2012 Greenhouse Gas Emission Inventory for the Town of Carrboro, NC

April 2015

Prepared by
David Agudelo-Frankel
Brian Beaman
Grace Marshall
Jessica Myers

Executive Summary

Climate change is happening now and humans are contributing to it by emitting greenhouse gases like CO_2 and N_2O. These greenhouse gases trap heat in Earth's atmosphere, causing the greenhouse gas effect, leading to multiple effects, such as higher temperatures, sea level rise, and extreme flooding. In order to reduce the negative effects of greenhouse gas emissions, communities must create mitigation strategies. Not only is mitigation essential for avoiding the devastating consequences of climate change, but many mitigation strategies provide co-benefits that make them attractive regardless of climate change.

The first critical step in developing mitigation strategies is for communities to perform a greenhouse gas emission inventory. As defined by the EPA, "[a] greenhouse gas inventory is an accounting of greenhouse gases (GHGs) emitted to or removed from the atmosphere over a period of time."[1] A greenhouse gas emission inventories allow policy makers to collect baseline emission data, understand the main sources of emissions in their community, and develop informed mitigation strategies. Subsequent emission inventories provide policy makers with insight to the effectiveness of their mitigation strategies.

Our mission was to work with the Town of Carrboro to create an updated greenhouse gas inventory for 2012 and compare our findings to the previous 2009 inventory to identify trends. We conducted the inventory using the updated ICLEI software, ClearPath. Using our findings, we have recommended mitigation strategies that we think are best suited for the Town, considering their past and current efforts.

The inventory revealed a total of 111,954 tons of CO_2e were emitted by the Town of Carrboro in 2012. About 93% of the total emissions came from the community sector, 7% from the local government. Within the community sector, residential energy made up the largest percentage of emissions: 41.5%. Transportation and commercial energy emissions were close behind residential at 29.8% and 25.7% respectively.

Between 2009 and 2012, Carrboro's greenhouse gas emissions reduced slightly despite a growing population. Per capita emissions decreased from 5.7 to 5.5 tons CO_2e. Emissions from residential energy use dropped 18.29% from 2009.While transportation emissions decreased by 1.25% from 2009 and commercial energy increased by 45.3%.

Local government operations contributed the largest reduction in greenhouse gas emissions. Overall, the local government decreased its emissions 15.32% from 2009 to 2012, but there was some variability between the different local government sectors. Buildings, including all

[1] "Developing a Greenhouse Gas Inventory." United States Environmental Protection Agency. Accessed March 24, 2015. http://www.epa.gov/statelocalclimate/local/activities/ghg-inventory.html

municipal buildings and schools, had a 20.45% decrease in emissions. The largest contributor to this decrease was the drop in Carrboro school's emissions; municipal building emissions from 2009 to 2012 did not vary much. There was a 9.29% decrease in emissions due to municipal vehicle fleet, while there was a 16.27% increase in emissions due to streetlights.

While we attempted to make this report as comparable to the 2009 report as possible, differences in software and data records used to calculate the emissions may limit the comparability of certain emissions sources, in particular solid waste.

With the new greenhouse gas inventory data, we developed mitigation strategies that we recommend to the Town, for example the requirement of energy performance ratings on all residential homes and buildings. If these strategies are implemented, Carrboro can continue to reduce their overall greenhouse gas emissions.

Table of Contents

Introduction

Over the past century the average temperature in the United States has increased by 1.3°F to 1.9°F, with the majority of the increase occurring after 1970. The ten hottest years on record have occurred since 1998, with 2012 being the hottest year recorded in the U.S.; climate change is happening now. Seasonal dynamics are changing. In addition to being warmer, summer is longer, and winter is shorter. Rain is coming down in sudden, heavier bursts. Flooding is occurring more often in coastal cities and cities near rivers. The duration of the wildfire season in the West is longer, increasing the amount of land that is burned. All of these observable changes are consistent with climate change[2].

The Southeast is seeing evidence of climate change through decreased water availability, increasing sea level rise, and extreme heat, resulting in negative effects on health, energy, and agriculture. Climate change may contribute to the Southeast seeing more billion-dollar weather disasters than any other region in the U.S.[3] More specifically, the National Resource Defense Council argues Orange County is currently experiencing multiple effects from global warming. It has had more days than expected of extreme heat and flooding. These effects may influence the health of county residents. Extreme heat may increase elderly mortality and pooling water may increase the mosquito population, leading to an increase in mosquito-carried viruses, such as dengue fever. Finally, the changing climate is causing increases in smog cover and ragweed pollen in Orange County, which can inflame allergy and respiratory issues[4].

The Science of Climate Change

Both natural and human factors can cause climate change. Before the Industrial Revolution in the 1700s, climate changes could be attributed to natural causes, such as shifts in solar energy, changes in ocean currents, and volcanic eruptions. However, natural processes alone cannot explain the post-industrial rise in temperatures[5]. Actually, the overall climate would have slightly decreased over the past fifty years if there had been no human influences[6].

Humans influence climate change by contributing to the greenhouse effect. After Earth absorbs sunlight, some of the absorbed energy is then released back into the atmosphere as heat, which is then lost to space. Greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), that are present in Earth's atmosphere can absorb the heat released,

---

[2] Melillo, Jerry, Terese Richmond, and Gary Yohe. "National Climate Assessment." National Climate Assessment. January 1, 2014. Accessed April 16, 2015. http://nca2014.globalchange.gov/highlights#section-5682.

[3] ibid.

[4] "What Will Climate Change Mean to Your Community?" National Resource Defense Council. June 15, 2013. Accessed April 16, 2015. http://www.nrdc.org/health/climate-in-your-community.asp.

[5] "Causes of Climate Change." Environmental Protection Agency. March 18, 2014. Accessed April 16, 2015. http://www.epa.gov/climatechange/science/causes.html.

[6] Melillo, Jerry, Terese Richmond, and Gary Yohe. "National Climate Assessment." National Climate Assessment. January 1, 2014. Accessed April 16, 2015. http://nca2014.globalchange.gov/highlights#section-5682.

slowing or inhibiting its return to space. This trapping of heat by greenhouse gases causes what is known as the "greenhouse effect"[7].

Many human practices add to the amount of greenhouse gases present in the atmosphere. Deforestation and the burning of fossil fuels like coal, oil, and gas have increased the amount of atmospheric carbon dioxide by 40% since the Industrial Revolution[8]. Carbon dioxide is the primary greenhouse gas contributing to climate change. Humans release over 30 billion tons of CO_2 per year, and its current concentration is greater than it has been in at least 800,000 years. Agricultural practices have also increased nitrous oxide and methane concentrations[9].

This increase in heat-trapping gases will have multiple effects on Earth's climate today and in the future. They will cause an increase in the climate's temperature. The warmer weather will reduce ice and snow cover, causing the sea level to rise. Precipitation patterns for snow and rain will be altered. As carbon dioxide concentrations rise, the ocean will become more acidic. These changes will then impact our food and water supply, infrastructure, ecosystems, and our health[10].

Climate Change Mitigation

The degree of future climate change and its impacts are dependent on current greenhouse gas emissions[11]. Actions taken today to reduce greenhouse gas emissions mean less warming and less severe impacts. Climate change mitigation "refers to efforts to reduce or prevent emission of greenhouse gases"[12]. While mitigation is essential to prevent extreme climate change, it can also provide numerous short-term and long-term benefits to local communities.

By reducing emissions, communities will enjoy higher quality health.[13] Combustion of fossil fuels produce not only greenhouse gases that contribute to climate change but also pollutants such as nitrous oxides, a precursor to ground-level ozone. By limiting greenhouse gas emissions there is potential to also limit these dangerous pollutants and reduce health impacts. All residents of the community will benefit from this, especially populations most susceptible to respiratory illness such as the poor and elderly[14,15]. Beyond the direct health impact of lower

---

[7] "Causes of Climate Change." Environmental Protection Agency. March 18, 2014. Accessed April 16, 2015. http://www.epa.gov/climatechange/science/causes.html.

[8] Melillo, Jerry, Terese Richmond, and Gary Yohe. "National Climate Assessment." National Climate Assessment. January 1, 2014. Accessed April 16, 2015. http://nca2014.globalchange.gov/highlights#section-5682.

[9] "Causes of Climate Change." Environmental Protection Agency. March 18, 2014. Accessed April 16, 2015. http://www.epa.gov/climatechange/science/causes.html.

[10] ibid.

[11] Melillo, Jerry, Terese Richmond, and Gary Yohe. "National Climate Assessment." National Climate Assessment. January 1, 2014. Accessed April 16, 2015. http://nca2014.globalchange.gov/highlights#section-5682.

[12] "Climate Change Mitigation." United Nations Environment Programme. Accessed March 24, 2015. http://www.unep.org/climatechange/mitigation/

[13] Luber, George, Kim Knowlton, John Balbus, Howard Frumkin, Mary Hayden, Jeremy Hess, Michael McGeehin, and Nicky Sheats. "Human Health." National Climate Assessment. Accessed March 24, 2015. http://nca2014.globalchange.gov/report/sectors/human-health#statement-16524.

[14] "Society Impacts." United States Environmental Protection Agency. September 9, 2013. Accessed March 24, 2015. http://www.epa.gov/climatechange/impacts-adaptation/society.html

emissions, some emission reduction strategies will also improve public health, such as increased bicycle use[16].

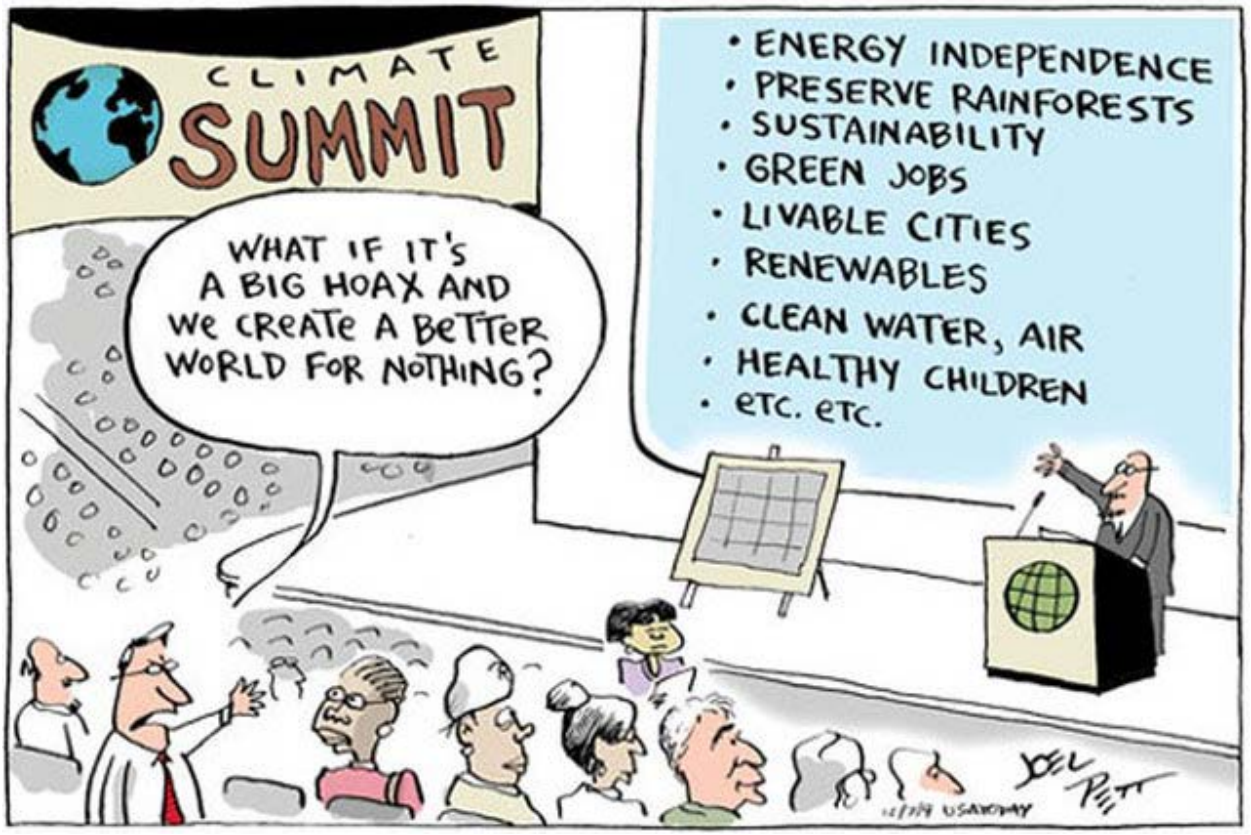

Figure 1. Co-benefits of climate change mitigation.

Many strategies also have co-benefits that produce immediate cost savings and improve quality of life. For example, if more trees are planted to increase CO_2 capture, citizens will enjoy a greener community and cooler temperatures in the summer. Energy costs will likely be lower for both the government and the community as a result of many emission reduction strategies. Furthermore, strategies like waste reduction will not only decrease emission productions, but will also increase the health of the environment in, and around, the community[17]. In summary, many climate change mitigation strategies are worth enacting for their co-benefits alone, with

---

[15] *"Climate change impacts add to the cumulative stresses currently faced by vulnerable populations including children, the elderly, the poor, some communities of color, and people with chronic illnesses ... These threats include poor air quality, heat, drought, flooding, and mental health stress. Over time, the accumulation of these stresses will be increasingly harmful to these populations."*
Luber, George, Kim Knowlton, John Balbus, Howard Frumkin, Mary Hayden, Jeremy Hess, Michael McGeehin, and Nicky Sheats. "Human Health." National Climate Assessment. Accessed March 24, 2015. http://nca2014.globalchange.gov/report/sectors/human-health#statement-16520

[16] Hosking, Jamie, Pierpaolo Mudu, and Carlos Dora. "Health Co-benefits of Climate Change Mitigation." World Health Organization. January 1, 2011. Accessed March 24, 2015. http://www.who.int/hia/green_economy/transport_sector_health_co-benefits_climate_change_mitigation/en/

[17] Smith, Alison. "The Big Picture: Climate Policies & Co-benefits." In *The Climate Bonus: Co-benefits of Climate Policy*, 8. Abingdon, Oxford: Routledge, 2013.

reductions in greenhouse gas emissions being an ancillary benefit. As Figure 1 comically demonstrates, the results of many mitigation strategies are outcomes that communities strive for regardless of climate change.

Greenhouse Gas Emission Inventories

The EPA concisely and clearly explains the purpose of a greenhouse gas emission inventory:

> *A greenhouse gas inventory is an accounting of greenhouse gases (GHGs) emitted to or removed from the atmosphere over a period of time. Policy makers use inventories to establish a baseline for tracking emission trends, developing mitigation strategies and policies, and assessing progress. An inventory is usually the first step taken by entities that want to reduce their GHG emissions. An inventory can help local governments:*
>
> - *Identify the sectors, sources, and activities within their jurisdiction that are responsible for greenhouse gas emissions*
> - *Understand emission trends*
> - *Quantify the benefits of activities that reduce emissions*
> - *Establish a basis for developing a local action plan*
> - *Track progress in reducing emissions*
> - *Set goals and targets for future reductions*[18]

While individual emission inventories can help communities gain insight to their Town's emissions, subsequent emission inventories can help track progress towards mitigation goals and analyze the success of emission mitigation strategies. Although trends across emission inventories can be difficult to attribute to specific policies and do not provide foolproof strategies for reducing future emissions, they can be valuable sources of data. In this Capstone report, we update the 2009 emission inventory for the Town of Carrboro. By having multiple sources of comparable data, we hope the Town's policy-makers can better understand the effect, or lack of effect, of their policies.

Mission

The Environmental Sciences Capstone Course at the University of North Carolina is a course focused on "interdisciplinary, team-based analysis of environmental phenomena"[19]. Capstone courses provide an opportunity for students to conduct research typical of professional practice and channels the universities' expertise to help find creative solutions to environmental

[18] "Developing a Greenhouse Gas Inventory." United States Environmental Protection Agency. Accessed March 24, 2015. http://www.epa.gov/statelocalclimate/local/activities/ghg-inventory.html

[19] "Curriculum for the Environment and Ecology." In *University of North Carolina at Chapel Hill (UNC-CH) Undergraduate Bulletin*. University of North Carolina, Chapel Hill (UNC-CH), 2014. http://www.unc.edu/ugradbulletin/depts/ecol.html

issues in communities[20]. Capstone projects have ranged from green public housing to developing more environmentally responsible chicken feed. We are a group of seniors studying in the fields of environmental health and environmental studies. Through this course we have worked to analyze greenhouse gas emissions, their possible consequences, and mitigation strategies to reduce them.

Our mission was to work with the Town of Carrboro to create an updated greenhouse gas inventory. In 2011, another Capstone team completed Carrboro's baseline greenhouse gas emission inventory. The previous Capstone utilized data for the calendar year of 2009. Our inventory uses data from 2012, the most recent year for which all data was available. We replicated the methodology from the 2009 inventory as closely as possible to ensure that the data could be compared between the two inventories and trends could be identified. Using our findings, we have recommended mitigation strategies, taking the Town of Carrboro's current situation into consideration. Our recommendations promote a healthier environment and work toward the Town's goals of reducing greenhouse gas emissions.

The Town of Carrboro

The Town of the Carrboro is located in Orange County, North Carolina and is made up of 6.46 square miles (16.8 square km). In 2012, the estimated population of Carrboro was 20,265[21]. It lies in close proximity to the University of North Carolina at Chapel Hill, causing it to be the place of residence for numerous students. This small community has a long history of environmental activism and awareness. In 2005, Carrboro signed the Mayors' Climate Protection Agreement and for the last decade the Town has taken multiple actions to address climate change:

- **2005** - signed Mayors' Climate Protection Agreement, in which 1,060 mayors around the nation signed the agreement pledging to reduce their greenhouse gas emissions to 7% below their 1990 levels by 2012[22].
- **2005** - Orange County emission inventory initiated by International Council for Local Environmental Initiatives (ICLEI)
- **2009** - passed Climate Protection Resolution, taking responsibility for the Town's share of CO_2 emissions. The resolution was as followed:

  > *The Town of Carrboro will seek, and will facilitate the community at large, to cut CO2 emissions by its proportion of the amount which is required to stabilize the climate back to less than 350 ppm of CO2 in the atmosphere in time for a*

[20] "Capstone Research Projects." Institute for the Environment at UNC-Chapel Hill. Accessed March 16, 2015. http://www.ie.unc.edu/for_students/courses/capstone.cfm.

[21] "North Carolina Municipal Population Estimates." North Carolina Office of State Budget and Management. Accessed March 16, 2015. http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/municipal_estimates.shtm.

[22] "About the Center - Mayors Climate Protection Center." The United States Conference of Mayors - Climate Protection Center. Accessed March 16, 2015. http://www.usmayors.org/climateprotection/about.asp.

90% probability for success as defined by the most up to date scientific consensus.[23]

- **2011** - UNC Capstone team completes first community greenhouse gas inventory for Carrboro
- **2011-2013** - implementation of Worthwhile Investments Save Energy (WISE) program[24], which expanded the energy efficiency program by creating subsidies for energy efficiency assessments and improvements in residential and small commercial buildings.
- **2012** - The Town begins conducting annual GHG inventories for municipal operations
- **2014** - The Town adopts its first Energy and Climate Protection Plan

Most recently, the Town created the Energy and Climate Protection Plan (ECPP)[25], which outlines recommendations to make the Town more energy efficient and generate more renewable energy. Carrboro is a Town already centered on values of energy efficiency and a love for the environment. This report will not only reference Carrboro's past and ongoing efforts to reduce greenhouse gas emissions, but also build upon these strategies and suggest additional policies and approaches that would benefit the Town based on the trends we have found in the updated inventory. In doing so, we hope to further Carrboro's efforts to reduce greenhouse gas emissions.

[23] "Carrboro 2009 Climate Protection Resolution." Town of Carrboro - Sustainability, Energy, and Climate Change. December 8, 2009. Accessed March 16, 2015. http://www.ci.carrboro.nc.us/DocumentCenter/Home/View/2387.
[24] "Carrboro WISE Final Report." Town of Carrboro - Sustainability, Energy, and Climate Change. July 31, 2013. Accessed March 16, 2015. http://www.townofcarrboro.org/DocumentCenter/Home/View/1788.
[25] "Energy and Climate Protection Plan." Town of Carrboro - Sustainability, Energy, and Climate Change. May 28, 2014. Accessed March 16, 2015. http://www.townofcarrboro.org/DocumentCenter/Home/View/553.

Methodology

This inventory catalogs Carrboro's greenhouse gas emissions for the calendar year of 2012. This is the most recent year for which all the necessary data was available. Most data sources update their records annually, but some sources are only updated every two or in one instance every five years. Ideally, greenhouse gas emission inventories would be conducted each calendar year, but for many places this is not feasible. We have selected the year 2012 and believe it is a sufficient comparison to the previous 2009 report.

To complete this inventory, we collected data from multiple sources, then entered and analyzed the data in ClearPath. Below, we describe ClearPath and detail our methods for each emission source. For a list of data sources and contacts, refer to Appendix A.

ClearPath Software

To analyze our data, we chose to use ClearPath, ICLEI's most updated software for analyzing and interpreting local greenhouse gas emissions. ICLEI, or the International Council for Local Environmental Initiatives, is an international organization, founded in 1990, bringing local governments together under the commitment to sustainable development[26]. ClearPath replaced ICLEI's earlier software, CACP, which the previous Capstone used in their analysis. Because our goal was to compare our findings to the previous Capstone, our primary reason for choosing ClearPath was its similarity to CACP. ClearPath also provided a way for multiple users to collectively work on a single project. Moving forward we recommend that Carrboro continue to use ClearPath to track emissions.

ClearPath divides emissions into two tracks: government and community. The government track includes all operations or those operations directly influenced and funded by the local government. It is important to note for this inventory that some of the local government operations captured are administered not by the Town of Carrboro directly, but rather by Chapel Hill-Carrboro City Schools and Orange County. Examples of government "sectors" are schools, government buildings, vehicle fleet, and streetlights. The community track measures everything that does not fall under the municipal operations including residential, commercial, and industrial buildings as well as local transportation.

To calculate greenhouse gas emissions, ClearPath requires both direct measures and factor sets. Direct measures quantify activities that produce greenhouse gas emissions. For example, kilowatt hours (kWh) of energy used or vehicle miles travelled (VMT) are direct measures. To convert direct measures into tons of CO_2, ClearPath uses factor sets such as fuel economy for transportation, grid electricity emissions factors, and waste characterization factors. Once these factor sets are created and entered into ClearPath, they can easily be accessed for calculations reducing repetitive data entry and calculation error.

[26] "About ICLEI." ICLEI - Local Governments for Sustainability. Accessed March 16, 2015. http://www.icleiusa.org/about-iclei.

ICLEI's updates to CACP include the ability to "develop baseline and subsequent inventories, track emissions progress over time, forecast multiple scenarios for future emissions, analyze benefits of emissions reduction measures, and visualize alternative planning scenarios."[27] Most changes between CACP and ClearPath expand how the program can be used, but several changes make comparison between inventories more difficult. For example, the waste characterization changed between the two software programs. Consequently, emissions from waste are not comparable for inventories completed in CACP and ClearPath. These challenges are addressed further in our methodology and discussion.

Community Track

Electricity:

In order to obtain the electricity consumption from Carrboro's community track, we reached out to Duke Energy and PEMC, the Town's two electricity providers. PEMC provided kilowatt-hours (kWh) estimates for its residential and commercial customers in 2012. For both residential and commercial, we totaled kWh from all customers and entered into ClearPath (for kWh energy use and raw data reference Appendix B). Duke Energy provided the total kWh consumed for customers in Carrboro in 2012, divided into the subgroups of residential, commercial and industrial. These numbers were also entered into ClearPath.

In order to calculate greenhouse gas emissions from electricity use, the amount of carbon dioxide, nitrogen oxide, and methane produced by a single kWh must be calculated and then multiplied by total electricity use. These conversions are called emission factors. The Environmental Protection Agency (EPA) provides emission factors in the Emissions and Generation Resource Integrated Database (eGRID) for different regions of the U.S. Regional emission factors reflect differences in regional electricity generation; for example, the Northwest region would have lower emission factors since most of their electricity is produced through hydropower. We used the emissions factors for the Virginia/Carolina subregion.

The EPA states that "eGRID data can be used to support...greenhouse gas registries and inventories." ClearPath incorporates these factor sets into its software so that entering electricity or fuel use automatically generates emission values using these emission factors. The 2009 inventory used the 2007 eGRID emission factors, while our inventory uses the 2010 eGRID emission factors as these were the most current emissions factors for the 2012 emissions data. The updated eGRID data accounts for changes in electricity generation in that time. The emission factors for both inventories are included in Appendix C.

Natural Gas:

In order to obtain the community natural gas use, we reached out to PSNC Energy. PSNC Energy provided us with the average customer therms (a unit of heat equivalent to 100,000 Btu or 1.055×10^8 joules) use for 2012 and the approximate residential and commercial customer

[27] "ClearPath Software - About." ICLEI - Local Governments for Sustainability. Accessed March 16, 2015. http://www.icleiusa.org/.

count for Carrboro for 2012. When inputting the data into ClearPath, it is important to multiply the average residential customer therms use by the approximate number of residential customers to get the total therms used. This number, total residential natural gas use, goes into the "community residential energy use" category in ClearPath. ClearPath then automatically converts the total therms to the CO_2 equivalent (CO_2e). The same must be done for "community commercial energy use," but using the average commercial customer therms use and the approximate number of commercial customers.

Solid Waste:

In order to analyze the community solid waste emission data for 2012, it was first necessary to obtain community waste generation data. We retrieved data the tons of waste generated by Carrboro from the Orange County Solid Waste (OCSW) website (all data sources are included in Appendix A). The previous Capstone team also acquired their data from OCSW.

The previous Capstone team used the 2010 Town of Carrboro waste composition study for their factor sets, since no updated composition study was available we also used the 2010 waste composition study[28] for the ClearPath factor sets. According to the 2009 inventory, "percentages for different waste composition categories required for the CACP software were matched with those most closely matching the OCSW breakdown."

Table 1. Comparison of 2009 CACP and 2012 ClearPath waste characterization factor set.

CACP Factor Set	2009 Percentage	Waste Composition Category	ClearPath Factor Set	2012 Percentage	Waste Composition Category
Paper Products	23.2%	Paper	Percentage Newspaper	2.1%	"newspaper/print" under "paper"
			Percentage Office Paper	2.2%	"mixed office paper" under "paper"
			Percentage Corrugated Cardboard	1.5%	"recyclable cardboard" under "paper"
			Percentage Magazines/Third Class Mail	0.9%	"glossy magazines" under "paper"
Food Waste	37.0%	Organics	Percentage Food Scraps	21.2%	"food waste" category under "organics"
Plant Debris	1.8%	Yard Waste,	Percentage Grass	0.6%	⅓ of "yard waste"

[28]"Town of Carrboro Waste Composition." Orange County Waste Characterization Study. April 1, 2010. Accessed March 16, 2015. http://www.co.orange.nc.us/recycling/documents/WasteSort2010/Carrboro_composition.pdf

					because it “includes grass, leaves, small branches”
			Percentage Leaves	0.6%	⅓ of “yard waste” because it “includes grass, leaves, small branches”
			Percentage Branches	0.6%	⅓ of “yard waste” because it “includes grass, leaves, small branches”
Wood and Textiles	2.1%	Wood	Percentage Dimensional Lumber	1.4%	“lumber” under “wood”
All Other Waste	35.9%	Plastics, Ferrous Metal, Non-Ferrous Metal, Glass, Inert, Special Waste, and Brown Goods	Mixed Solid Waste	68.9%	100% minus all previous categories

Since the ClearPath factor set for waste was different than the CACP factor set, different waste composition categories were used. We attempted to use categories that matched verbatim the categories as shown in Table 1. The difference in factor sets between CACP and ClearPath, and the resulting difference in division of waste may result in different emission estimates since the factor set categories are used to calculate the amount of methane released by the breakdown of biodegradable materials. We discuss this and other differences in methodology further in the Discussion.

Transportation:

For the community transportation sector we used the boundary of Carrboro’s city limits when determining the vehicle miles travelled and subsequent emissions for Carrboro. This means all trips taken within Carrboro, whether it be by a resident or nonresident of Carrboro, were counted, and trips taken outside of Carrboro’s city limits by residents were not counted. We chose to limit our analysis to trips made within Carrboro’s city limits so that an accurate comparison with the 2009 report, which used the same boundary, could be made. This assumption is frequently made in emission inventories because data on distance travelled by residents is scarce, but traffic studies can provide estimates of trips within a community.

The NC Capital Area Metropolitan Planning Organization (CAMPO) provided annual vehicle miles travelled (AVMT) for Orange County and daily vehicle miles travelled (DVMT) for Orange County and the Town of Carrboro for the year of 2012. The data for Orange County

was used to find a conversion factor to convert Carrboro's DVMT to AVMT. Carrboro's DVMT cannot be simply multiplied by 365.25 days/year because this does not take into account variations of vehicle miles travelled due to holidays and weekends. Thus, Orange County's AVMT was divided by DVMT (1,575,068,000/4,335,000) to obtain the conversion factor of 363.33748 days/year. Carrboro's DVMT was then multiplied by this conversion factor (190,780 * 363.33748) to obtain Carrboro's AVMT of 69,317,524 miles/year.

The data used in the transportation factor set, which was entered into ClearPath, was obtained from statistics produced by the U.S. Department of Transportation. The factor set for transportation required a breakdown of vehicle type and an average fuel economy for each vehicle. The U.S. Department of Transportation had the breakdown of vehicle type for North Carolina, which was used as a proxy for Carrboro[29]. Fuel economy by vehicle type was reported in the U.S. D.O.T's National Transportation Statistics[30]. Because national and state averages are being used as a proxy, it is important to note that actual emissions in Carrboro will vary from the calculated emissions to the degree its vehicle type and fuel economy deviate from state and national averages.

Table 2. Factor Set for Community Transportation

Type of Vehicle	Percentage	Fuel Economy (miles/gallon)
Passenger Vehicles	71.73%	23.3
Light Trucks	20.49%	17.1
Heavy Trucks	6.04%	7.3
Motorcycles	0.85%	43.5

Municipal Track

Schools:

The Sustainability Coordinator for the Chapel Hill-Carrboro School system provided data on monthly billing for electricity (in kWh) and natural gas (in therms) use for each school that is in the town limits of Carrboro. There are currently 5 schools located in the town limits. The data for each month was summed for all of 2012 and entered into ClearPath. All five schools were totaled together for a single estimate for school electricity and natural gas use.

[29] "Highway Statistics Series." Table VM-4 – Office of Highway Policy Information (OHPI) – FHWA. November 1, 2014. Accessed April 16, 2015. http://www.fhwa.dot.gov/policyinformation/statistics/2013/vm4.cfm.
[30] "National Transportation Statistics." Bureau of Transportation Statistics. Accessed April 16, 2015. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html.

Electricity:

The monthly billing statements for electricity use from Duke Energy were provided by the Town of Carrboro. Estimates of kilowatt-hours (kWh) for each building, as well as lighting (e.g. streetlights and stoplights) for the entire year of 2012 were provided for each government building (e.g. Town Hall, Century Center, etc.). The data for each building were added independently into ClearPath.

In order to calculate greenhouse gas emissions from electricity used by municipal buildings and schools we used EPA's 2010 eGRID. The eGRID provides regionally specific conversion or emission factors to convert kWh of electricity to tons of carbon dioxide, nitrogen oxide, and methane. ClearPath incorporates these factor sets into its software so that entering electricity or fuel use automatically generates emission values. We used the emissions factors for the Virginia/Carolina subregion as that is the region in which the Town of Carrboro is located. The EPA updates eGRID every few years; the most recent update used data from 2010, which is the eGRID data that we used. The 2009 inventory used the 2007 eGRID emission factors (the emission factors for both inventories are included in the Appendix C).

Natural Gas:

The monthly billing statements for natural gas use from PSNC were provided by the Town of Carrboro. Estimates of therms of natural gas use for the entire year of 2012 were provided for each government building. The natural gas estimates for each building were added independently into ClearPath.

Vehicle Fleet:

The annual estimates of vehicle gasoline and biofuel use for each of Carrboro's departments was provided in gallons. The Fire Department and Public Works were the only two departments whose fleets used both gasoline and biofuel. Each fuel type was added into ClearPath independently for each department. The biofuel and gasoline estimates for the Fire Dept. and Public Works were also added separately. All Carrboro fleet vehicles used B20 biofuel, which is a blend of fuels consisting of 20% biofuel and 80% gasoline. The ClearPath software, unlike the CACP software, is able to calculate emissions from biofuel use instead of having to separately calculate values for biofuel and gasoline in the biofuel mixture.

Transit:

Chapel Hill Transit (CHT) is a local public transportation system of buses that serves the Towns of Chapel Hill and Carrboro. The 2012 emissions estimates of the entire fleet were provided by CHT. Since not all of the bus emissions of the transit fleet are linked to the Town of Carrboro, the 2009 inventory attributed Carrboro 15% - the percentage of funding CHT receives from the Town of Carrboro. CHT suggested using the same estimate for 2012. The total emissions values for the transit system were multiplied by 0.15 to produce the amount attributable to the Town of Carrboro.

Results and Discussion

In 2012, the Town of Carrboro emitted a total of 111,954 CO_2e (tons of CO_2 equivalent). This equates to 5.5 tons CO_2e per a person. This is low compared to state and national per capita emissions. The state of North Carolina as a whole emitted 12.7 tons of CO_2e per person in 2011[31] and in 2012 the United States emitted 16.4 tons CO_2e per capita[32]. The world also had higher per capita emissions (7.65 tons CO_2e) than the Town of Carrboro in 2012[33]. Carrboro's emissions are significantly lower than these averages mainly because it does not have an emissions from industry. Still, overall, these comparisons show that Carrboro has been doing well at managing their greenhouse gas emissions.

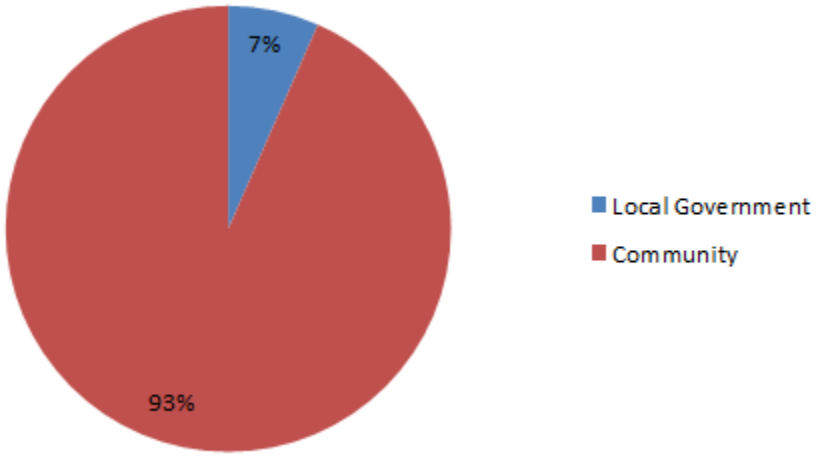

Figure 1. Comparison of Community vs. Local Government Emissions

The community track contributes 93% of Carrboro's greenhouse gas emissions. Local government operations make up only 7% of emissions.

The residential sector had the largest emissions in the community track. Energy use from this sector in 2012, generated 43,406 metric tons of CO_2e. This is over 10,000 metric tons more than the next largest sector, transportation. Transportation contributed 31,183 tons of CO_2e. Commercial energy use generated roughly one-fourth of the total emissions at 26,836 metric tons of CO_2e. Solid waste and the industrial sector were the smallest sources of emissions.

---

[31] "Table 5. Per Capita Energy-related Carbon Dioxide Emissions by State (2000–2011)." U.S. Energy Information Administration. Accessed April 16, 2015. http://www.eia.gov/environment/emissions/state/analysis/pdf/table5.pdf.

[32] Olivier, Jos, Greet Janssens-Maenhout, Marilena Muntean, and Jeroen Peters. "Trends in Global CO2 Emissions 2013 Report." European Commission. January 1, 2013. Accessed April 16, 2015. http://edgar.jrc.ec.europa.eu/news_docs/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf.

[33] "GHG (CO2, CH4, N2O, F-gases) Emission Time Series 1990-2012 per Region/country." European Commission. April 16, 2015. Accessed April 16, 2015. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012.

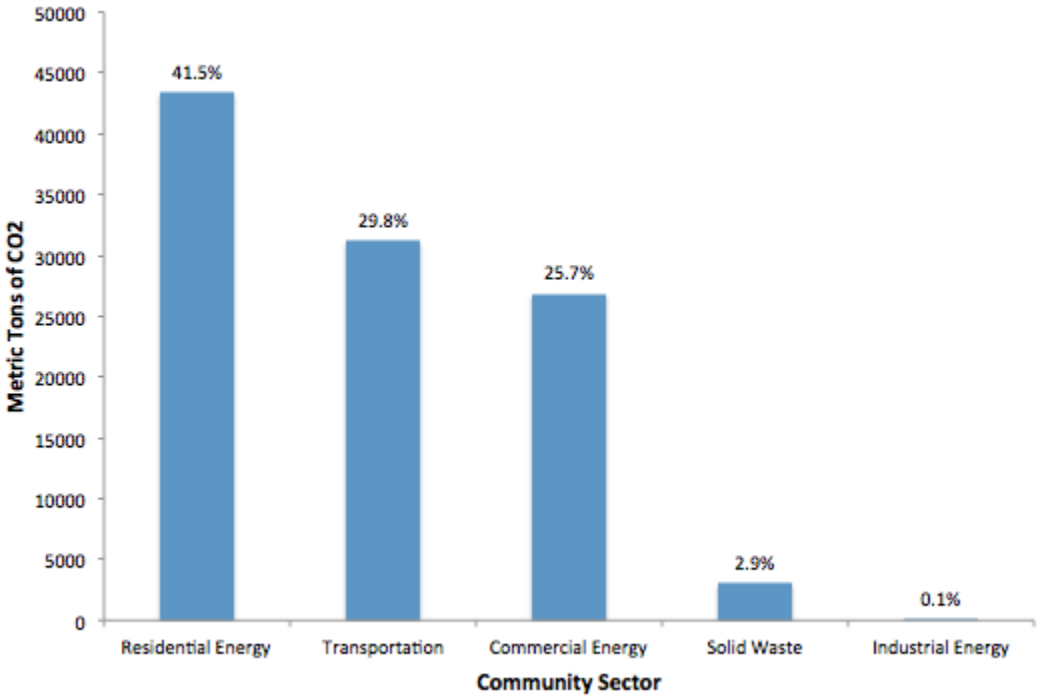

Figure 2. Summary of Community Sector Emissions

In each sector of local government emissions, buildings were the largest contributor to emissions at 5,190 tons of CO_2e. Transit fleet, vehicle fleet, and lighting contributed less, but still significant, amount of greenhouse gases.

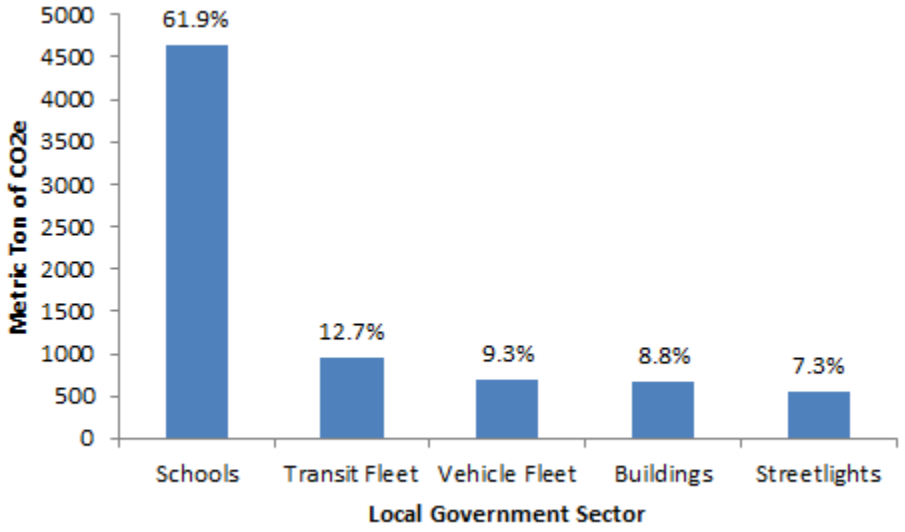

Figure 3. Local government greenhouse gas emissions for the Town of Carrboro by sector.

Buildings are the largest contributors of greenhouse gas emissions in the local government sector. The Century Center contributes the most emissions compared to any other

building with a value of 310 tons of CO_2e. The five Carrboro schools were not included in this graph, but also contributed an even larger amount of 4,532 tons of CO_2e.

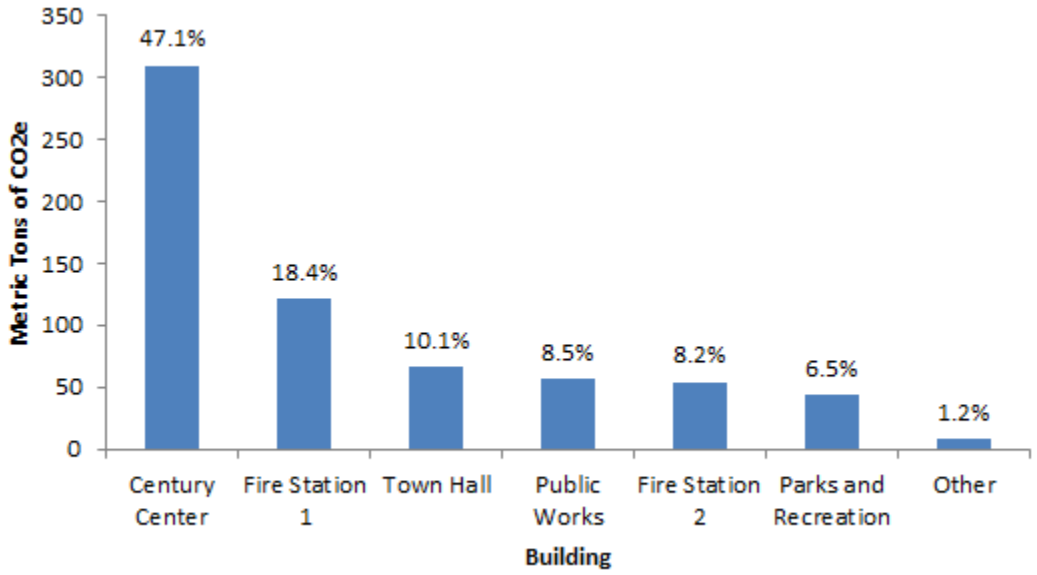

Figure 4. Local government greenhouse gas emissions by building of the Town of Carrboro.

In the vehicle fleet, the Public Works and Police department are the largest sources of emissions. Both contribute about the same amount of CO_2e, 305 and 292 tons, respectively. The Fire Department contributes significantly less than Public Works and Police, but more than the remaining departments. The values for Public Works and the Fire Department include both gasoline and biofuel emissions added together whereas the other departments only used gasoline.

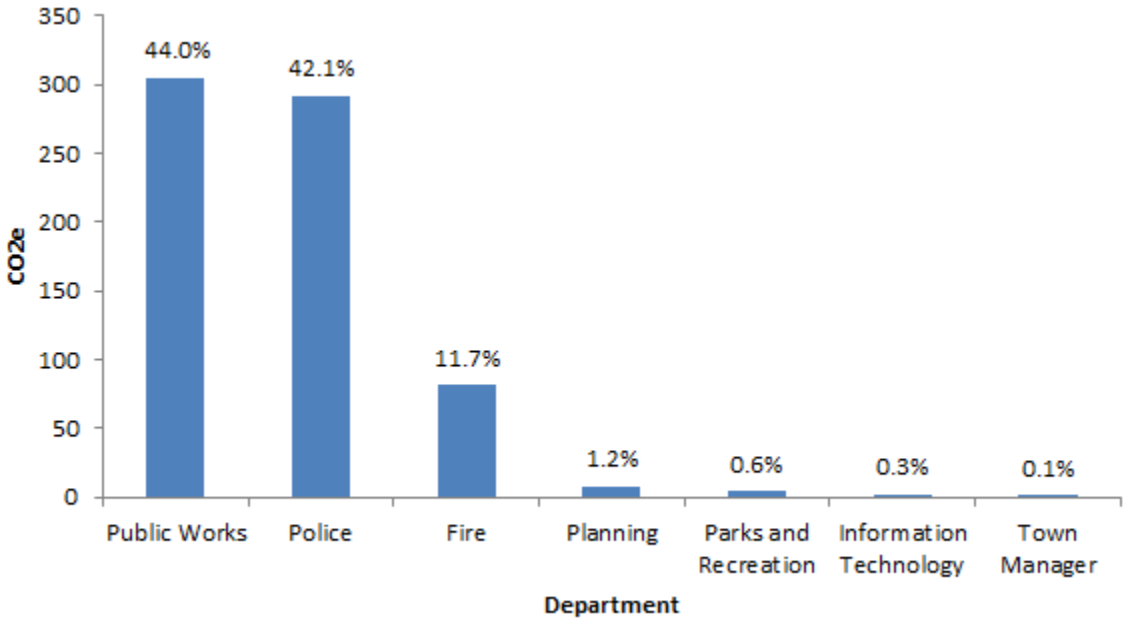

Figure 5. Municipal greenhouse gas emissions by vehicle fleet of each department of the Town of Carrboro.

2012 & 2009 Comparison:

Between 2009 and 2012, Carrboro's greenhouse gas emissions reduced slightly from 113,617 to 111,954 tons of CO_2e despite a growing population. Per capita emissions decreased from 5.7 to 5.5 tons CO_2e, a reduction of 3.51%. The 2009 report included emissions related to water and sewer use by the local government. While we did not include those emissions in our report, we recalculated 2009 emissions to reflect this difference in order to draw more accurate comparisons.

Emission reduction was greatest in the municipal track. Local government emissions dropped 1,336 tons CO_2e or 15.32% reduction. The largest reduction was in government buildings, which decreased by 20.45%. The largest contributor to this decrease was the drop in Carrboro school's emissions; municipal building emissions from 2009 to 2012 did not vary much. There were also emission reductions in the transit and vehicle fleet. Over the same time, emissions from streetlights increased by 16.27%.

Table 3. Comparison of 2009 and 2012 local government emissions.

	2009 CO_2 Emissions (metric tons)	2012 CO_2 Emissions (metric tons)	Change in CO_2 Emissions	Percent Change
Buildings	6,527	5,192	-1335	-20.45%
Transit Fleet	960	954	-6	-0.625%
Vehicle Fleet	764	693	-71	-9.29%
Streetlights	467	543	76	16.27%
Total	8718	7382	-1336	-15.32%

In the community sector, emissions from residential energy decreased the most, dropping by 18% or 9,715 tons of CO_2. Emissions from solid waste, industrial energy use, and commercial energy use all increased. The increase in commercial energy use contributed the largest amount of additional CO_2, 8,367 tons.

Table 4. Comparison of 2009 and 2012 community emissions.

	2009 CO_2 Emissions (metric tons)	2012 CO_2 Emissions (metric tons)	Change in CO_2 Emissions	Percent Change
Solid Waste	1,678	3,034	1,356	80.81%
Transportation	31,576	31,183	-393	-1.25%
Residential Energy	53,121	43,406	-9715	-18.29%
Commercial Energy	18,469	26,836	8367	45.30%
Industrial Energy	55	113	58	105.45%
Total	104,899	104,572	-327	-0.31%
Per Capita	5.27	5.31	.04	<1%

Between 2009 and 2012, there was an 8% decrease in emissions generated by community use of natural gas. This is due to the large decreases in residential use, which dropped from 8,430 to 6,237 tons CO_2e. Meanwhile, commercial natural gas use increased. It is possible that the 8% decrease in emissions is attributable to 2012 being one of the hottest years in North Carolina to date. Since one of the main uses for natural gas is heating, a significant increase in average

temperature for the year could translate to decreased natural gas use, but this does not explain the decrease use in the residential sector and increase in the commercial sector.

Table 5. Change in natural gas emissions 2009 to 2012.

Year (Population)	Residential Therms (CO_2)	Commercial Therms (CO_2)	Total Therms (CO_2)	Per capita Therms (CO_2)
2009 (19,891)	(8,430)	(1,782)	(10,227)	(.52 CO_2 tons)
2012 (19,702)	1,173,000 (6,237)	597,000 (3,175)	1,770,000 (9,412)	(.48 CO2 tons)
Change (-189)	(-2,193)	(+1,393)	(-815)	

While we tried to replicate the methodology from the 2009 inventory as closely as possible, there are some discrepancies that may influence the comparison between 2009 and 2012 emissions. For the most part, these discrepancies are due to changes in software and data availability. For example, in 2009, Duke Energy was only able to provide energy consumption for Orange County as a whole. To determine energy use in Carrboro, the previous team had to determine what fraction of Orange Counties energy use could be attributed to Carrboro residents. For 2012, Duke provided energy used by commercial, industrial, and residential customers in Carrboro. This data allowed for more accurate estimation of Carrboro's greenhouse gas emissions, but limits comparisons to 2009. It is difficult to determine how much the decrease in GHG emissions from residential energy use can be attributed to changes in data versus mitigation policies.

Similarly, the 2009 team was not able to get Carrboro-only data from OCSW, and therefore had to make assumptions on Carrboro's portion. Additionally, the 2009 team used ICLEI's CACP software which had a different factor set than ClearPath for waste composition (discussed further under *Methods*). Unfortunately, this likely affected the comparability of the waste emissions. The amount of Greenhouse gas emissions from solid waste increased significantly between 2009 and 2012 despite a decrease in tons of waste produced. According to the 2009 report, pounds of waste generated per person per day dropped from 3.2 pounds in 2005 to 2.3 pounds in 2009. Based on our data, this trend has continued with residents producing only 2.24 pounds of waste a day in 2012. Not only did per capita waste generation decrease, but total waste generation decreased as well. Nevertheless, total waste emissions nearly doubled from 1,678 to 3,034 tons CO_2e.

Table 6. Change in solid waste emissions from 2009 to 2012:

Year (Population)	Tons (CO_2)	Per Capita
2009 (19,891)	8,349 (1,678)	2.3 lbs (.08 CO_2 tons)
2012 (19,702)	8,047 (3,034)	2.24 lbs (.15 CO_2 tons)

Change (-189)	-302 (1,356)	-.06 lbs (.07 CO_2 tons)

Major Findings

In summation, several major findings stood out to us as we organized the data we had collected:

- Total emissions decreased between 2009 and 2012 from 113,617 to 111,954.
- Municipal emission, which decreased 15%, was largely responsible for overall reductions.
- The decrease in municipal emission was largely due to a reduction of 1,335 tons CO_2e in local government buildings. A 9% emission reduction by the vehicle fleet helped to offset a 16% emission increase by streetlights.
- While the community sector only saw a slight decrease in total emissions, there was significant decrease residential energy use. Residential energy emissions decreased by 9,715 metric tons of CO_2, which is more than an 18% reduction.

Mitigation Strategies

Residential Energy

As our data shows, residential energy usage makes up the majority of the Town's greenhouse gas emissions. Consequently, it is an important area to target to reduce overall emissions.

Because of Carrboro's proximity to the University of North Carolina at Chapel Hill, it is the temporary place of residence for numerous students and many houses or apartments are rented to these students. Only 33% of homes are owner occupied, compared to 59% renter occupied (the remaining 8% of homes are vacant)[34]. Because renters pay the utility bill, landlords may be less inclined to worry about the consequences, financial and others, of a lack of energy efficiency. Since they will not reap the benefits of increasing and improving energy efficiency, landlords have little incentive to make these updates. Conversely, renters have no incentive to make investments in a property they do not own.

Keeping this in mind, we recommend the implementation of energy performance rating requirements for all homes and residential buildings. These ratings will act as a form of inspection on the overall energy efficiency of the building. With this information homeowners can make informed decisions on improvements and updates made to the building. The ratings will also be available to prospective renters and buyers. The energy efficiency of a house or apartment will affect the prices of utilities and may persuade the renter one way or another. By influencing a property's appeal to future renters and buyers, the required ratings will serve as an incentive for homeowners to improve the energy efficiency of their homes. If a low rating will negatively affect their success in the market, renters may be more inclined to update their building's standards.

With the hopes of reducing the total energy of all buildings built before 2010, the City of Portland, Oregon advised this action in their 2009 Climate Action Plan. The City is currently proposing a similar policy for commercial buildings over 20,000 square feet. For the Town of Carrboro, adoption of this strategy, specifically in the residential sector, could be very beneficial and put the Town on track to reach their own goals of energy reduction. Other cities using or considering this strategy include:

- Seattle, WA[35]
- Berkeley, CA[36]
- Austin, TX[37]

---

[34]"Carrboro, NC Homes and Housing." USA City Facts. Accessed April 9, 2015. http://www.usacityfacts.com/nc/orange/carrboro/homes/.

[35] "Seattle City Council Climate Action Plan Resolution Summary." Emerald Cities Collaborative. Accessed March 16, 2015. http://emeraldcities.org/cities/seattle/resources/summary-of-seattle-city-council-climate-action-plan-resolutio.

[36] "Berkeley Climate Action Plan: Tracking Our Progress - Building Energy Use." City of Berkeley. April 14, 2014. Accessed March 16, 2015. http://www.ci.berkeley.ca.us/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/Green Building and Energy Certification CAP.pdf.

A website tracking different jurisdictions efforts for transparency in energy efficiency, specifically in their buildings, can be found at http://www.buildingrating.org/jurisdictions . BuidlingRating.org provides a way to view and compare policies that are being implemented to improve and benchmark building energy efficiency.

It is possible that Carrboro would need to acquire statutory authority from the State to pursue such a strategy.

Commercial Energy

Greenhouse gas emission increased for the commercial sector between 2009 and 2012, suggesting that additional mitigation strategies should be pursued in this area. There are multiple ways to encourage business owners to increase their energy efficiency. The first is to simply educate them of the resources that already exist for increasing energy efficiency. There are a number of state and federal programs that provide financial incentives for business owners to increase their energy efficiency. For example, the U.S. Department of Energy provides a federal tax deduction, called a 179D tax deduction, for buildings that are able to show a certain amount of energy use reductions[38].

For some business owners, a pamphlet that outlines the potential savings of increasing their energy efficiency (such as changing to LED bulbs) may be all they need to be more energy efficient. The Town could also provide them with information regarding financing options for energy efficiency improvements. Holding workshops about operations and maintenance improvements may also lead to improvements in energy efficiency. The U.S. Office of Energy Efficiency & Renewable Energy states that "By one estimate, O&M measures cost about 20 times less and achieve roughly the same energy savings as energy efficiency upgrades"[39]. It is worth noting that the Town's Energy Efficiency Revolving Loan Fund did not result in significant reductions by 2012, although several loans were initiated in 2012-2013.

Waste

While the per capita waste generation for Carrboro is significantly lower than the national average, it will be essential to reduce waste generation as much as possible since the Orange County landfill has closed as of 2015. Since Carrboro's waste now has to travel to Durham, each

---

[37] "Energy Conservation Audit and Disclosure Ordinance." Austin Energy. Accessed March 18, 2015. http://austinenergy.com/wps/portal/ae/programs/ecad-ordinance/energy-conservation-audit-and-disclosure-ordinance/!ut/p/a1/jZAxT8MwFIR_S4eMjo0rwGUzpgqhlEykIUvlJq-OpdSObKcR_HpSWChqoW876bt7usMlLnBp5F4rGbQ1sj3o8mZNKKOPgtA0uaWM8ETcL67zl6sZIyPw9hPI5tkDSfMs59lCkERML_SfOU7-8z9d8IC6pVgqXHYyNEibrcUFGHDqHVXWeHD7r7ZI9rUOSJoa1dpXrfW9A2RdrY00FRyCuNlM2RjkYAsOXNy7caEmhM7fRSQiwzDEylrVQlzZXUROWRrrAy6OSbzC5V81-Jz-Bk7s_A2cH7LbvRYfz7BiYZZqPpl8AjKatdw!/dl5/d5/L2dBISEvZ0FBIS9nQSEh/.

[38] "179D DOE Calculator." United States Department of Energy. May 3, 2012. Accessed April 9, 2015. http://apps1.eere.energy.gov/buildings/commercial/179d/

[39] "Improve Operations & Maintenance." Energy.gov. Accessed April 9, 2015. http://www.energy.gov/eere/buildings/improve-operations-maintenance

pound of trash now has a higher emission footprint. To encourage citizens to produce less waste, the Carrboro Town government can create campaigns emphasizing the importance of recycling. Not only does recycling reduce emissions, but since the location of the recycling center is not changing, there is also no increase in emissions from transportation.

Additionally, Carrboro should encourage citizens to compost and provide resources for them to do so. Some city and town governments have even implemented compost collection programs, thereby taking most of the legwork out of it for citizens. While Carrboro currently has a yard waste collection program, all organics produce methane when they anaerobically decompose (as happens in a landfill). Methane is 21 times more potent as a greenhouse gas than CO2, therefore, reducing the amount of organics that end up in a landfill is essential for reducing community GHG emissions[40,41].

Transportation

The transportation sector had only a 1% reduction between 2009 and 2012. This could have several explanations. One explanation is the transportation sector is more difficult than other sectors to invoke change as it relies heavily on individuals changing their practices. The International Society of Sustainability Professionals (ISSP) discusses how changing the individual's transportation mindset takes time and is often sequential. People usually begin with starting to use public transportation for some trips, which allows them to realize other places it can take them. Often some people will tire of waiting for the bus, causing them to find bike routes to reduce commuting time. Finally, after people begin to bike to certain appointments, they will then begin to realize other events they can bike to[42]. Another explanation is that the methodology is not sensitive to changes. For example, CAMPO can't capture local trips very accurately and vehicle type and fuel economy are not well represented by state and national averages.

Now let's discuss interventions that can be implemented to reduce transportation emissions. Overall Carrboro should encourage alternative forms of transportation, such as biking and walking. In order for individuals to begin walking and biking, there must be infrastructure for it. Creating bike lanes and wider roads and providing bicycle racks, shower or locker rooms, and trail maps improve the infrastructure[43]. Also, people may be more likely to bike or walk if

---

[40] "USCC Position Statement: Keeping Organics Out of Landfills." US Composting Council. Accessed April 15, 2015. http://compostingcouncil.org/admin/wp-content/uploads/2011/11/Keeping-Organics-Out-of-Landfills-Position-Paper.pdf

[41] Daigneau, Elizabeth. "Curbside Composting Added to a Major City: Is It Yours?" Curbside Composting Added to a Major City: Is It Yours? February 1, 2012. Accessed April 15, 2015. http://www.governing.com/topics/energy-env/gov-curbside-composting-added-to-major-city.html.

[42] "10 Things Cities Are Doing Now to Reduce Greenhouse Gases." Cool Trends. January 1, 2008. Accessed April 16, 2015. http://www.sustainabilityprofessionals.org/files/Cool Trends.pdf.

[43]"Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources." Transportation and Global Climate Change: A Review and Analysis of the Literature. Accessed April 16, 2015. http://www.fhwa.dot.gov/Environment/glob_c5.pdf.

they consider it to be safe. The local government can improve safety through features like crosswalks, sidewalks, and brighter streetlights[44].

In addition to improving infrastructure, city events can expose people to and encourage alternative modes of transportation. The organization the Carrboro Bicycle Coalition is currently holding events in Carrboro that the local government could expand upon. Once a year the coalition holds the ciclovía event "Carrboro Open Streets," where Weaver St. is blocked off to motor vehicles and is open to pedestrians and cyclists. They also carry out a Bicycle Friendly Business Program, which recognizes businesses that encourage their customers and employees to cycle. The local government can expand upon this by championing for businesses to participate in a Bike Saturday's program, where they offer discounts to patrons who bike to their business on a certain day[45]. Another program that Carrboro may wish to continue or accelerate is the Safe Routes to School Program. This type of program was proven effective in Boulder, CO, where one school reported that 75% of their students walked or biked to school (a 620% increase from before the program started)[46].

Alternative modes of transportation can be influenced by economic incentives that are employed in conjunction with the programs discussed above or through other means. For example, Carrboro could provide a tax break to businesses that participate in the Bike Saturdays program. Another economic incentive would be to have a mandatory parking cash-out. This would give the employees the option of taxable income, instead of parking, which is subsidized by the government, causing employees to see the cost of driving to work as income waived[47]. Eight case studies in California showed the effectiveness of cash-out programs. They saw an overall vehicle miles travelled decrease by 12%, with large increases in carpooling (64%) and use of public transit (50%)[48].

Economic incentives can discourage personal vehicle use as well. For example, public parking fees can be increased, leading to less congestion and also income for the local government that can go towards other transportation control measures[49]. In addition to parking fees, parking supply limit methods can be used. These strategies include decreasing minimum-

---

[44] "10 Things Cities Are Doing Now to Reduce Greenhouse Gases." Cool Trends. January 1, 2008. Accessed April 16, 2015. http://www.sustainabilityprofessionals.org/files/Cool Trends.pdf.

[45] "Local Projects." Bike Carrboro Bicycles and Bicycling in Carrboro Chapel Hill and the Triangle NC. January 1, 2015. Accessed April 16, 2015. http://bikecarrboro.com/what-we-do/local-projects.

[46] "Transportation Control Measures." Local Government Climate and Energy Strategy Series. March 1, 2011. Accessed April 16, 2015. http://www.epa.gov/otaq/stateresources/policy/430r09040.pdf.

[47] "Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources." Transportation and Global Climate Change: A Review and Analysis of the Literature. Accessed April 16, 2015. http://www.fhwa.dot.gov/Environment/glob_c5.pdf.

[48] "Transportation Control Measures." Local Government Climate and Energy Strategy Series. March 1, 2011. Accessed April 16, 2015. http://www.epa.gov/otaq/stateresources/policy/430r09040.pdf.

[49] ibid.

parking ratios in zoning, creating area-wide parking caps, and limiting parking to certain times of day or certain users[50].

Many of these strategies echo recommendations made during Carrboro's Transportation Forum of fall 2014. When prioritizing these strategies we suggest that the Town of Carrboro first focus on improving and building infrastructure for alternative modes of transportation. The infrastructure must be in place before the other transportation strategies will work. The Transportation Forum suggested similar strategies, such as ensuring bike parking at high-demand bus stops and encouraging developers to promote multi-modal transportation options. Once the infrastructure is in place, the Town of Carrboro should enhance current programs and events - the foundation for them is already in place. The Transportation Forum largely focused on creating a Safe Routes to School program by supporting the actions of a *Safe Routes to School Action Committee* and planning to develop a bike route connecting Carrboro High School to Southern Village. Lastly, parking strategies can be used to limit personal vehicle use and increase revenue, which can then be used for economically-incentivized, emission-limiting methods.

Municipal Strategies

Although the municipal sector makes up only 7% of the total emissions for the Town of Carrboro, there are still things that the Town can do to reduce its greenhouse gas emissions. Buildings are the largest contributors of GHGs out of the municipal sectors. The Town of Carrboro can continue to promote the upkeep of outdated technology and appliances used by the Town. For example, the Century Center is the building with the most emissions which has a lot to do with the fact that it's an older building with older technology. When new appliances are required, purchase of Energy Star certified appliances would be beneficial. Secondly, the Town could work to improve its own building's energy codes. The Town's Energy and Climate Protection Plan already discusses assessing the Century Center's HVAC system and Town Hall in order demonstrate how it can meet USEPA Energy Star standards. More investment into Energy Star certification of Town buildings are a potential, but it is unsure when the payback of this investment would occur.

Lighting is another area in which it is easy to enact change in some ways but difficult in others. Promoting use of fluorescent light bulbs inside buildings has likely already been happening, but use of LED bulbs for outdoor and streetlights are harder to implement as the Duke Energy owns the lights and lighting infrastructure. Our understanding from Town staff is that recent actions by the North Carolina Utilities Commission have not resulted in a rate structure that is financially attractive for the Town to work with Duke to install LED fixtures. We recommend that the Town continue to pursue this opportunity because of the energy savings potential. Recently, Duke Energy Progress received approval from the N.C. Utilities Commission to begin replacing old mercury lights with new LED ones. The Town of Carthage,

[50] "Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources." Transportation and Global Climate Change: A Review and Analysis of the Literature. Accessed April 16, 2015. http://www.fhwa.dot.gov/Environment/glob_c5.pdf.

located in the Sandhills of North Carolina, began efforts to update their street and area lights to LED lights in 2014. The Town of Carthage is estimated to save $3,464 annually[51]. The neighboring Town of Southern Pines has also requested an upgrade to LED lights and is currently working with Duke Energy Progress to complete this transition, which is estimated to be completed by July 2015[52].

Another major municipal sector that contributes to GHG emissions is the Town's vehicle fleet. The Public Works and Fire Department, which are the largest contributors of emissions in this sector, already have significant use of biofuel but increasing biofuel use in all department vehicles would reduce emissions. Another idea to reduce emissions from vehicle fleet is shutting off vehicles instead of idling on the job. This mainly applies to the Police Dept., Public Works, and the Fire Dept., who often leave vehicles on while completing their task on call. Idle vehicles may be a significant contributor to GHG emissions.

[51] Natt, T.M. 2015. "A Bright Idea: Towns Update Street Lighting, Save Money". *The Pilot*. http://www.thepilot.com/news/a-bright-idea-towns-update-street-lighting-save-money/article_9696c852-95c3-11e4-80f4-dfa02784e1ee.html

[52] http://www.southernpines.net/DocumentCenter/View/2102

Appendix A: Data Sources

Community Data Sources:

	Organization	**Contact**
Electricity	Duke Energy	Indira Everett – District Manager Duke Energy Corporation indira.everett@duke-energy.com Kim Ellis Kim.Ellis@duke-energy.com
Electricity	Piedmont Electric Membership Corporation	Dawn Reinwald Dawn.Reinwald@pemc.coop
Heating Fuel	PSNC Energy	Julie Roper PSNC Energy 1312 Annapolis Dr., Suite 200 Raleigh, NC 27608 919-836-2338 jroper@scana.com
Solid Waste Services	NC DENR Dept. of Waste Management	217 West Jones Street, Raleigh, NC 27603 (919) 707-8200 David Lee - Environmental Assistance Coordinator 3800 Barrett Drive Raleigh, NC 27609 Email: David.Lee@ncdenr.gov Phone: (919) 791-4203
Solid Waste Services	Orange County Solid Waste	Pollock, Blair L. – Solid Waste Planner Orange County Solid Waste Management Department bpollock@co.orange.nc.us (919) 968-2788
Community Transportation – Regional Transportation Models	Capital Area Metropolitan Planning Organization	Gerald Daniel - Transportation Modeling Engineer Phone: 919-996-4395 Fax: 919-996-1729 Email: gerald.daniel@campo-nc.us
Breakdown of Vehicle Types, and Fuel Economy	United States Department of Transportation	Highway Statistics Series, Bureau of Transportation Statistics

Public Data Sources:

Data Set	Source	Contact
Electricity, Heating Fuel	Town of Carrboro	Randy Dodd - Environmental Planner 301 West Main Street Carrboro, NC 27510 919-918-7326 rdodd@townofcarrboro.org
Electricity, Heating Fuel, Water and Sewer Services	Chapel Hill-Carrboro City Schools	Dan Schnitzer - Sustainability Coordinator Chapel Hill-Carrboro Schools 750 South Merrit Mill Road Chapel Hill, NC 27516 919-967-8211 x28322 dschnitzer@chccs.k12.nc.us
Public Transit Fuel, VMT and GHG Emissions	Chapel Hill Transit	Jesse Freedman - Energy Management Specialist 405 Martin Luther King Jr. Blvd. Chapel Hill, NC 27514 919-969-5008 jfreedman@townofchapelhill.org

Appendix B: Data Table

Community Sector

Residential Energy

Source	Fuel	CO2 (MT)	CH4 (MT)	N2O (MT)	CO2e (MT)	Energy Equivalent (MMBtu)	Electricity Used (kWh)	Fuel Use (Therms)
PSNC	Natural Gas	6219	0.5865	0.01173	6237	117300		1173000
PEMC	Electricity	1897	0.038319	0.031164	1907	13293	3894809	
Duke Energy	Electricity	35073	0.70854	0.57624	35262	245795	72017858	

Commercial Energy

Source	Fuel	CO2 (MT)	CH4 (MT)	N2O (MT)	CO2e (MT)	Energy Equivalent (MMBtu)	Electricity Used (kWh)	Fuel Use (Therms)
PSNC	Natural Gas	3165	0.2985	0.00597	3175	59700		597000
PEMC	Electricity	4714	0.095239	0.077456	4740	33039	9680331	
Duke Energy	Electricity	18820	0.3802	0.30921	18921	131892	38644446	

Solid Waste

Source	Tons	CO2 (MT)	Per Capita lbs/day	Per Capita CO2 (MT)/day
OCSW	8,047	3,034	2.24 lbs	.15 CO2 tons

Industrial Energy

Source	CO2 (MT)	CH4 (MT)	N2O (MT)	CO2e (MT)	Electricity Energy Equivalent (MMBtu)	Electricity Used (kWh)
Ready Mix Concrete Plant	54	0.00108	0.00088	54	377	110598
Duke Energy	58	0.00117	0.00095	59	409	119740

Transportation

	DVMT	AVMT	CO_2e (tons)
Orange County	4,335,000	1,575,068,000	-
Carrboro	190,780	69,317,524	31,183

Local Government

Buildings

Source	**CO_2 (MT)**	**CH_4 (MT)**	**N_2O (MT)**	**CO_2e (MT)**	**Electricity Energy Equivalent (MMBtu)**	**Electricity Used (kWh)**	**Fuel Use (Therms)**
Carrboro Schools (Duke Energy Progress)	3675	0.074249	0.060385	3695	25757	7546795	
Carrboro Schools (PSNC)	941	0.088772	0.001775	944	17754		177544
Century Center (Duke)	207	0.004188	0.003406	208	1453	425686	
Century Center (PSNC)	102	0.009576	0.000191	102		1915	19152
Town Hall (Duke)	64	0.001284	0.001044	64	446	130590	
Town Hall (PSNC)	2	0.000144	0.000002	2		29	288
Fire Station 1 (Duke)	113	0.002292	0.001864	114	795	232960	
Fire Station 1 (PSNC)	7	0.0006435	0.00001287	7		129	1287
Fire Station 2 (Duke)	43	0.00087287	0.00070988	43	303	88720	

Fire Station 2 (PSNC)	11	0.0010755	0.00002151	11		215	2151
Public Works (Duke)	44	0.00088186	0.0007172	44	306	89634	
Public Works (PSNC)	12	0.0011675	0.00002335	12		234	2335
Parks (Duke)	43	0.00086624	0.0007045	43	301	88047	
Other (Duke)	8	0.00015897	0.00012929	8	55	16158	

Vehicle Fleet

Source	**CO_2 (MT)**	**CH_4 (MT)**	**N_2O (MT)**	**CO_2e (MT)**	**Gallons of Fuel Use**	**Vehicle Miles Traveled**
Police Dept.	292	0	0	292	33210	471982
Public Works (Biofuel)	236	0	0	236	28941	163404
Public Works (Gasoline)	69	0	0	69	7824	44175
Fire Dept. (Biofuel)	67	0	0	67	8240	112816
Fire Dept. (Gasoline)	14	0	0	14	1585	21701
Planning	8	0	0	8	949	12501
Parks and Recreation	4	0	0	4	502	7587
Town Manager	1	0	0	1	130	10000
Information Technology	2	0	0	2	183	2973

Appendix C: Factor Sets

Factor Set for Community Transportation

Type of Vehicle	**Percentage**	**Fuel Economy (miles/gallon)**
Passenger Vehicles	71.73%	23.3
Light Trucks	20.49%	17.1
Heavy Trucks	6.04%	7.3
Motorcycles	0.85%	43.5

Factor Set for Community Solid Waste

ClearPath Factor Set	**2012 Percentage**	**Waste Composition Category**
Percentage Newspaper	2.1%	"newspaper/print" under "paper"
Percentage Office Paper	2.2%	"mixed office paper" under "paper"
Percentage Corrugated Cardboard	1.5%	"recyclable cardboard" under "paper"
Percentage Magazines/Third Class Mail	0.9%	"glossy magazines" under "paper"
Percentage Food Scraps	21.2%	"food waste" category under "organics"
Percentage Grass	0.6%	⅓ of "yard waste" because it "includes grass, leaves, small branches"
Percentage Leaves	0.6%	⅓ of "yard waste" because it "includes grass, leaves, small branches"
Percentage Branches	0.6%	⅓ of "yard waste" because it "includes grass, leaves, small branches"
Percentage Dimensional Lumber	1.4%	"lumber" under "wood"
Mixed Solid Waste	68.9%	100% minus all previous categories

Factor Set for Grid Electricity

	2007	**2010**
CO2 lbs/MWh	1134.88	1073.65
CH4 lbs/GWh	23.77	21.69
N2O lbs/GWh	19.79	17.64

Works Cited

"10 Things Cities Are Doing Now to Reduce Greenhouse Gases." Cool Trends. January 1, 2008. Accessed April 16, 2015. http://www.sustainabilityprofessionals.org/files/Cool Trends.pdf.

"179D DOE Calculator." United States Department of Energy. May 3, 2012. Accessed April 9, 2015. http://apps1.eere.energy.gov/buildings/commercial/179d/

"About ICLEI." ICLEI - Local Governments for Sustainability. Accessed March 16, 2015. http://www.icleiusa.org/about-iclei.

"Berkeley Climate Action Plan: Tracking Our Progress - Building Energy Use." City of Berkeley. April 14, 2014. Accessed March 16, 2015. http://www.ci.berkeley.ca.us/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/Green Building and Energy Certification CAP.pdf.

"Carrboro, NC Homes and Housing." USA City Facts. Accessed April 9, 2015. http://www.usacityfacts.com/nc/orange/carrboro/homes/.

"Carrboro 2009 Climate Protection Resolution." Town of Carrboro - Sustainability, Energy, and Climate Change. December 8, 2009. Accessed March 16, 2015. http://www.ci.carrboro.nc.us/DocumentCenter/Home/View/2387.
"Carrboro WISE Final Report." Town of Carrboro - Sustainability, Energy, and Climate Change. July 31, 2013. Accessed March 16, 2015. http://www.townofcarrboro.org/DocumentCenter/Home/View/1788.

"Capstone Research Projects." Institute for the Environment at UNC-Chapel Hill. Accessed March 16, 2015. http://www.ie.unc.edu/for_students/courses/capstone.cfm.

"Causes of Climate Change." Environmental Protection Agency. March 18, 2014. Accessed April 16, 2015. http://www.epa.gov/climatechange/science/causes.html.

"ClearPath Software - About." ICLEI - Local Governments for Sustainability. Accessed March 16, 2015. http://www.icleiusa.org/.

"Climate Change Mitigation." United Nations Environment Programme. Accessed March 24, 2015. http://www.unep.org/climatechange/mitigation/

"Curriculum for the Environment and Ecology." In *University of North Carolina at Chapel Hill (UNC-CH) Undergraduate Bulletin*. University of North Carolina, Chapel Hill (UNC-CH), 2014. http://www.unc.edu/ugradbulletin/depts/ecol.html

Daigneau, Elizabeth. "Curbside Composting Added to a Major City: Is It Yours?" Curbside Composting Added to a Major City: Is It Yours? February 1, 2012. Accessed April 15, 2015. http://www.governing.com/topics/energy-env/gov-curbside-composting-added-to-major-city.html.

"Developing a Greenhouse Gas Inventory." United States Environmental Protection Agency. Accessed March 24, 2015. http://www.epa.gov/statelocalclimate/local/activities/ghg-inventory.html

"Energy and Climate Protection Plan." Town of Carrboro - Sustainability, Energy, and Climate Change. May 28, 2014. Accessed March 16, 2015. http://www.townofcarrboro.org/DocumentCenter/Home/View/553.

"Energy Conservation Audit and Disclosure Ordinance." Austin Energy. Accessed March 18, 2015. http://austinenergy.com/wps/portal/ae/programs/ecad-ordinance/energy-conservation-audit-and-disclosure-ordinance/!ut/p/a1/jZAxT8MwFIR_S4eMjo0rwGUzpgqhlEykIUvlJq-OpdSObKcR_HpSWChqoW876bt7usMlLnBp5F4rGbQ1sj3o8mZNKKOPgtA0uaWM8ETcL67zl6sZIyPw9hPI5tkDSfMs59lCkERML_SfOU7-8z9d8IC6pVgqXHYyNEibrcUFGHDqHVXWeHD7r7ZI9rUOSJoa1dpXrfW9A2RdrY00FRyCuNlM2RjkYAsOXNy7caEmhM7fRSQiwzDEylrVQlzZXUROWRrrAy6OSbzC5V81-Jz-Bk7s_A2cH7LbvRYfz7BiYZZqPpl8AjKatdw!/dl5/d5/L2dBISEvZ0FBIS9nQSEh/.

"GHG (CO2, CH4, N2O, F-gases) Emission Time Series 1990-2012 per Region/country." European Commission. April 16, 2015. Accessed April 16, 2015. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012.

"Highway Statistics Series." Table VM-4 – Office of Highway Policy Information (OHPI) – FHWA. November 1, 2014. Accessed April 16, 2015. http://www.fhwa.dot.gov/policyinformation/statistics/2013/vm4.cfm.

Hosking, Jamie, Pierpaolo Mudu, and Carlos Dora. "Health Co-benefits of Climate Change Mitigation." World Health Organization. January 1, 2011. Accessed March 24, 2015. http://www.who.int/hia/green_economy/transport_sector_health_co-benefits_climate_change_mitigation/en/

"Improve Operations & Maintenance." Energy.gov. Accessed April 9, 2015. http://www.energy.gov/eere/buildings/improve-operations-maintenance

"Local Projects." Bike Carrboro Bicycles and Bicycling in Carrboro Chapel Hill and the Triangle NC. January 1, 2015. Accessed April 16, 2015. http://bikecarrboro.com/what-we-do/local-projects.

Luber, George, Kim Knowlton, John Balbus, Howard Frumkin, Mary Hayden, Jeremy Hess, Michael McGeehin, and Nicky Sheats. "Human Health." National Climate Assessment. Accessed March 24, 2015. http://nca2014.globalchange.gov/report/sectors/human-health#statement-16520

Luber, George, Kim Knowlton, John Balbus, Howard Frumkin, Mary Hayden, Jeremy Hess, Michael McGeehin, and Nicky Sheats. "Human Health." National Climate Assessment. Accessed March 24, 2015. http://nca2014.globalchange.gov/report/sectors/human-health#statement-16524.

Melillo, Jerry, Terese Richmond, and Gary Yohe. "National Climate Assessment." National Climate Assessment. January 1, 2014. Accessed April 16, 2015. http://nca2014.globalchange.gov/highlights#section-5682.

"National Transportation Statistics." Bureau of Transportation Statistics. Accessed April 16, 2015. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html.

Natt, T.M. 2015. “A Bright Idea: Towns Update Street Lighting, Save Money”. *The Pilot*. http://www.thepilot.com/news/a-bright-idea-towns-update-street-lighting-save-money/article_9696c852-95c3-11e4-80f4-dfa02784e1ee.html

"North Carolina Municipal Population Estimates." North Carolina Office of State Budget and Management. Accessed March 16, 2015.

http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/municipal_estimates.shtm.

"North Carolina Municipal Population Estimates." North Carolina Office of State Budget and Management. Accessed March 16, 2015. http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/municipal_estimates.shtm.

Olivier, Jos, Greet Janssens-Maenhout, Marilena Muntean, and Jeroen Peters. "Trends in Global CO2 Emissions 2013 Report." European Commission. January 1, 2013. Accessed April 16, 2015. http://edgar.jrc.ec.europa.eu/news_docs/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf.

"Seattle City Council Climate Action Plan Resolution Summary." Emerald Cities Collaborative. Accessed March 16, 2015. http://emeraldcities.org/cities/seattle/resources/summary-of-seattle-city-council-climate-action-plan-resolutio.

Smith, Alison. "The Big Picture: Climate Policies & Co-benefits." In *The Climate Bonus: Co-benefits of Climate Policy*, 8. Abingdon, Oxford: Routledge, 2013.

"Society Impacts." United States Environmental Protection Agency. September 9, 2013. Accessed March 24, 2015. http://www.epa.gov/climatechange/impacts-adaptation/society.html

"Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources." Transportation and Global Climate Change: A Review and Analysis of the Literature. Accessed April 16, 2015. http://www.fhwa.dot.gov/Environment/glob_c5.pdf.

"Table 5. Per Capita Energy-related Carbon Dioxide Emissions by State (2000–2011)." U.S. Energy Information Administration. Accessed April 16, 2015. http://www.eia.gov/environment/emissions/state/analysis/pdf/table5.pdf.

"Transportation Control Measures." Local Government Climate and Energy Strategy Series. March 1, 2011. Accessed April 16, 2015. http://www.epa.gov/otaq/stateresources/policy/430r09040.pdf.

"Town of Carrboro Waste Composition." Orange County Waste Characterization Study. April 1, 2010. Accessed March 16, 2015. http://www.co.orange.nc.us/recycling/documents/WasteSort2010/Carrboro_composition.pdf

"USCC Position Statement: Keeping Organics Out of Landfills." US Composting Council. Accessed April 15, 2015. http://compostingcouncil.org/admin/wp-content/uploads/2011/11/Keeping-Organics-Out-of-Landfills-Position-Paper.pdf

"What Will Climate Change Mean to Your Community?" National Resource Defense Council. June 15, 2013. Accessed April 16, 2015. http://www.nrdc.org/health/climate-in-your-community.asp.