the following web address: http://www.eia.gov/environment/emissions/state/

Table 24 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion for the United States, and Selected States in the Year 2014 and Madison County, Alabama in the Year 2015. 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	18.7
New York	9.5
California	10.2
Vermont	10.4
Massachusetts	10.4
Oregon	10.6
Florida	12.7
North Carolina	14.1
Madison County, Alabama (2015)	***14.4***
Georgia	15.3
South Carolina	17.1
Tennessee	17.4
Mississippi	23.6
Alabama	28.0
Kentucky	34.8
Louisiana	51.8
Alaska	52.5
West Virginia	58.7
North Dakota	87.2
Wyoming	123.9

electricity generated within the State to other States.[56] 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.

Figure 10 – Per Capita Carbon Dioxide Emissions From Fossil Fuel Combustion for the United States, and Selected States in the Year 2014 and Madison County, Alabama in the Year 2015. 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.

[56] The Energy Information Administration compiles detailed State-by-State information on electricity generation and consumption. In 2014, Wyoming generated 48,696 million kWh of electricity (88 % from coal-fired plants) and exported 30,055 million kWh to other States (62 % of net generation). Alabama generated 149,340 million kWh of electricity (31.7 % from coal), and exported 47,963 million kWh to other States (32 % of net generation). Tables summarizing electricity generation and disposition data, by year and by State, are 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 2015 are summarized in Table 25 and depicted graphically for Years 2000, 2005, 2010 and 2015 in Figure 11. Percent contribution of electricity consumption, transportation fuel combustion and stationary source fuel combustion to total emissions is also shown in Table 25 and is depicted for years 2000, 2010 and 2015 in Figure 12.

Table 25 – Greenhouse Gas Emissions (Tons CO_2 Eq.) From City of Huntsville Municpal Government Operations in Years 2000 and 2015.

	2000		***2015***	
Electricity Consumption	25,253	(54.8 %)	21,314	(51.5 %)
Stationary Source Fuel Combustion	6,684	(14.5 %)	5,022	(12.1 %)
Transportation Fuel Combustion	14,125	(30.7 %)	15,044	(36.4 %)
TOTAL	46,062	(100.0 %)	41,380	(100.0 %)

Figure 11 – City of Huntsville Municipal Government Greenhouse Gas Emissions (CO_2 Eq.) in Years 2000, 2005, 2010 and 2015.

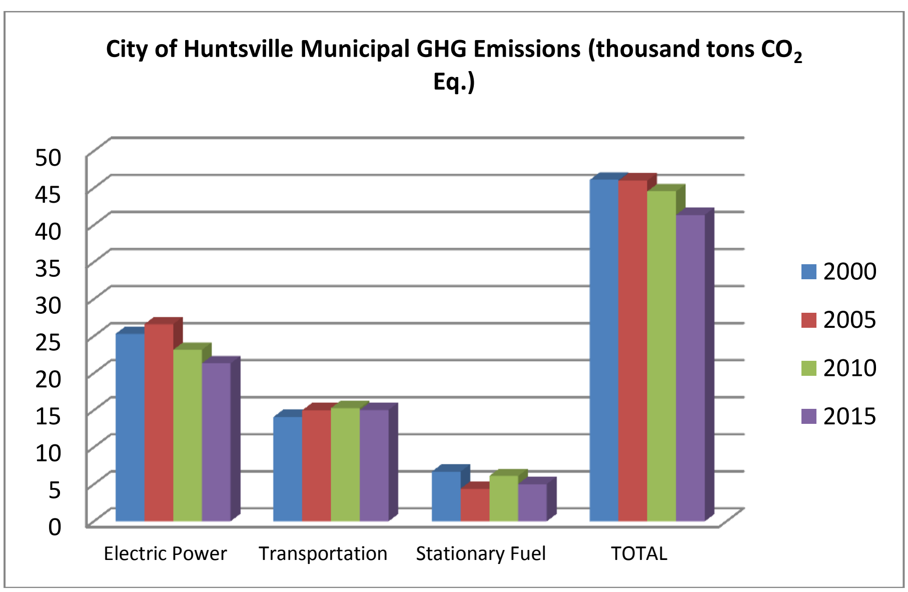
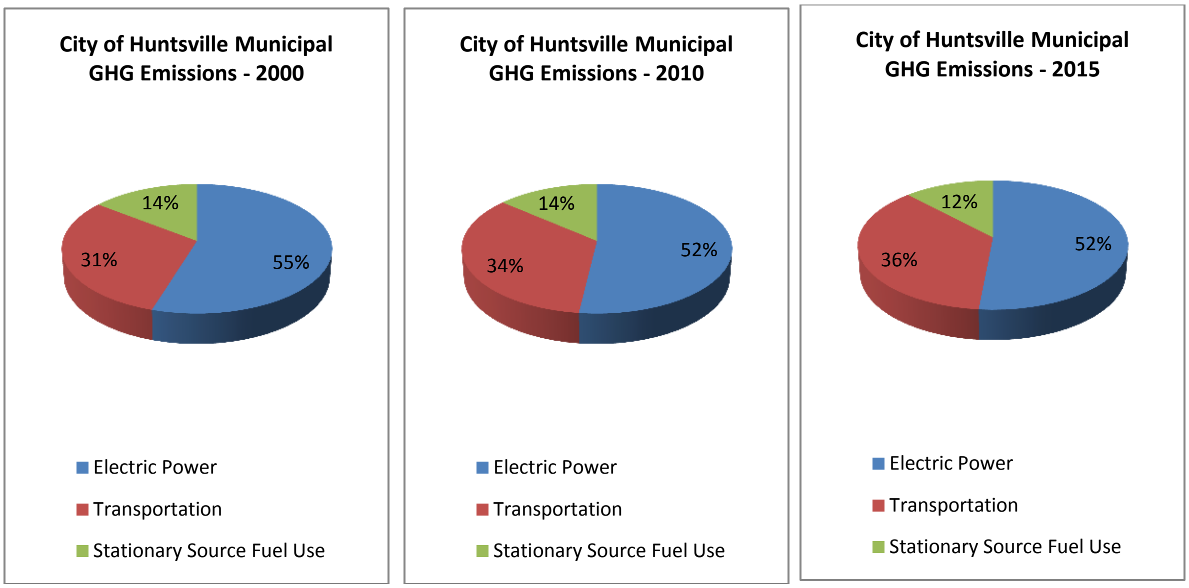


Figure 12 – City of Huntsville Municipal Operations Greenhouse Gas Emissions (CO_2 Eq.) by Source in Years 2000, 2010 and 2015.



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 %. A larger reduction in total emissions is evident over the five-period from 2010 to 2015, with total emissions dropping to 41,380 tons, a decrease of just over 7 %. Although there were decreases in each of the three emissions categories, the largest decrease was evident in the emissions associated with electricity usage, which saw a reduction from 23,125 tons in 2010 to 21,314 tons in 2015 (a decrease of nearly 8 %). The decrease in emissions from stationary source fuel combustion was smaller in magnitude, but large in percentage, declining from 6104 tons in 2010 to 5022 tons in 2015 (a decrease of nearly 18 %). The decrease in emissions from transporation fuel usgae was smaller – from 15,316 tons in 2010 to 15,044 tons in 2015 (a decrease of just under 2 %). Since the time of the initial greenhouse gas emissions inventory for the year 2000, greenhouse gas emissions resulting from City of Huntsville municipal operations have declined from 46,062 tons/year to 41,380 tons/year, a decrease of just over 10 %.

The reductions in emissions associated with electricity usage from 2010 (23,125 tons CO_2 Eq.) to 2015 (21,314 tons CO_2 Eq.), a decrease of roughly 8 %, is due entirely 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. Although greenhouse gas emissions decreased, municipal electricity usage actually increased from 39.03 GWh in 2010 to 42.20 GWh in 2015 (an increase of 8 %). However, electricity usage in City buildings declined over the five-year period and the entire increase is attributable to increased electricity consumption in wastewater treatment. Note that the large increase in electricity usage at the Vermont Road wastewater treatment plant was accompanied by a large decrease in natural gas usage at this treatment facility. The shift is the result of replacement of the aeration blowers powered by natural-gas fuelded engines with new electric blowers. In contrast to the reduction in emissions from electricity consumption, the reductions in emissions associated with fuel usage in both ths stationary source and transportation categories resulted from decreasses in actual fuel usage over the five-year period.

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 2015. In 2015 the proportion of municipal emissions associated with electricity usage (52 %) was only slightly higher than for the community as a whole (49 %), and the contribution from stationary source fuel combustion to total municipal greenhouse gas emissions (12 %) was somewhat higher than Countywide (8 %). Emissions from municipal fleet operations (36 %) constituted about the same proportion of the inventory as the transportation sector in the Countywide inventory (38 %).

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, a little less than two-thirds of the total emissions from municipal operations are attributable to fixed facility operation (63.6 %) and just over one-third of the total emissions are from operation of the City's motor vehicle fleet (36.4 %). The Countywide inventory is strikingly similar with 37.7 % of total greenhouse gas emissions attributable to the transportation sector and 62.3 % attributable to fixed facility operations (including solid waste disposal).

Appendix A

Electricity GHG Emission Calculations

Fuel Usage GHG Emission Calculations

Waste Disposal GHG Emission Calculations

GHG Emission Summary Calculations

Economic Sector GHG Emission Calculations

U.S. GHG Emissions Inventory Calculations

Per Capita GHG and CO_2 Emission Calculations

GHG Emissions from Electricity Usage - Madison County 2015

Economic Sector	***Usage (GWh)***	***CO2 (TPY)***	***CH4 (TPY CO2 Eq.)***	***N2O (CO2 Eq.)***	***Total (CO2 Eq.)***
Industrial	487	244,737.0	90.2	1,145.0	245,972.2
Commercial	2190	1,100,562.6	405.7	5,149.2	1,106,117.5
Residential	2488	1,250,319.5	460.9	5,849.8	1,256,630.3
	5,165.0	2,595,619.1	956.8	12,144.1	2,608,720.0
	502.54				
	2.35122				
	0.18525				
	505.07647				

GHG Emissions from Electricity Usage - City of Huntsville 2015

General Services	22.87	11,493.1	4.2	53.8	11,551.1
Water Pollution Control	19.33	9,714.1	3.6	45.4	9,763.1
		21,207.2	7.8	99.2	21,314.2

GHG Emissions from Fuel Combustion - Madison County 2015

Natural Gas

Economic Sector	***Natural Gas (MSCF)***	***CO2 (TPY)***	***CH4 (TPY CO2 Eq.)***	***N2O (TPY CO2 Eq.)***	***TOTAL (TPY CO2 Eq.)***	***TOTAL (TPY CO2 Eq.)***
Industrial	332,633	20,057.8	9.6	109.0	20,176	111,429
	1,504,418	90,716.4	43.3	493.1	91,253	
Commercial	2,168,687	130,771.8	62.3	710.9	131,545	153,254
	357,895	21,581.1	10.3	117.3	21,709	
Residential	1,825,010	110,048.1	52.5	598.2	110,699	133,064
	368,715	22,233.5	10.6	120.9	22,365	
	6,557,358.0	395,408.7	188.5	2,149.5	397,746.7	397,746.7

GHG Emissions from Fuel Combustion - COH 2015

General Services	72,622	4,379.1	2.1	23.8	4,405
Water Pollution Control	2,818	169.9	0.1	0.9	171
Digester Gas	7,355	443.5	0.2	2.4	446
	82,795	4,992.5	2.4	27.1	5,022

GHG Emissions from Fuel Combustion - Coal & Coke 2015

	Tons of Fuel	***CO2 (TPY)***	***CH4 (TPY CO2 Eq.)***	***N2O (TPY CO2 Eq.)***	***TOTAL (TPY CO2 Eq.)***
Coal	560	1,435.3	4.2	7.5	1,447.0
Coke	675	2,285.9	17.9	28.2	2,331.9
		3,721.2	22.1	35.7	3,778.9

Totals for Stationary Fuel Combustion

	CO2 (TPY)	***CH4 (TPY CO2 Eq.)***	***N2O (TPY CO2 Eq.)***	***TOTAL (TPY CO2 Eq.)***
Industrial	114,495.3	74.9	637.9	115,208.1
Commercial	152,352.9	72.6	828.2	153,253.7
Residential	132,281.6	63.1	715.6	133,060.2
	399,129.9	210.6	2,181.6	401,522.1

SWDA 2015 GHG Emissions

	Biogenic CO2 (metric tons)	Biogenic CO2 short tons	Non-Biogenic CO2 (metric tons)	Non-Biogenic CO2 short tons	CH4 (metric tons)	CH4 short tons	CH4 - CO2 Eq tons	N2O metric tons	N2O short tons	N2O - CO2 Eq. tons	TOTAL CO2-Eq (tons)
WTE Plant	106,333.0	117,211.9	94,295.3	103,942.7	70.78	78.0	1,950.54	9.29	10.2	3,051.7	108,944.8
MSWL					6,819.92	7,517.7	187,941.65				187,941.7

Madison County GHG Emissions - 2015

		CO2 (TPY)	CH4 (TPY CO2 Eq.)	N2O (TPY CO2 Eq.)	TOTAL (TPY CO2 Eq.)	
Electricity	Industrial	244,737.0	90.2	1,145.0	245,972.2	
	Commercial	1,100,562.6	405.7	5,149.2	1,106,117.5	
	Residential	1,250,319.5	460.9	5,849.8	1,256,630.2	
	TOTAL	2,595,619.1	956.8	12,144.0	2,608,719.9	0.49114
Stationary Fuel Combustion	Industrial	114,495.3	74.9	637.9	115,208.1	0.02169
	Commercial	152,352.9	72.6	828.2	153,253.7	0.02885
	Residential	132,281.6	63.1	715.6	133,060.3	0.02505
	TOTAL	399,129.8	210.6	2,181.7	401,522.1	0.07559
Fuel + Electricity (by Sector)	Industrial	359,232.3	165.1	1,782.9	361,180.3	0.06800
	Commercial	1,252,915.5	478.3	5,977.4	1,259,371.2	0.23710
	Residential	1,382,601.1	524.0	6,565.4	1,389,690.5	0.26164
	TOTAL	2,994,748.9	1,167.4	14,325.7	3,010,242.0	
Transportation	Gasoline	1,445,090.1	1,931.4	17,549.4	1,464,570.9	
	Diesel	420,169.4	33.1	375.5	420,578.0	
	Aviation	117,637.1	328.5	1,305.4	119,271.0	
	TOTAL	1,982,896.6	2,293.1	19,230.3	2,004,420.0	0.37737
Solid Waste	WTE Plant	103,942.7	1,950.5	3,051.7	108,944.9	
	MSWLF		187,941.7		187,941.7	
	TOTAL	103,942.7	189,892.2	3,051.7	296,886.6	0.05589
GRAND TOTAL		5,081,588.2	193,352.7	36,607.7	5,311,548.5	

COH GHG Emissions - 2015

		CO2 (TPY)	CH4 (TPY CO2 Eq.)	N2O (TPY CO2 Eq.)	TOTAL (TPY CO2 Eq.)	
Electricity	General Services	11,493.1	4.2	53.8	11,551.1	
	WPC	9,714.1	3.6	45.4	9,763.1	
	TOTAL	21,207.2	7.8	99.2	21,314.2	0.51509
Stationary Fuel Combustion	General Services	4,379.1	2.1	23.8	4,405.0	
	WPC	613.4	0.3	3.3	617.0	
	TOTAL	4,992.5	2.4	27.1	5,022.0	0.12136
Transporation	Gasoline	8,831.8	11.7	106.6	8,950.0	
	Diesel	6,086.7	0.6	6.3	6,093.5	
	TOTAL	14,918.5	12.2	112.8	15,043.5	0.36355
GRAND TOTAL		41,118.2	22.4	239.1	41,379.7	1.00000

Madison County GHG Emissions by Sector

Sector	Electricity	Fuel Usage	Total	Fraction of Total	% of Total	
Industrial	245,972.2	115,208.1	361,180.3	0.067999058	6.8	
Commercial	1,106,117.5	153,253.7	1,259,371.2	0.23710057	23.7	
Residential	1,256,630.2	133,060.3	1,389,690.5	0.261635656	26.2	
						100
	2,608,719.9	401,522.1	3,010,242.0			
						100
Transportation	2,004,420.0			0.37737017	37.7	
Solid Waste	296,886.6			0.055894546	5.6	
	5,311,548.6					
Electricity				0.491141115	49.1	
Fuel Combustion				0.075594169	7.6	

2014 US GHG EI

Gas	MMT (CO2 Eq.)	Fr. Of Total	% of Total	Short Tons Million Tons)	2014 US Population (millions)	GHG Emissions (TPY) (per capita)
CO2	5556	0.80867477	80.9			
CH4	730.8	0.1063678	10.6			
N2O	403.5	0.05872935	5.9			
Fluorinated Compds.	180.1	0.02621352	2.6			
	6870.4	0.99998545	100			
	6870.5			7573.429855	318.563456	23.77369316

2014 US GHG Minus Agriculture & Fluorine

Gas	MMT (CO2 Eq.)	Fr. Of Total	% of Total
CO2	5556	0.90652483	90.7
CH4	505.3	0.08244546	8.2
N2O	67.6	0.01102971	1.1
Fluorinated Compds.	0	0	0
	6128.9	1	100

2014 US GHG Minus Agriculture, NG Transmission & Fluorine

Gas	MMT (CO2 Eq.)	Fr. Of Total	% of Total
CO2	5556	0.93334229	93.3
CH4	329.2	0.05530171	5.5
N2O	67.6	0.011356	1.1
Fluorinated Compds.	0	0	0
	5952.8	1	99.9

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 2014 GHG Emissions (Minus Agriculture and Fluorine Compounds)

United States	6072.3	6693.557013	318.563456	21.01	19.06
U.S. (Total)	6870.5	7573.420855	318.563456	23.77	21.57

Per Capita GHG Emissions in Select U. S. Cities

	Year					
Atlanta, GA	2014	9.46	10.4278526	0.456002	22.87	20.75
Baltimore, MD	2010	7.579144	8.354566223	0.620961	13.45	12.21
Boston, MA	2011	7.767	8.56164177	0.625087	13.70	12.43
Detroit, MI	2012	10.629772	14.770954	0.701475	21.06	19.10
Las Vegas	2014		30.588113	2.069681	14.78	13.41
Minneapolis, MN	2010				14.77	13.4
Nashville, TN	2014				22.20	20.14
New York, NY	2014				6.39	5.8
Raleigh, NC	2010	5.38248	5.933161529	0.40389	14.69	13.33
Seattle, WA	2014				5.73	5.2
Washington, DC	2013				13.12	11.9
Los Angeles, CA	2013	29	31.96699	3.884	8.23	

Table 1. State emissions by year (1990 - 2014)

Million metric tons of carbon dioxide	1990	2014	Change from 1990 - 2(Percent	Absolute	Population	Per Capita	Rank
Alabama	110	123	12.1%	13	4,843,214	28.04	12
Alaska	35	35	1.4%	1	736,705	52.52	4
Arizona	63	93	48.2%	30	6,719,993	15.27	32
Arkansas	51	69	35.3%	18	2,966,912	25.64	16
California	364	358	-1.6%	-6	38,680,810	10.20	49
Colorado	65	92	40.5%	26	5,349,648	18.87	26
Connecticut	41	35	-14.2%	-6	3,591,873	10.77	45
Delaware	18	13	-24.4%	-4	934,948	15.68	30
District of Columbia	5	3	-33.3%	-2	659,005	5.02	DC
Florida	189	228	21.0%	40	19,888,741	12.65	39
Georgia	139	140	0.6%	1	10,087,231	15.30	31
Hawaii	22	18	-15.2%	-3	1,416,349	14.32	34
Idaho	11	17	45.6%	5	1,633,532	11.20	43
Illinois	193	234	21.3%	41	12,867,544	20.05	22
Indiana	206	207	0.4%	1	6,595,233	34.58	8
Iowa	60	82	36.3%	22	3,108,030	29.05	11
Kansas	70	70	0.0%	0	2,899,360	26.54	13
Kentucky	119	139	17.0%	20	4,413,057	34.82	6
Louisiana	198	218	10.4%	21	4,647,880	51.80	5
Maine	19	17	-13.1%	-3	1,330,719	13.75	38
Maryland	70	62	-12.5%	-9	5,967,295	11.36	42
Massachusetts	84	64	-23.8%	-20	6,749,911	10.42	47
Michigan	180	163	-9.8%	-18	9,915,767	18.06	27
Minnesota	79	95	20.3%	16	5,453,109	19.18	25
Mississippi	49	64	30.8%	15	2,992,400	23.61	19
Missouri	103	132	28.6%	29	6,060,930	24.04	18
Montana	28	32	16.6%	5	1,022,867	34.81	7
Nebraska	33	52	58.8%	19	1,881,145	30.53	9
Nevada	31	37	20.9%	6	2,833,013	14.40	33
New Hampshire	15	15	2.0%	0	1,328,743	12.44	40
New Jersey	110	114	3.0%	3	8,925,001	14.02	36
New Mexico	53	50	-6.0%	-3	2,083,024	26.51	14
New York	209	170	-18.8%	-39	19,718,515	9.49	50
North Carolina	111	127	13.8%	15	9,934,399	14.07	35
North Dakota	44	59	31.8%	14	739,904	87.15	2
Ohio	247	232	-6.1%	-15	11,594,408	22.04	20
Oklahoma	88	105	18.8%	17	3,877,499	29.85	10
Oregon	31	38	23.4%	7	3,968,371	10.56	46
Pennsylvania	265	245	-7.4%	-20	12,790,565	21.14	21
Rhode Island	9	11	19.1%	2	1,054,480	11.08	44
South Carolina	61	75	22.6%	14	4,828,430	17.10	29
South Dakota	12	15	28.6%	3	852,561	19.78	23
Tennessee	105	104	-1.5%	-2	6,544,663	17.43	28
Texas	563	642	14.1%	79	26,944,751	26.25	15
Utah	54	65	20.0%	11	2,941,836	24.47	17
Vermont	6	6	7.3%	0	626,984	10.37	48
Virginia	95	104	9.1%	9	8,317,372	13.78	37
Washington	71	73	3.5%	3	7,054,196	11.47	41
West Virginia	104	98	-4.9%	-5	1,848,514	58.68	3
Wisconsin	86	101	17.7%	15	5,758,377	19.35	24
Wyoming	57	66	15.1%	9	583,642	123.90	1
United States	5,028	5,405	7.5%	377	318,563,456	18.70	

Source: U.S. Energy Information Administration, State Energy Data System and

Per Capita Energy Usage

	2000	2005	2010	2015
Electricity (GWh)	4439	4945	5537	5165
Per Capita (MWh)	16.03	16.52	16.54	14.63
Natural Gas (1000 scf)	6,786,452	6,298,584	7,032,545	6,557,358
Per Capita (1000 scf)	24.50	21.04	21.00	18.57
Vehicle Fuel (gal)	147,324,896	160,571,063	179,110,124	184,689,061
Per Capita	531.91	536.29	534.96	523.07
HDD	3176	3015	3442	2548
CDD	2040	1967	2470	2299
HDD+CDD	5216	4982	5912	4847
HDD+CDD %		-0.0449	0.1334	-0.0707
Elec. Per Cap %		0.0305	0.0319	-0.0873
Nat. Gas Per Cap %		-0.0719	0.0363	-0.2421
Motor Fuel Per Cap %		0.0082	0.0057	-0.0166
Population	276,972	299,409	334,811	353,089
	142,033,333	156,927,700	171,393,767	176,968,000
	786,818	794,029	894,691	899,230
	544,100	620,228	575,125	544,011
	450,660	438,281	440,538	395,944
	403,884	476,228	482,617	442,272
	27,902	33,370	24,646	28,612
	154,079	310,607	337,685	362,837
	209,323	213,620	236,467	213,009
	205,567	240,020	277,592	301,998
	2,385,088	348,717	4,269,560	4,398,347
	124,142	168,263	177,436	134,801
	147,324,896	160,571,063	179,110,124	184,689,061

Appendix B

Total Fuel Usage &VMT

VMT by Vehicle Class

Gas Versus Diesel

Motor Vehicle Age Distribution

Motor Vehicle GHG Emissions

COH Fleet GHG Emissions

	Gas & Diesel	Gasoline	Diesel
Taxed Fuel	176,968,000		
City of Huntsville		899,230	544,011
Madison County		395,944	442,272
Madison Co. Schools		28,612	362,837
Huntsville Utilities		213,009	301,998
Redstone Arsenal		4,398,347	134,801
Total	176,968,000	5,935,142	1,785,919
TOTAL	184,689,061		
VMT (Urban)	3,392,802,930		0.0544355404 gal/mi
VMT (Urban & Rural)	3,219,175,588		0.05737154 gal/mi
VMT (Registration)	3,681,717,337		0.050163835 gal/mi
2010 VMT	3,356,349,693		
2010 Total Fuel	179,110,124		
2015 VMT	3,392,802,930	% Increase (VMT)	0.010860977
2015 Total Fuel	184,689,061	% Increase (Total Fuel)	0.031148083

2014 National VMT by Vehicle Class		**Urban Areas**						
			Gasoline	Diesel	FR. Gas		Fr. Diesel	
Short WB LDV	1,513,503	0.719096719	0.712733032	0.006363688	0.991150442		0.008849558	
Long WB LDV	420,536	0.199805391	0.199299554	0.000505836	0.997468354		0.002531646	
Motorcycles	13,221	0.006281572	0.006281572		1		0	
Buses	10,458	0.004968813		0.004968813	0		1	
SU Trucks	66,641	0.031662524	0.006178053	0.02548447	0.195121951		0.804878049	
Combination Trucks	80,369	0.038184982		0.038184982	0		1	
	2,104,728	1.00000000	0.92449221	0.07550779				
	Urban & Rural Areas							
Short WB LDV	2,072,071	0.684833862	0.678773386	0.006060477	0.991150442		0.008849558	
Long WB LDV	638,484	0.211023398	0.210489162	0.000534236	0.997468354		0.002531646	
Motorcycles	19,970	0.006600224	0.006600224		1		0	
Buses	15,999	0.005287781		0.005287781	0		1	
SU Trucks	109,301	0.03612474	0.00704873	0.02907601	0.195121951		0.804878049	
Combination Trucks	169,830	0.056129995		0.056129995	0		1	
	3,025,655	1.00000000	0.90291150	0.09708850				
Registration - # Vehicles by Class								
Short WB LDV	187,554,928	0.720392749	0.714017592	0.006375157				
Long WB LDV	52,600,309	0.20203618	0.201524696	0.000511484				
Motorcycles	8,417,718	0.032332198	0.032332198					
Buses	872,027	0.003349429		0.003349429				
SU Trucks	8,328,759	0.031990509	0.006242051	0.025748458				
Combination Trucks	2,577,197	0.009898935		0.009898935				
	260,350,938	1.00000000	0.95411654	0.04588346				
Fuel Usage based on Urban VMT		3,392,802,930	184,689,061				**Fuel Use Based on Urban VMT**	
	Fr. Of Fleet	MPG	Fr. Of Fleet/mpg	Gasoline	Diesel		Gasoline	Diesel
Short WB LDV	0.7190967194	23.2	0.030995548	0.03072125	0.000274297	Short WB LDV	104,231,152	930,635
Long WB LDV	0.1998053905	17.1	0.011684526	0.01165494	2.95811E-05	Long WB LDV	39,542,930	100,363
Motorcycles	0.0062815718	43.5	0.000144404	0.00014440	0	Motorcycles	489,934	0
Buses	0.0049688131	7.2	0.000690113	0.00000000	0.000690113	Buses	0	2,341,417
SU Trucks	0.0316625236	7.3	0.004337332	0.00084631	0.003491023	SU Trucks	2,871,359	11,844,354
Combination Trucks	0.0381849816	5.8	0.006583618	0.00000000	0.006583618	Combination Trucks	0	22,336,917
	1.00000000		0.054435540410	0.0433669087	0.0110686317		147,135,375	37,553,686
Fuel Usage based on URBAN & Rural VMT			3,392,802,930.02	18.37035129			184,689,061	
	Fr. Of Fleet	MPG	Fr. Of Fleet/mpg				**VMT Based on Urban VMT**	
Short WB LDV	0.684833862	23.2	0.029518701			Short WB LDV	2,418,162,718	21,590,739
Long WB LDV	0.211023398	17.1	0.01234055			Long WB LDV	676,184,111	1,716,203
Motorcycles	0.006600224	43.5	0.000151729			Motorcycles	21,312,135	0
Buses	0.005287781	7.2	0.000734414			Buses	0	16,858,204
SU Trucks	0.03612474	7.3	0.004948595			SU Trucks	20,960,918	86,463,785
Combination Trucks	0.056129995	5.8	0.009677585			Combination Trucks	0	129,554,118
	1.00000000		0.057371574				3,136,619,882	256,183,048
Fuel Usage Based on Registration							3,392,802,930	
Short WB LDV	0.720392749	23.2	0.031051412					
Long WB LDV	0.20203618	17.1	0.011814981					
Motorcycles	0.032332198	43.5	0.000743269					
Buses	0.003349429	7.2	0.000465198					
SU Trucks	0.031990509	7.3	0.004382261					
Combination Trucks	0.009898935	5.8	0.001706713					
			0.050163835					

2010				
171,393,767				
	894,691	575,125		
	440,538	482,617		
	24,646	337,685		
	236,467	277,592		
	4,269,560	177,436		
171,393,767	5,865,902	1,850,455		179,110,124
	165,126,981	13,983,143		
	0.92192991	0.07807009		
2015				
176,968,000				
	899,230	544,011		
	395,944	442,272		
	28,612	362,837		
	213,009	301,998		
	4,398,347	134,801		
176,968,000	5,935,142	1,785,919		184,689,061
	147,135,375	37,553,686		
	0.79666535	0.20333465		

Age		Motorcycles			Passenger Cars			Light Duty Trucks		
0	2015	0.0585			0.042			0.0496		
1	2014	0.0565	1996 - 2015	0.9542	0.0472	2004-2015	0.6324	0.044	2005-2015	0.6315
2	2013	0.0614	1995 & Earlier	0.0458	0.043	2000-2003	0.1715	0.0335	2001-2004	0.1845
3	2012	0.1088			0.0545	1995-1999	0.1293	0.0587	1995-2000	0.1245
4	2011	0.0968			0.0597	1981-1994	0.0669	0.0626	1986-1994	0.0579
5	2010	0.0917			0.0562	1975-1980		0.0644	1975-1985	0.0016
6	2009	0.0803			0.0562	1973-1974		0.0677		
7	2008	0.0682		1.00000	0.0526		1.00010	0.0686		1.00000
8	2007	0.0583			0.0551			0.0638		
9	2006	0.0514			0.055			0.0624		
10	2005	0.0436			0.0534			0.0562		
11	2004	0.0348			0.0575			0.0545		
12	2003	0.0263			0.05			0.0504		
13	2002	0.0224			0.0441			0.0424		
14	2001	0.0215			0.042			0.0372		
15	2000	0.0188			0.0354			0.0284		
16	1999	0.0142			0.0367			0.0274		
17	1998	0.0163			0.029			0.025		
18	1997	0.0133			0.0249			0.0175		
19	1996	0.0111			0.0209			0.0142		
20	1995	0.0088			0.0178			0.012		
21	1994	0.0071			0.015			0.0106		
22	1993	0.0053			0.0124			0.0108		
23	1992	0.0045			0.0097			0.0092		
24	1991	0.0044			0.008			0.007		
25	1990	0.0037			0.0065			0.0071		
26	1989	0.0031			0.0053			0.0049		
27	1988	0.0028			0.0042			0.004		
28	1987	0.002			0.0025			0.0024		
29	1986	0.0016			0.0017			0.0019		
30	1985	0.0025			0.0016			0.0016		
		1.00000			1.00010			1.00000		

Age		Heavy Duty Gas Vehicles		
0	2015	0.035	2004 and Later	0.5609
1	2014	0.0216	1996-2003	0.2842
2	2013	0.0231	1985-1995	0.1551
3	2012	0.0479		
4	2011	0.0629		
5	2010	0.0666		
6	2009	0.0577		
7	2008	0.0506		
8	2007	0.0438		
9	2006	0.0393		
10	2005	0.0427		
11	2004	0.0697		
12	2003	0.0591		
13	2002	0.0334		
14	2001	0.0459		
15	2000	0.0308		
16	1999	0.0423		
17	1998	0.0323		
18	1997	0.0225		
19	1996	0.0179		
20	1995	0.0162		
21	1994	0.022		
22	1993	0.0211		
23	1992	0.0188		
24	1991	0.0171		
25	1990	0.0154		
26	1989	0.0132		
27	1988	0.0113		
28	1987	0.0067		
29	1986	0.0067		
30	1985	0.0066		
		1.0002		

	fuel (gal)	CO2 EF (lb/gal)	CO2 (lb)	CO2 (TPY)	CH4 (TPY)	CH4 (TPY CO2 Eq.)	NO2 (TPY)	NO2 (TPY CO2 Eq.)	TOTAL (CO2 Eq.)
gasoline	147,135,375	19.643	2,890,180,171	1,445,090.1	77.26	1,931.44	58.89	17,549.37	1,464,570.9
diesel	37,553,686	22.377	840,338,832	420,169.4	1.32	33.11	1.26	375.49	420,578.0
				1,865,259.50	78.58	1,964.55	60.15	17,924.86	1,885,148.91
		0.139184442							
VMT =	3,392,802,930		1 lb =	453.592					
	3,393,142,210								
		Aviation		117,637.14	13.14159	328.53975	4.38053	1305.39794	119,271.1
GASOLINE		**Transportation**		1,982,896.64	91.72	2,293.09	64.53	19,230.25	2,004,419.99

Vehicle Class	Fr. Of VMT	VMT	MY	Fr. In MY Range	VMT for MY	Fr. Gasoline Fueled	CH4 EF (g/mi)	CH4 (TPY)	N2O EF (g/mi)	N2O (TPY)
Motorcycles	0.0063	21,374,658.5	1996 and Later	0.9542	20,395,699.1	1	0.0672	1.510819172	0.0069	0.155128754
			1995 and Earlier	0.0458	978,959.4	1	0.0899	0.097012785	0.0087	0.009388334
SWB LDV (Passenger Cars)	0.7191	2,439,764,587	2004 - 2015	0.6323	1,529,087,713	0.9912	0.0173	29.15970457	0.0036	6.067915401
			2000 - 2003	0.1715	414,737,534	0.9912	0.0105	4.8002876	0.015	6.857553715
			1995 - 1999	0.1293	312,685,499	0.9912	0.0271	9.340747889	0.0429	14.78664518
			1981 - 1984	0.0669	161,783,913	0.9912	0.0704	12.55488132	0.0647	11.53836394
				1.000000	2,418,294,659					
LWB LDV (Light Duty Trucks)	0.1998	677,882,025.4	2005-2015	0.6315	427,012,293	0.9975	0.0163	7.672424087	0.0066	3.106625704
			2001 - 2004	0.1845	124,756,561	0.9975	0.0148	2.035306065	0.0157	2.159074677
			1995 - 2000	0.1245	84,185,321	0.9975	0.0452	4.194492547	0.0871	8.082750018
			1986 - 1994	0.0579	39,151,246	0.9975	0.0776	3.348975156	0.1056	4.557368253
			1985 and Earlier	0.0016	1,081,900	0.9975	0.1516	0.180796836	0.0639	0.076206582
				1.000000	676,187,320					
Heavy Duty Gas Vehicles (Single-unit Trucks)	0.0317	107,551,852.9	2004 and Later	0.5608	11,767,472	0.1951	0.0333	0.431948552	0.0134	0.173817135
			1996 - 2003	0.2841	5,961,374	0.1951	0.0655	0.430419876	0.175	1.149976767
			1985 - 1995	0.1551	3,254,520	0.1951	0.4181	1.499932618	0.0473	0.169688622
				1.000000	20,983,366	**TOTAL Gasoline**		77.25774906		58.89050308
DIESEL						**TOTAL CO2 Eq.**	25	1,931.444	298	17,549.370

Vehicle Class	Fr. Of VMT	VMT	MY	Fr. In MY Range	VMT for MY	Fr. Diesel Fueled	CH4 EF (g/mi)	CH4 (TPY)	N2O EF (g/mi)	N2O (TPY)
SWB LDV (Passenger Cars)	0.7191	2,439,764,587	ALL	1	21,469,928.4	0.0088	0.0005	0.011833282	0.001	0.023666564
LWB LDV (Light Duty Trucks)	0.1998	677,882,025.4	ALL	1	1,694,705.1	0.0025	0.001	0.001868094	0.0015	0.002802141
HDDV (S-Unit Trucks)	0.0317	107,551,852.9	ALL	1	86,568,486.4	0.8049	0.0051	0.486670048	0.0048	0.458042398
HDDV (Buses & Semi's)	0.0432	146,569,086.6	ALL	1	146,569,086.6	1	0.0051	0.823980958	0.0048	0.77551149
						TOTAL Diesel		1.324352382		1.260022593
						TOTAL CO2 Eq.	25	33.109	298	375.487

City of Huntsville Gasoline and Diesel VMT and Fuel Usage

	Gallons	**CO_2 (TPY)**	**CH_4 (TPY)**	**CH_4 (TPY CO_2 Eq.)**	**N_2O (TPY)**	**N_2O (TPY CO_2 Eq.)**	**TOTAL (CO_2 Eq.)**
Total Gasoline Usage =	899,230	8,831.79	0.47	11.67	0.36	106.58	8,950.04
Total Diesel Usage =	544,011	6,086.67	0.02	0.56	0.02	6.25	6,093.47
				25		298	**15,043.52**

Gasoline	**Fr. Of Urban VMT**	**Fr. Of Gasoline VMT**	**MPG**	**Weighted MPG**	**VMT/MPG**	**VMT**
SWB Light Duty Vehicles	0.7191	0.7772	23.2	18.03190661	0.03350161	15,099,601
LWB Light Duty Vehicles	0.1998	0.2160	17.1	3.692801556	0.012628848	4,195,383
Motorcycles	0.0063	0.0068	43.5	0.296206226	0.000156537	132,287
	0.9252	1.0000		22.0209	0.04628699	19,427,271
				21.60434049		
Diesel	**Fr. Of Urban VMT**	**Fr. Of Diesel VMT**				
Buses	0.004969	0.1357	7.2	0.976734282	0.018841325	537,721
S-Unit Trucks	0.03166	0.8643	7.3	6.309699965	0.118403077	3,426,091
	0.036629	1.0000		7.2864	0.13724440	3,963,812

Gasoline	1 lb =	453.592					
		Fr. In MY Range	VMT for Model Year	CH_4 EF (g/mi)	CH_4 (TPY)	N_2O EF (g/mi)	N_2O (TPY)
Motorcycles	1996 and Later	0.9542	126,228	0.0672	0.009350397	0.0069	0.000960085
	1995 and Earlier	0.0458	6,059	0.0899	0.000600408	0.0087	5.8104E-05
SWB Light Duty Vehicles	2004 - 2015	0.6323	9,547,478	0.0173	0.182070409	0.0036	0.037887484
	2000 - 2003	0.1715	2,589,582	0.0105	0.029972537	0.015	0.04281791
	1995 - 1999	0.1293	1,952,378	0.0271	0.058322737	0.0429	0.0923264
	1981 - 1984	0.0669	1,010,163	0.0704	0.078391479	0.0647	0.072044442
LWB LDV (Light Duty Trucks)	2005-2015	0.6315	2,649,385	0.0163	0.047603319	0.0066	0.019274964
	2001 - 2004	0.1845	774,048	0.0148	0.012627994	0.0157	0.013395912
	1995 - 2000	0.1245	522,325	0.0452	0.0260246	0.0871	0.050149174
	1986 - 1994	0.0579	242,913	0.0776	0.020778613	0.1056	0.028276051
	1985 and Earlier	0.0016	6,713	0.1516	0.001121748	0.0639	0.000472821
			19,427,271		0.466864		0.357663
Diesel							
Buses & S-Unit Trucks		1	3,963,812	0.0051	0.022283727	0.0048	0.02097292