Town of Chapel Hill
Community Greenhouse Gas Inventory

2012

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UNC Chapel Hill Institute for the Environment
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*This paper represents work done by a UNC-Chapel Hill undergraduate student team. It is not a formal report of the Institute for the Environment, nor is it the work of UNC-Chapel Hill faculty*
**Executive Summary**

**Introduction and background**

The goal of this report is to establish a 2012 baseline for the quantity of greenhouse gas (GHG) emissions produced by the Town of Chapel Hill community. A community-wide inventory includes the major direct sources of GHGs within the town boundaries, such as motor vehicles or the cogeneration facility operated by the University of North Carolina at Chapel Hill (UNC). Also included are emissions generated outside of the Town of Chapel Hill as a result of activities of residents and business, including the upstream lifecycle emissions of consumer goods.

**Methods**

Our inventory is structured using the International Council for Local Environmental Initiatives (ICLEI) U.S. Community Protocol, a series of data collection guidelines and GHG emission quantification equations. Data are drawn from a wide variety of sources and is fully detailed in the appendix of this report. Emissions in this report are quantified in units of tonnes (metric ton, 1000 kg) carbon dioxide equivalents (CO₂e), which scales the potential of the specific gas to warm the planet to the warming potential of carbon dioxide.

**Findings**

In 2012 the estimated community-wide emissions for Chapel Hill totaled 1,281,863 tonnes CO₂e, or 21.9 tonnes per capita. The largest category of emissions are public utilities (electricity and natural gas), representing 63% of the total. Comparing our emissions profile to the national average reveals approximately 30% higher per capita electricity emissions in Chapel Hill, though we found substantially lower than average transportation and agricultural emissions.

**Recommendations**

With a baseline emissions profile established for the Town of Chapel Hill, we hope that regular future inventory updates will provide policy makers with the necessary information to guide meaningful climate action policy and planning.
Introduction and Project Overview

Greenhouse gases (GHGs), including water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and CFCs, make up only a small portion of earth’s atmosphere. Despite their relatively low concentrations, by absorbing the sun’s energy and re-radiating it as heat, GHGs have warmed the planet through the greenhouse effect to its currently hospitable temperature.¹ Since the industrial revolution human activity related mostly to burning fossil fuels and land use changes have been releasing once-stored carbon into the atmosphere at ever-accelerating rates. As the concentration of greenhouse gases in our atmosphere has increased, so too has the average global surface temperature. Data compilations show that the decade spanning 2001-2010 was the warmest on global average record.² The altered composition of our atmosphere and resulting rise in temperature is expected to drive significant changes across earth’s physical and biological systems, including alteration of precipitation and species distributions, more frequent and severe storm events, and rising sea levels.

Even if all anthropogenic emissions were to stop today, changes in surface temperatures, rainfall, and sea level will be unavoidable for perhaps as many as 1,000 years into the future³, underscoring the already dramatic human alteration of earth’s atmosphere. Though considerable uncertainty remains as to the rate at which some of these changes will occur, tangible climate change is already being observed.⁴ There is clearly a pressing need to understand the sources of these emissions so that we can track them and may make educated decisions on mitigating the warming trend.

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**Figure 1** A time series of data on atmospheric CO₂ taken at Hawaii’s Mauna Loa Observatory. Data begins in 1958 and continues through Nov. 2013. The black curve represents a seasonal correction (annual average).
In 2005, the Town of Chapel Hill began compiling an annual inventory of GHG emissions generated by municipally controlled operations, including public transportation and the energy demands of government buildings. This project builds on that work by presenting an inventory of emissions generated across the entire community in the 2012 calendar year. Community-wide emissions include the direct sources of greenhouse gases within the Town boundaries, as well as the activities of residents and business that generate emissions anywhere, including those produced outside of the community boundaries. This report provides a baseline for our community’s emissions that we hope will inform meaningful climate action policy. The recently published International Council for Local Environmental Initiatives (ICLEI) U.S. Community Protocol provides a standardized framework for GHG accounting. ICLEI is an international organization of local governments committed to the shared goal of sustainable development. Since 1990, ICLEI has provided technical training and consultation, as well as various tools and resources designed to expedite cost-effective climate action and development strategies. Chapel Hill and Carrboro join more than 1,200 municipalities around the world that enjoy these benefits. Among these consultation materials is the set of protocols designed to sum the greenhouse gas emissions at a community level.

Though emissions themselves may be any of a variety of greenhouse gases, all numbers in this report are in units of metric tonnes (1000 kg) of carbon dioxide equivalents (mtCO2e). Different greenhouse gasses have different potentials to store heat relative to an equal amount of CO2, a quality called global warming potential (GWP). Carbon dioxide equivalents represent the mass of CO2 that would warm the planet equivalently to the given amount of the specific greenhouse gas. For example, nitrous oxide, a powerful greenhouse gas, has a 100 year GWP of 310, meaning over a 100 year period in the atmosphere it will warm 310 times more than the same amount of CO2 (a GWP of 1). So, for any

![Figure 2 A map displaying the Town of Chapel Hill boundary](image-url)
given mass of nitrous oxide emitted, a much larger mass of CO$_2$e is reported. To the left is a bar representing the community’s total emissions for 2012. Each segment represents one of the major categories of emissions covered in this report that contribute to the community’s total, represented as the entire bar. The data and calculations involved in the accounting process are discussed in detail in the appendices of this document.
Utilities

Below is an inventory of carbon emissions from electricity production for the Town of Chapel Hill for the 2012 calendar year. Emissions are divided into sectors (where data were available) such as residential, commercial, and industrial. This categorization will help the Town realize which sectors contribute the most to its carbon footprint and which areas have the most room to reduce carbon emissions to meet future emission goals.

The figures for electricity consumption for the Town for 2012 were provided by Duke Energy (with the exception of the “Piedmont” data, which were provided by Piedmont EMC and were not available by sector). See Table 4 in the attached appendix for these data.

Included in the figures provided by Duke Energy is the electricity consumption of UNC-Chapel Hill, a dominant presence in the Town of Chapel Hill. These data were included in the “Commercial” sector but the electricity consumption information for the university was acquired and has been accounted for in the table below.

To determine the carbon emissions associated with total electricity production, a “Carbon Dioxide-equivalent emission factor” was acquired from the ICLEI Protocol, Appendix C. An electricity emission factor represents the amount of GHGs emitted per unit of electricity delivered in...
terms of Carbon Dioxide and typically has units of pounds or metric tonnes of CO₂ equivalent per megawatt-hour (tonnes- CO₂e/MWh).

Duke Energy provided the number of customers for each sector, so the CO₂e per customer was calculated for each by dividing the mass of carbon emitted for 2012 by the number of customers (a customer is a Duke Energy account). Additionally, the CO₂e per resident in Chapel Hill was calculated by dividing the carbon-equivalent emissions for the Town of Chapel Hill by the number of residents, 58,424. The per capita CO₂e emission due to electricity consumption for 2012 was calculated to be **10.63 tonnes**. The division of carbon production per capita or per customer could be useful as the Town of Chapel Hill compares its carbon emissions over time and begins to make goals of lessening its carbon footprint in the future.

<table>
<thead>
<tr>
<th>Sector</th>
<th>2012 MWh</th>
<th>CO₂e Annual (mt/yr)</th>
<th>% of Total Electricity Emissions</th>
<th>CO₂e/Customer (mt/yr)</th>
<th>Natural Gas CO₂e (mt/yr)</th>
<th>% of Natural Gas Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>253,666.03</td>
<td>126,840</td>
<td>20.4</td>
<td>5.64</td>
<td>66,834</td>
<td>35.5</td>
</tr>
<tr>
<td>Duke Energy</td>
<td>209,433.47</td>
<td>104,722</td>
<td>16.9</td>
<td>5.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Piedmont EMC</td>
<td>44,232.57</td>
<td>22,117</td>
<td>3.6</td>
<td>7.77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commercial</td>
<td>674,146.50</td>
<td>494,065</td>
<td>79.5</td>
<td>107.73</td>
<td>69,417</td>
<td>36.8</td>
</tr>
<tr>
<td>Non-UNC</td>
<td>223,081.17</td>
<td>111,547</td>
<td>18</td>
<td>-</td>
<td>62,828</td>
<td>33.4</td>
</tr>
<tr>
<td>UNC Co-gen Coal</td>
<td>451,065.33</td>
<td>225,545</td>
<td>36.3</td>
<td>-</td>
<td>6,589</td>
<td>3.4</td>
</tr>
<tr>
<td>UNC Co-gen Coal</td>
<td>-</td>
<td>156,974</td>
<td>25.3</td>
<td>-</td>
<td>31,515</td>
<td>16.7</td>
</tr>
<tr>
<td>Industrial</td>
<td>763.80</td>
<td>382</td>
<td>0.1</td>
<td>381.92</td>
<td>20,674</td>
<td>10.9</td>
</tr>
<tr>
<td>Total Chapel Hill</td>
<td>928,576.33</td>
<td>621,287</td>
<td>100</td>
<td>27.26</td>
<td>188,441</td>
<td>100</td>
</tr>
</tbody>
</table>

Electricity that is transmitted through the grid over relatively long distances inherently produces some waste heat, and therefore wastes some electricity. This loss is calculated by multiplying a transmission loss factor by the electricity consumed by the Town. This says that the actual amount of electricity produced for the Town is greater than the electricity consumed because some is lost to waste heat during transmission. This transmission loss has been included in the CO₂e calculations.

Finally, the raw tonnage of coal burned by UNC’s cogeneration plant was acquired in order to determine the carbon byproducts of the plant. The plant burns coal to produce electricity and heat for campus use. In 2012, the raw tonnage of coal burned was 66,905 tonnes. By multiplying an appropriate emission factor for the combustion of coal (addressed at length in the Appendix) by the raw tonnage of coal, it was calculated that the cogeneration plant produced 156,974 tonnes of CO₂e in 2012 from the combustion of coal alone.
The emissions from natural gas and coal have been calculated separately; though they are both stationary fuels, they have very different uses and emissions in the community. Natural gas is used by nearly 10,000 homes and businesses within Chapel Hill, the Cogeneration plant and the University to provide energy and heat. And while natural gas produces fewer emissions per BTU than coal, a significant overall portion of the community’s emissions are from the combustion of this fossil fuel. Ultimately, natural gas accounts for 188,441 mt CO$_2$e annually within Chapel Hill. Each residential customer of natural gas emits around 5.4 mt CO$_2$e annually, and per capita emissions are around 2.6 mt CO$_2$e annually. Notably, the CO$_2$e emission factor for natural gas is five times greater in the residential and commercial sectors than for the industrial sector.

The continued or increased use of natural gas will remain a matter of interest for Chapel Hill as the state considers a move to allow fracking – potentially reducing the demand for coal and perhaps introducing negative externalities as well. A complete breakdown of emissions can be found in the appendix.

**Quick Look at Utilities**

- Total Electricity and NG emissions (including upstream NG emissions): **809,728 mtCO$_2$e**
- Emissions per capita (electricity): **10.63 mtCO$_2$e**
  Emissions per capita (natural gas): **2.6 mtCO$_2$e**
- Percent of total Town of Chapel Hill emissions: **63.1%**
Food Consumption

Producing, processing, transporting, storing and selling food requires a lot of energy, and produces a significant share of the total emissions in most cities. The national average is approximately 10%, but these emissions are generally far-reaching enough so as to go unnoticed; most of us regularly consume foods that have travelled hundreds if not thousands of miles, often from another climate altogether, to ours. Despite distinct regional differences of food availability, it turns out that average food expenditures are highly regular in the United States and that the value of a given food-dollar can reliably quantify CO$_2$e emissions.

In Chapel Hill, surveys report that the average household spends just over $8,000 annually on all food expenditures – which means typical households account for 9.98 mtCO$_2$e/yr., and that the food demands of the average citizen produce 3.41 tonnes CO$_2$e/yr. With close to 60,000 people, the food demands for the entire community are responsible for 199,233 tonnes CO$_2$e/yr. Of course, determining the food-related emissions for a single person is far more difficult, as all foods carry a distinct carbon footprint. In any event, each of us may choose to be mindful of the upstream consequences of our daily food decisions. Emissions can be decreased in any of the following ways:

- Buying locally produced foods
- Eating fewer processed foods
- Eating foods in season
- Eating less meat
- Planting a garden

Quick Look at Food

- Total food consumption emissions: **199,233 mtCO$_2$e**
- Emissions per capita: **3.41 mtCO$_2$e**
- Percent of total Town of Chapel Hill emissions: **15.5%**

Figure 5 Vendors at Carrboro Farmer’s Market

Photo: Ashley Young
Transportation

Even in a relatively environmentally conscious town such as Chapel Hill, transportation, especially day-to-day passenger travel, involves a sizeable amount of direct emissions due to the burning of gasoline and releasing carbon dioxide, methane, and nitrous oxide. In fact, this inventory accounts only for emissions that occur inside the Town boundary due to data limitations, so while at first glance it may seem that the 1.592 tonnes CO$_2$e/yr per capita, totaling 93,009 tonnes CO$_2$e/yr, is not too extensive, it has not accounted for any trips by residents that extend to Raleigh, Durham, Greensboro, etc., most of the smaller roads, or any non-car/truck emissions, which could double or even triple these totals. If each Chapel Hill resident drove the national average 13,476 miles, the emissions number would increase by a factor of 2.86. It is likely, however, that, due to the extensive free bus system, the large population of students that either cannot or do not own vehicle, and a vehicle mix that has a higher percentage of efficient vehicles, the exact number is not actually as high as 2.86 times the number calculated in this report.

**Passenger Vehicles**

Emissions from residents driving via day-to-day activities such as errands, commuting, etc. constitute the vast majority of the the transportation emissions associated with the Town, as they account for approximately 98% of the vehicle miles traveled inside of the Town boundary. These miles create nearly all of the total emissions, at 92,718 tonnes CO$_2$e/yr, which amounts to 1.587 tonnes CO$_2$e/yr per capita, chiefly comprising gasoline-fueled car and light trucks (63,517.74 and 29,124.37 tonnes CO$_2$e/year, respectively). Clearly this is the section where there is potential for the largest impact for emissions reductions.
To the left is a map of the Annual Average Daily Traffic (AADT) for passenger vehicles, highlighting the road segments with the highest traffic counts from NCDOT data.

**Freight and Trucks**

Compared to the passenger vehicles, local freight and heavy trucks make up an almost negligible amount of emissions, largely due to the lack of major shipping corridors within the Town boundaries, as I-40 lies outside and NC 54, US 15-501, and NC 86 are not quite as large or as densely populated with large trucks. This results in only **291.03 tonnes CO\(_2\)e/yr (.005 tonnes CO\(_2\)e/yr per person)**, which constitutes about 2% of the total emissions. Long-distance freight, which would greatly increase the amount of emissions due to the drastic increase in vehicle miles, is accounted for in the **Miscellaneous Emissions** section of the report. Below is a map of the Annual Average Daily Truck Traffic (AADTT) for freight vehicles, highlighting the road segments with the highest traffic counts from NCDOT data.

**Other Emissions**

Rail and water emissions were deemed to be negligible within Chapel Hill, and while air travel would surely create some emissions from the Town, lack of available data on flights from RDU made it difficult to ascertain any emissions from air travel; in keeping with the ICLEI protocol, we attribute no air emissions to the Town's residents.
Recommendations
As far as ways that both the Town of Chapel Hill and individual residents can decrease transportation-related emissions, the Town already has many programs in place, such as the Bike and Pedestrian Action Plan and Green Fleets, as well as many informational documents detailing methods to reduce Chapel Hill’s carbon emissions. These plans and other emissions reductions strategies could be:
- Expansion of the extent and use public transit
- Carpooling programs
- Charging stations and parking spots for electric cars
- Bike lanes on more major roads

Quick Look at Transportation

- Total Transportation Emissions: 93,009 mtCO$_2$e
  (99% from passenger vehicles)
- Emissions per capita: 1.59 mtCO$_2$e
- Percent of total Town of Chapel Hill emissions: 7.3%
- Town per capita VMT: 4,697 miles/year
  National average per capita VMT: 13,476 miles/year
Solid Waste & Recycling

How do landfills produce greenhouse gases?

Organic waste placed in a landfill (such as paper and food) is initially decomposed by aerobic bacteria (bacteria that require oxygen). When the oxygen is depleted, anaerobic bacteria (bacteria that do not require oxygen) convert the organic material to simpler forms that are further broken down by fermentation. Then, methane-producing anaerobic bacteria convert the fermentation products into approximately 50% CO\textsubscript{2} and 50% CH\textsubscript{4} gas.

Included in this report are the calculated emissions for solid waste generated by the Town of Chapel Hill community (regardless of where it is disposed) as well as emissions arising from solid waste disposed of inside the Town's boundaries (regardless of where it was generated) for the year 2012. The Orange County landfill, which opened in 1973, was the disposal site for residential and commercial waste (excluding waste from UNC) for the Town of Chapel Hill until the landfill closed in the summer of 2013. The implications of the landfill closing will be discussed later in the Solid Waste section. This report calculates emissions based on calendar...
year 2012 during which the OC landfill was still open, so all calculations used the Orange County landfill as the destination of the Town’s solid waste. UNC’s waste had a different destination from the rest of the Town’s solid waste. Since August 2008, UNC’s solid waste has been taken to the Waste Industries transfer station in Durham, and from there, to a Waste Industries-owned landfill in Sampson County, NC.

Methods
We used the methods outlined in the ICLEI Protocol Appendix E to calculate the greenhouse gas emissions resulting from solid waste. The data needs and calculations were adequately explained and straightforward. The Protocol also offered a consistent approach to analyzing and reporting data for all sources of emissions. Data were collected and analyzed according to the protocol for methane emissions from landfills, combustion of municipal solid waste, composting, community-generated waste sent to landfills, process emissions associated with landfilling, collection and transportation emissions, and community-generated waste sent to combustion facilities.

Results
Most of the emissions accounted for in this report are from the facility emissions (the in-boundary landfill): 25,115 mtCO₂e. The second highest contributor is the community-generated waste sent to landfills. This calculation estimates future emissions resulting from the solid waste deposited in that inventory year-10,289 mtCO₂e. Other sources of emissions were landfill processes at 323 mtCO₂e, and solid waste transportation at 88.4 mtCO₂e. The total emissions due to solid waste for 2012 are 35,815 mtCO₂e, or 0.613 mtCO₂e/resident. This accounts for 2.8% of the emissions for the Town of Chapel Hill for 2012. For comparison, in 2010, waste activities (including landfills, wastewater treatment, and composting) generated only 1.9% of total United States greenhouse gas emissions.

Uncertainties
The community-generated waste calculation, which accounted for the majority of the community’s emissions from solid waste, included the default carbon equivalent
factor for methane of 21, which means that methane has 21 times the greenhouse gas effect of CO₂. The ICLEI protocol claims that the macro-level default emission factor may be appropriate on a national level but may not be suitable to estimate emissions at the facility level, but the factor was used because there was no better alternative. Another source of uncertainty, which may be underestimating emissions, are the calculations that use the assumed 75% capture efficiency for landfill gas collection systems. There is controversy over this efficiency, with some claiming it to be as low as 15%. Because the prevailing practice for many greenhouse gas inventories has been to use the 75% efficiency and because no other widely accepted rate is available at this time, 75% capture efficiency was used in the calculations of this report.

**Recommendations**

Because methane is such a huge component of the solid waste emissions, it is recommended that all waste be deposited in landfills with gas capture capabilities (starting in 2013 all solid waste generated by the Town will be in landfills with this capability). Because a high percentage of the solid waste that enters the landfill is food waste and because food waste contributes significantly to methane emissions, we recommended that the Town should increase food waste collection and composting to reduce methane emissions. Continued or increased recycling efforts are also recommended, as recycling can reduce upstream emissions from materials manufacturing. UNC has special events that generate particularly significant quantities of solid waste (for example: move-in and move-out days, football games, fall fest). At these particular events, increased efforts and effective measures to reduce waste would have the greatest effect.

**Quick Look at Waste**

- Total solid waste and recycling emissions: **80,812 mtCO₂e**
- Emissions per capita: **1.38 mtCO₂e**
- Percent of total Town of Chapel Hill emissions: **6.3%**
What’s happening next?
After the closing of the Orange County landfill in the summer of 2013, Chapel Hill’s solid waste is now transported to Waste Industries landfill in Sampson County, NC via the Waste Industries transfer station in Durham, NC. There are some implications for solid waste emissions production and accounting as a result. The affected categories of emissions are: transportation and community-generated waste (methane production). Because the Sampson County landfill has a gas capture system, there is actually a calculated drop in emissions (due to decreased methane production). This calculation is based on EPA’s WARM model, which uses 75% efficiency gas collection, which, according to other research, may be an overestimate. The move to the Waste Industries adds 111 miles to the trip (one way) of hauling, increasing transportation emissions. However, the greenhouse gas effects of trucking the waste a greater distance is minor compared to the benefits of flaring landfill gas and capturing it for energy production instead of venting the gas into the atmosphere.

Source

Recycled Goods
Chapel Hill is fortunate to have a comprehensive and efficient recycling program. The upstream emissions from the most commonly recycled goods in Chapel Hill are for 0.84 tonnes CO₂e/yr per resident, and 48,997 tonnes CO₂e/yr for the community at large.
- Every citizen should take advantage of Chapel Hill’s single-stream recycling program
- Likewise, numerous recycling facilities throughout the county are equipped to handle a wide array of materials and items. Residents should be encouraged to recycle everything they can!

Figure 13 Eubanks Road Recycling Center. Photo: Michael Everhart
Other Emissions Sources

Cement
The construction of private homes, commercial facilities and industrial operations requires a significant amount of raw materials, such as cement, and a significant amount of energy is required to produce them. The cement consumption in Chapel Hill is responsible for \textbf{15,190 tonnes CO2e/yr.} from upstream emissions.

The emissions from producing any sort of construction material are largely fixed, but they are variable amongst material type, and some recycled materials have a lower emissions factor than cement.

Long-Distance Freight
Nearly every good consumed within Chapel Hill has been brought to the city over some distance, and the net result of these upstream emissions is rather large. Each resident of Chapel Hill is responsible for \textbf{0.61 tonnes CO2e/yr.}, as the result of these shipping emissions, and the community at large is responsible for \textbf{35,854 tonnes CO2e/yr.}

Reducing long distance-freight emissions can be achieved by buying less and buying more locally produced items.

Wastewater Treatment
In 2012, the Orange County Water and Sewer Authority oversaw the treatment of more than 2.5 billion gallons of wastewater at the centralized Mason Farm Water Treatment Plant. Emissions are primarily nitrous oxide (N2O) released during the biological treatment process of nitrogen removal, as well as during various side reactions as treated effluent is discharged. Treating wastewater to remove nitrogen and other organic nutrients is critical to preventing eutrophication and contamination downstream of our point of discharge, Morgan Creek. Emissions generated by wastewater treatment account for a small fraction of the Town’s total, \textbf{352 tonnes CO2e/yr.}
Kerosene
In Chapel Hill, only 186 homes are served by kerosene. When compared to the nearly 10,000 homes connected to natural gas, kerosene consumption is a small fraction. However, the average emissions associated with each one of these homes is 1.02 tonnes CO$_2$e/yr, and the total emissions are 192 tonnes CO$_2$e/yr.

Propane
In Chapel Hill, only 106 residences are served by propane. Much like kerosene, this represents a very small percentage of the total stationary fuel use in the community. The average emissions from each house using propane are 0.94 tonnes CO$_2$e/yr, and the total community emissions are 100 tonnes CO$_2$e/yr.

Kerosene, propane and heating oil all produce more emissions than does natural gas, or electricity. If possible, homeowners may consider replacing old heating systems with a lower-emission option.

Figure 15 Residential stationary fuel storage. Photo: InspectAPedia

Quick Look at Other Emissions

- Total other emissions: 99,531 mtCO$_2$e
- Emissions per capita: 1.7 mtCO$_2$e
- Percent of total Town of Chapel Hill emissions: 7.8%
Comparisons

To get an idea of how Chapel Hill’s emissions compare with the local, national, and global community, we can compare the per capita emissions of municipalities that used ICLEI approved or similar techniques to construct their inventories.

In 2005, Durham conducted a baseline community greenhouse gas inventory using consultation from ICLEI. Though their report was not structured using same protocol we followed, the per capita emissions makes for an interesting comparison. In 2005, Durham’s citizens generated approximately 25.7 tonnes CO₂e per capita (reported as short tons GHG). Our own inventory indicates that the citizens of Chapel Hill generated approximately 21.9 tonnes CO₂e per resident. The difference in these numbers can be accounted for by higher reported transportation emissions in Durham (per capita, compared to Chapel Hill’s baseline per capita).

Methodology difference
Comparing Chapel Hill to the national figure, we find nearly identical numbers. According to the EPAs estimates for the nation’s 2011 emissions, transportation accounts for about 30% of the total. Our estimate of low transportation emissions

![Figure 9 Town of Chapel Hill 2012 emissions by category](image-url)
are partially offset in the national per capita number by higher levels of industrial (20% of total) and agricultural (8%) emissions in the country at large.

![Per Capita GHG Emissions](image)

**Figure 10 Per capita emissions comparison Data sources**

The clear difference in *per capita* emissions between Chapel Hill and New York City can be explained primarily by differences in built environment. Extensive public transportation and dense, upward growth provide substantial advantages towards reducing emissions. Lower still is the global average, a number that reflects the stark difference in the distributions of resources and energy among the global communities, which range from undeveloped to intensely developed.

In an effort to understand the potential carbon offset from renewable energy technologies used in the community, we attempted to obtain data regarding the renewable generation in the Town on a yearly basis. However only Piedmont Electric Energy Cooperative agreed to share their data on renewable energy generation: Duke/Progress Energy denied our request out of security concerns. We were able to obtain publicly available data from NC GreenPower, a non-profit group dedicated to the expansion and knowledge of renewable energy technologies in North Carolina. According to the publicly available data at NC GreenPower, 36 private residences and businesses within the Town of Chapel Hill have solar installations, which provide a total yearly energy flow of 270,808 kWh. Likewise, PEMC reports that approximately 80 of their Chapel Hill customers are producing renewable energy to the amount of 193,916 kWh / year. However, we do not know the extent to which these numbers cross over. It is possible that all of the PEMC customers are listed with NC GreenPower, or that none of them are.
Solar Panel Suitability and Greenhouse-Gas Mitigation in Chapel Hill, North Carolina

This analysis locates areas in Chapel Hill which are highly suitable for solar panel development and determines potential energy yield. Areas must be south facing, have slope less than 10%, be free of tree cover, 50 feet from waterways and 200 feet from roads. Non-shaded rooftops are considered highly suitable. Annual insolation is calculated across these suitable areas and emissions reductions are calculated based on standard conversions. (Specific assumptions below)

**Findings:**
There are 6,885,325 ft² in Chapel Hill which are currently potentially suitable for solar arrays. Of these, 1,672,245 ft² are highly suitable for solar arrays (~2% of Chapel Hill).
These include primarily rooftops, but also some areas of open land or parking lots.

Those highly suitable sites represent 207,225 kWh of potential annual energy.

Development of the proposed 347,225 kWh/yr could mitigate up to 245,790 mtonCO₂e yr⁻¹
Every m² of solar panel could mitigate up to 0.3 mtonCO₂e yr⁻¹
Appendices: Data and Calculations

Note that appendix labels correspond to their original ICLEI protocol designations, for ease of reference.

Appendix C. Built Environment Emissions

Methods

BE.1 - Emissions from Stationary Fuel Combustion (Natural Gas only, see below for other fuels)
Calculating emissions from natural gas is straightforward in this case, because consumption data is provided by sector in 2012 from PSNC Energy as well as UNC and the UNC Cogeneration plant. Annual emissions of CO$_2$e from source combustion of natural gas are found using ICLEI Appendix C, section BE.1.1 with the following procedure.

1. Obtain local Natural Gas consumption data by sector (residential, commercial, industrial, UNC, Cogeneration).\(^{17}\)
2. Apply the listed conversion factors to calculate total CO$_2$ from natural gas consumption.
3. Calculate CO$_2$e annual total from N$_2$O and CH$_4$ emissions using the conversion factors listed.
4. Sum CO$_2$ and CO$_2$e to determine total CO$_2$e from natural gas community consumption.
### Table 1: Natural Gas by Sector and Emission, 2012

<table>
<thead>
<tr>
<th>Natural Gas (CO₂)</th>
<th>Therms</th>
<th>MMBTU</th>
<th>CO₂ E-Factor (mt/MMBTU)</th>
<th>CO₂ (mt/yr)</th>
<th>CO₂/Resident (mt/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>10,162,740</td>
<td>1,016,274</td>
<td>0.05302</td>
<td>53,882.85</td>
<td>0.9223</td>
</tr>
<tr>
<td>Commercial</td>
<td>9,553,652</td>
<td>955,365</td>
<td>0.05302</td>
<td>50,653.46</td>
<td>0.8670</td>
</tr>
<tr>
<td>Industrial</td>
<td>3,148,698</td>
<td>314,870</td>
<td>0.05302</td>
<td>16,694.40</td>
<td>0.2857</td>
</tr>
<tr>
<td>UNC</td>
<td>1,001,959</td>
<td>100,196</td>
<td>0.05302</td>
<td>5,312.39</td>
<td>0.0909</td>
</tr>
<tr>
<td>UNC Co-gen</td>
<td>4,799,741</td>
<td>479,974</td>
<td>0.05302</td>
<td>25,448.23</td>
<td>0.4356</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28,666,790</strong></td>
<td><strong>2,866,679</strong></td>
<td><strong>0.05302</strong></td>
<td><strong>151,991.32</strong></td>
<td><strong>2.6015</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Natural Gas (CH₄)</th>
<th>2012 MMBTU</th>
<th>CH₄ E-Factor (mt/MMBTU)</th>
<th>CO₂,e E-Factor</th>
<th>CO₂,e (mt/yr)</th>
<th>CO₂,e/Resident (mt/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1,016,274</td>
<td>0</td>
<td>21</td>
<td>106.71</td>
<td>0.0018</td>
</tr>
<tr>
<td>Commercial</td>
<td>955,365</td>
<td>0</td>
<td>21</td>
<td>100.31</td>
<td>0.0017</td>
</tr>
<tr>
<td>Industrial</td>
<td>314,870</td>
<td>0</td>
<td>21</td>
<td>6.61</td>
<td>0.0001</td>
</tr>
<tr>
<td>UNC</td>
<td>100,196</td>
<td>0</td>
<td>21</td>
<td>10.52</td>
<td>0.0002</td>
</tr>
<tr>
<td>UNC Co-gen</td>
<td>479,974</td>
<td>0</td>
<td>21</td>
<td>10.08</td>
<td>0.0002</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,866,679</strong></td>
<td><strong>-</strong></td>
<td><strong>-</strong></td>
<td><strong>234.23</strong></td>
<td><strong>0.0040</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Natural Gas (N₂O)</th>
<th>2012 MMBTU</th>
<th>N₂O E-Factor (mt/MMBTU)</th>
<th>CO₂,e E-Factor</th>
<th>CO₂,e (mt/yr)</th>
<th>CO₂,e/Resident (mt/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1,016,274</td>
<td>-</td>
<td>310</td>
<td>31.50</td>
<td>0.0005</td>
</tr>
<tr>
<td>Commercial</td>
<td>955,365</td>
<td>-</td>
<td>310</td>
<td>29.62</td>
<td>0.0005</td>
</tr>
<tr>
<td>Industrial</td>
<td>314,870</td>
<td>-</td>
<td>310</td>
<td>9.76</td>
<td>0.0002</td>
</tr>
<tr>
<td>UNC</td>
<td>100,196</td>
<td>-</td>
<td>310</td>
<td>3.11</td>
<td>0.0001</td>
</tr>
<tr>
<td>UNC Co-gen</td>
<td>479,974</td>
<td>-</td>
<td>310</td>
<td>14.88</td>
<td>0.0003</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,866,679</strong></td>
<td><strong>-</strong></td>
<td><strong>-</strong></td>
<td><strong>88.87</strong></td>
<td><strong>0.0015</strong></td>
</tr>
</tbody>
</table>

#### BE.1.1 – Calculating Emissions from Stationary Fuel Combustion (Coal, see below for other fuels).

1. Determine annual use of each fuel combusted by each sector (residential, commercial, industrial) in your community.
   
   The Associate Director of Energy Services at UNC provided the raw tonnage of coal combusted by UNC cogenerations: **60,195 metric tonnes of coal for 2012**.

2. Determine the appropriate CO₂ emission factors for each fuel. Table B.1 Default Factors for Calculating Carbon Dioxide Emissions from Fossil Fuel Combustion on page 60 in appendix C provides CO₂ emission factors per unit mass of different coal and coke fuels. Since bituminous coal is the overwhelmingly most common form of coal...
combusted, the emission factor, 2,328.46 kg CO₂/short ton or **2,566.6 kg/metric tonne** was used.

3. Determine the appropriate CH₄ and N₂O emission factors for each fuel  
   Table B.3 Default Methane and Nitrous Oxide Emissions Factors by Fuel Type and Sector on page 64 of Appendix C provides emission factors for methane and nitrous oxide. Considering the end-use sector, UNC facilities, are considered commercial, **0.011 kg/MMBtu** was used for CH₄ and **0.0016 kg/MMBtu** for N₂O.

4. Calculate each fuel’s CO₂ emissions  
   In the following steps, 2,566.6 kg/tonne will be used to add all emissions from coal combustion at once.

5. Calculate each fuel’s CH₄ and N₂O emissions  
   The emission factors for methane and nitrous oxide were converted to kg/tonne by multiplying by appropriate conversion factors. The converted emission factors were found to be 0.302 kg/tonne for CH₄ and 13.33 kg/tonne for N₂O. These numbers will be applied further in the next step.

6. Convert CH₄ and N₂O emissions to CO₂ equivalent and determine total emissions.  
   Methane’s impact as a greenhouse gas is 21 times as great as carbon dioxides, so its emission factor was multiplied by 21, yielding 6.342 kg CO₂e/tonne. Similarly, nitrous oxide is 310 times as potent, yielding 13.33 kg CO₂e/tonne. Summing the CO₂e emission factors of all three pollutants yields 2,586.27 kg CO₂e/tonne. Multiplying this factor by 60,695.2 tonnes of coal, its combustion therefore produced **156,974.2 tonnes of CO₂e**

**BE.1.2 - Estimating Other Fuel Use in the Residential Sector** (Propane, Kerosene, Fuel Oil)  
Resistance from the majority of local fuel suppliers to sharing data prevented a precise determination of the total consumption of these other stationary fuels. In the absence of local data, procedure BE.1.2 allows for an estimate of their consumption at the residential level. We use state-wide data from the U.S. Energy Information Administration Residential Energy Consumption Survey, and the 2010 Census data for Chapel Hill. There are 106 households in Chapel Hill using propane, and 186 households using kerosene or fuel oil.
1. Obtain total # of households in North Carolina using stationary fuel by type, from U.S. Energy Information Administration, Residential Energy Consumption Survey (RECS)\(^\text{18}\):

   **Propane / LPG - 1.5 million**
   **Kerosene - 1.3 million**

2. Obtain North Carolina total residential stationary fuel use by fuel, from U.S. Energy Information Administration, State Energy Data System (SEDS)\(^\text{19}\), and determine usage/household

   **Propane / LPG - 21 trillion BTU, 13.69 MMbtu/Household yr\(^{-1}\)**
   **Kerosene - 1.5 trillion BTU, 11.25 MMbtu/Household yr\(^{-1}\)**

3. Obtain total # of Chapel Hill households using stationary fuels, from United States Census Bureau\(^\text{20}\).
4. Calculate total Chapel Hill Residential consumption of propane and kerosene.
   Apply conversion factor to mtCO\(_2\) and sum for total yearly residential Stationary Fuels emissions.
### Table 2: Kerosene and propane emissions

<table>
<thead>
<tr>
<th></th>
<th>MMBTU</th>
<th>CO2 Emission Factor (tonnes/MMBTU)</th>
<th>CO2 Annual (tonnes/yr)</th>
<th>CO2e/Customer (tonnes/yr)</th>
<th>CO2/Resident (tonnes/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kerosene</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CO₂</td>
<td>2092.5</td>
<td>0.075</td>
<td>156.94</td>
<td>0.84375</td>
<td>0.0026862</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conversion Factor (gallon/MMBTU)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CH₄</td>
<td>2092.5</td>
<td>6.8</td>
<td>0.0000015</td>
<td>21</td>
<td>0.0002142</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conversion Factor (tonnes/gallon)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- N₂O</td>
<td>2092.5</td>
<td>6.8</td>
<td>0.0000001</td>
<td>310</td>
<td>0.0002108</td>
</tr>
<tr>
<td><strong>Total CO₂e from Kerosene</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>156.94</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>MMBTU</th>
<th>CO2 Emission Factor (tonnes/MMBTU)</th>
<th>CO2 Annual (tonnes/yr)</th>
<th>CO2e/Customer (tonnes/yr)</th>
<th>CO2/Resident (tonnes/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Propane</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CO₂</td>
<td>1451.7391</td>
<td>0.06146</td>
<td>89.22</td>
<td>0.84</td>
<td>0.0015272</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conversion Factor (gallon/MMBTU)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>- CH₄</td>
<td>1451.7391</td>
<td>7.4</td>
<td>0.000001</td>
<td>21</td>
<td>0.0001554</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conversion Factor (tonnes/gallon)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- N₂O</td>
<td>1451.7391</td>
<td>7.4</td>
<td>0.0000001</td>
<td>310</td>
<td>0.0002294</td>
</tr>
<tr>
<td><strong>Total CO₂e from Propane</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>89.22</strong></td>
</tr>
<tr>
<td><strong>Total CO₂e from Kerosene and Propane, 2012 (tonnes)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>246.16</strong></td>
</tr>
</tbody>
</table>
BE.5.1 – Upstream Emissions from Stationary Fuel Combustion
Methods

Upstream emissions for all fuels and sectors are calculated at once, using the same aggregated MMBTU as in BE.1.1, and are found using procedure BE.5.1. The upstream emissions factor accounts for N₂O, CH₄ and CO₂ simultaneously, and is reported as follows.

1. Obtain total MMBTU per fuel
2. Apply appropriate volume conversion factor
3. Apply CO₂e emission factor
4. Sum CO₂e for all fuels

Table 2: Total Upstream and Source CO₂ Emissions, 2012

<table>
<thead>
<tr>
<th>Stationary Fuel</th>
<th>mtCO₂e</th>
<th>mtCO₂ /per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>188,441.46</td>
<td>3.23</td>
</tr>
<tr>
<td>Kerosene</td>
<td>191.98</td>
<td>0.00</td>
</tr>
<tr>
<td>Propane</td>
<td>100.18</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>188,890.55</strong></td>
<td><strong>3.23</strong></td>
</tr>
</tbody>
</table>

Uncertainties

The reported emissions from the consumption of natural gas seem to carry little uncertainty. Comprehensive data was reported Chapel Hill by sector from PSNC Energy for 2012 as well as usage by UNC and the Cogeneration plant. The only assumptions are the conversion factors for upstream emissions and source emissions, which were taken from Appendix C of the ICLEI protocol.

The most uncertainty lies with the estimated residential consumption (MMBTU) of kerosene and propane, as the estimates are derived from state-wide consumption data, averaged to the household level. While the total number of households in Chapel Hill using these fuels is precisely known, their consumption relative to the state-wide average is not. In any event, these fuels account for only 0.2% of total stationary fuels emissions, and 2.8% of households using stationary fuel. Estimates for commercial and industrial consumption of kerosene and propane within the community are not included. Ultimately, ~99% of the emissions from stationary fuel use are the result of natural gas.
Recommendations

It would be ideal to determine residential, commercial and industrial consumption of propane and kerosene exactly, which is possible only with comprehensive local numbers. As we found out, this process may not be very feasible, its success reliant upon cooperation from local suppliers and the accuracy of their reports. It is our recommendation that the Town explore the option of establishing annual reporting programs with all local fuel suppliers.

Similarly, this recommendation will prevail for every section of the report: collect complete survey data from as many residents as possible regarding every facet of energy use (home energy, transportation, resource consumption, etc.). Efficient survey and sampling strategies would provide the input necessary to make use of IMPLAN modeling techniques on a yearly basis, providing a more accurate picture of emissions from fuels other than natural gas.

BE. 2 – Emissions from Electricity Use

1. Obtain your community’s annual electricity use in kWh or MWh for each electricity utility serving your community

Duke-Progress Energy and Piedmont EMC are the two sole providers of electricity for the Town of Chapel Hill. Both organizations were cooperative in providing the total kWh sold to customers within the Town limits. Duke Energy provided their data separated into the following sectors: residential, commercial, and industrial, while Piedmont EMC was unable to do so. Brian Callaway, Energy Management Specialist for the Town of Chapel Hill, was able to collect the data for 2012 prior to the inventory.
Further, customer totals were also provided. Duke Energy reported 19,658 residential customers, 3,129 commercial customers (including UNC Chapel Hill accounts), and few industrial customers (the exact number cannot be disclosed due to privacy concerns). Piedmont EMC reported 2,846 customers, all of whom were assumed to be residential.

### Table 3: kWh sold by Duke and Piedmont Energy, Chapel Hill

<table>
<thead>
<tr>
<th>Month</th>
<th>Residential</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Total Commercial &amp; Industrial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan Duke</td>
<td>18,493,718</td>
<td>45,205,562</td>
<td>63,000</td>
<td>45,268,562</td>
<td>63,762,280</td>
</tr>
<tr>
<td>Feb Duke</td>
<td>17,270,691</td>
<td>47,113,374</td>
<td>63,300</td>
<td>47,176,674</td>
<td>64,447,365</td>
</tr>
<tr>
<td>Mar Duke</td>
<td>14,603,552</td>
<td>45,731,334</td>
<td>60,900</td>
<td>45,792,234</td>
<td>60,395,786</td>
</tr>
<tr>
<td>Apr Duke</td>
<td>10,023,903</td>
<td>53,034,951</td>
<td>58,200</td>
<td>53,093,151</td>
<td>63,117,054</td>
</tr>
<tr>
<td>May Duke</td>
<td>20,414,727</td>
<td>59,038,468</td>
<td>65,400</td>
<td>59,103,868</td>
<td>79,518,595</td>
</tr>
<tr>
<td>Jun Duke</td>
<td>10,139,248</td>
<td>64,791,001</td>
<td>64,500</td>
<td>64,855,501</td>
<td>74,994,749</td>
</tr>
<tr>
<td>Aug Duke</td>
<td>32,158,837</td>
<td>69,513,523</td>
<td>73,500</td>
<td>69,587,023</td>
<td>1,745,860</td>
</tr>
<tr>
<td>Oct Duke</td>
<td>14,748,577</td>
<td>68,112,701</td>
<td>60,000</td>
<td>68,172,701</td>
<td>82,921,278</td>
</tr>
<tr>
<td>Nov Duke</td>
<td>16,574,675</td>
<td>54,701,466</td>
<td>56,700</td>
<td>54,758,166</td>
<td>71,332,841</td>
</tr>
<tr>
<td>Dec Duke</td>
<td>15,937,317</td>
<td>56,763,663</td>
<td>60,300</td>
<td>56,823,963</td>
<td>72,761,280</td>
</tr>
<tr>
<td>Piedmont</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>44,232,568</td>
</tr>
<tr>
<td>Total</td>
<td>209,433,465</td>
<td>674,146,496</td>
<td>763,800</td>
<td>674,910,296</td>
<td>928,576,329</td>
</tr>
</tbody>
</table>

2. Select or obtain the appropriate emission factor for the electric utility serving the community
   
The latest eGRID electricity emission factors are provided on page 72 of Appendix C in Table B.10 2009 eGRID Electricity Emission Factors by eGRID Sub-Region. The table provides CO$_2$e (lb/MWh) for regions all throughout the United States. Chapel Hill falls under SRVC SERC Virginia/Carolina and therefore has an electricity emission factor of **1,041.73 lb/MWh**. These units were taken into account when performing calculations, as the final emissions are reported in metric tonnes per MWh.

3. Calculate the annual GHG emissions associated with the direct combustion of fuels to produce electricity used by the community
   
   GHG emissions were calculated by multiplying the electricity consumption (MWh) by the CO$_2$e emission factor obtained in step 2 and dividing by the conversion factor for pounds to metric tonnes, 2204.6. These emissions would be appropriate if the electricity produced matched exactly the electricity consumed but as Section BE.4 suggests, the amount of electricity produced must exceed the
electricity consumed in order to account for transmission losses, discussed below.

**BE.4 – Electric Power Transmission and Distribution Losses**

1. Look up your community’s annual electricity use in MWh
   This was discussed above in section BE.2.1.

2. Determine what sub-region your community is in and look up the appropriate CO$_2$e electricity emission factor
   \[1,041.73 \text{ lb/MWh},\] as obtained above in BE.2.1

3. Determine what region your community is in and look up the appropriate regional grid loss factor
   According to Table B.12 eGRID Regional Transmission and Distribution Loss Factors on page 72 of Appendix C, the Eastern region has a grid loss factor of 5.82%.

4. Calculate your community’s GHG emissions related to T&D electricity losses
   These emissions are calculated by multiplying the electricity consumption (previously calculated) by 1.0582, which will account for the transmission loss percentage. This factor has been included in Table 5 below as Transmission Loss Correction.

### Table 4: Electricity consumption and emissions factors

<table>
<thead>
<tr>
<th>Sector</th>
<th>2012 kWh</th>
<th>2012 MWh</th>
<th>CO$_2$ Emission Factor (lb/MWh)</th>
<th>Transmission Loss Correction</th>
<th>CO$_2$e Annual (mt/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>209,433,465.00</td>
<td>209,433.47</td>
<td>1041.73</td>
<td>1.0582</td>
<td>104,722.31</td>
</tr>
<tr>
<td>Commercial</td>
<td>674,146,496.00</td>
<td>674,146.50</td>
<td>1041.73</td>
<td>1.0582</td>
<td>337,091.19</td>
</tr>
<tr>
<td>Commercial minus UNC</td>
<td>223,081,167.00</td>
<td>223,081.17</td>
<td>1041.73</td>
<td>1.0582</td>
<td>111,546.52</td>
</tr>
<tr>
<td>Industrial</td>
<td>763,800.00</td>
<td>763.80</td>
<td>1041.73</td>
<td>1.0582</td>
<td>381.92</td>
</tr>
<tr>
<td>Piedmont</td>
<td>44,232,568.00</td>
<td>44,232.57</td>
<td>1041.73</td>
<td>1.0582</td>
<td>22,117.46</td>
</tr>
<tr>
<td>Chapel Hill Total</td>
<td>928,576,329.00</td>
<td>928,576.33</td>
<td>1041.73</td>
<td>1.0582</td>
<td>621,287.08</td>
</tr>
<tr>
<td>UNC (Duke Energy)</td>
<td>451,065,329.00</td>
<td>451,065.33</td>
<td>1041.73</td>
<td>1.0582</td>
<td>225,544.67</td>
</tr>
</tbody>
</table>
These data account for the electricity produced by external power supply companies and sold to entities with the Town borders. However, the cogeneration plant, located within the Town borders, produces a significant amount of electricity (and heat) for UNC consumption. The emissions associated with the coal combustion for the cogeneration plant were included above, in Stationary Fuel Combustion.

Below is a summary of emissions associated with the production of electricity and combustion of natural gas for the Town of Chapel Hill for 2012.

### Table 6: Utility Emissions for 2012

<table>
<thead>
<tr>
<th>Sector</th>
<th>2012 MWh</th>
<th>CO₂e Annual (mt/yr)</th>
<th>% of Total Electricity Emissions</th>
<th>CO₂e/ Customer (mt/yr)</th>
<th>Natural Gas CO₂e (mt/yr)</th>
<th>% of Natural Gas Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>253,666.03</td>
<td>126,840</td>
<td>20.4</td>
<td>5.64</td>
<td>66,834</td>
<td>35.5</td>
</tr>
<tr>
<td>Duke Energy</td>
<td>209,433.47</td>
<td>104,722</td>
<td>16.9</td>
<td>5.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Piedmont EMC</td>
<td>44,232.57</td>
<td>22,117</td>
<td>3.6</td>
<td>7.77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commercial</td>
<td>674,146.50</td>
<td>494,065</td>
<td>79.5</td>
<td>107.73</td>
<td>69,417</td>
<td>36.8</td>
</tr>
<tr>
<td>Non-UNC</td>
<td>223,081.17</td>
<td>111,547</td>
<td>18</td>
<td>-</td>
<td>62,828</td>
<td>33.4</td>
</tr>
<tr>
<td>UNC</td>
<td>451,065.33</td>
<td>225,545</td>
<td>36.3</td>
<td>-</td>
<td>6,589</td>
<td>3.4</td>
</tr>
<tr>
<td>UNC Cogen Coal</td>
<td>-</td>
<td>156,974</td>
<td>25.3</td>
<td>-</td>
<td>31,515</td>
<td>16.7</td>
</tr>
<tr>
<td>Industrial</td>
<td>763.80</td>
<td>382</td>
<td>0.1</td>
<td>381.92</td>
<td>20,674</td>
<td>10.9</td>
</tr>
<tr>
<td>Total Chapel Hill</td>
<td>928,576.33</td>
<td>621,287</td>
<td>100</td>
<td>27.26</td>
<td>188,441</td>
<td>100</td>
</tr>
</tbody>
</table>

**Uncertainties**

The uncertainties for emissions due to electricity production for the Town seem to be relatively small. Exact kWh’s for each provider were supplied and the exact raw tonnage of coal combusted for UNC cogenerations was also provided. The major assumptions were in the approximated emissions factors, which were drawn from regional averages and supplied by the ICLEI protocol, similarly to other stationary fuels in the protocol.

**Recommendations**

The main recommendation for data collection and procedure for electricity production is to encourage Piedmont EMC to collect/provide their electricity data by sector, as all of their customers were assumed to be residential.
Appendix D: Transportation Emissions

The ideal method for finding and calculating emissions from transportation via passenger vehicles is through protocol TR.1.A, which requires a regional travel model and origin/destination data which can be used to find the data for trips both into and out of the Town. These trips can be used to calculate emissions by taking half of each of inbound and outbound trip as well as optionally including intermediate stops. A similar method is used, with ideal data, for freight and service trucks in protocol TR.2.A.

We initially believed that we had a travel model in a 2010 Regional Transportation Model with which to use methods TR.1.A at least, if not also the TR.2.A. We were, however, neither able to find any metadata in the GIS file containing the model nor make contact with someone who would be able to decipher the field names. We decided to stop using the transportation model due to the lack of information and its cryptic nature in pursuit of different data that, while being less accurate would be both more current, using 2011 data, and more transparent in the sense of knowing what we are using. This proved to be an NCDOT annual average daily traffic shapefile. This would make the process more precise and ideally more repeatable for future comparisons, though sacrificing the accuracy that would result from a well-designed model.

Using method TR.1.B for passenger vehicles, and TR.2.B for freight, we used annual average daily traffic (AADT) data and road lengths from NC Department of Transportation (NCDOT) Data to get our vehicle miles traveled (VMT). We used the 2011 data as it was the most recent data with shapefiles and had AADT counts with essentially negligible differences from the 2012 counts. From VMT, vehicle mixes, respective miles per gallon, and emissions factors we can calculate the metric tonnes of CO$_2$e resulting from the transportation sector.

Methods

TR.1 – Emissions from Passenger Vehicles


(T) Travel Activity (method T4 from Table TR.1.1)
(E) Emissions or Energy (method E3 from Table TR.1.1)
(L) Local Adjustments for vehicle efficiency and fuel type (method L5 from Table TR.1.1)

1. Calculate VMT from length, AADT and equation TR.1.B.1
a. Obtain AADT and road length shapefile from the NCDOT website
b. Obtain Town boundary shapefile from either NCDOT or Town of Chapel Hill Website
c. Build (or Run) ArcGIS model taking shapefiles from (a) and (b) to calculate total VMT. Model Steps:
   i. Bound AADT file at town boundary
   ii. Add Field (to AADT) = Length
   iii. Add Field (to AADT) = AADM_Car
   iv. Calculate field (Length) = [python expression]
   v. Calculate field (AADM_Car), expression = Length*AADT
   vi. Sum Total for average daily VMT then multiply by 365 for total VMT

2. Calculating mt CO₂e – Done in excel worksheet
   a. Calculate mt CO₂ for each vehicle type using equation TR.1.B.2
      i. VMT from calculation
      ii. %₇ from Table TR.1.3 - Default vehicle mix values (why used over state mix in assumptions)
      iii. Average MPG₇ from Table TR.1.5 - Default fuel efficiency by vehicle type for inventory year
      iv. Emission Factors from Table TR.1.6 CO₂ Emission Factors by Transportation fuel
      v. Convert Units

\[
CO₂ = \sum \left( \frac{VMT \times \%₇ \times \text{Emission Factor}}{\text{Average MPG₇}} \right)
\]

b. Calculate mt CO₂e for each vehicle for N₂O and CH₄
   i. VMT From calculation
   ii. %₇ from Table TR.1.3 - Default vehicle mix values
   iii. hg/mi₇ from Table TR.1.4 - Passenger Vehicle per-mile N₂O and CH₄ Emission Factors by inventory year
   iv. Convert Units

\[
CH₄,N₂O = VMT \times \%₇ \times \frac{hg}{mi₇}
\]

c. Total yearly Carbon Emissions from Passenger Vehicles in Chapel Hill = 92,718 mt CO₂e
TR.2 – Emissions from Freight and Service Trucks

TR.2.A – Method for In-Boundary Estimate Based on Truck VMT

(T) Travel Activity (method T4 from Table TR.1.1)

(E) Emissions or Energy (method E3 from Table TR.1.1)

(L) Local Adjustments for vehicle efficiency and fuel type (method L5 from Table TR.1.1)

1. Calculate VMT from length and AADTT

\[ VMT = \sum Length_b \times Annual\ Average\ Daily\ Truck\ Traffic_b \times 365 \]

a. Obtain AADTT and road length shapefile from the NCDOT website
b. Obtain Town boundary shapefile from either NCDOT or Town of Chapel Hill Website
c. Build (or Run) ArcGIS model taking shapefiles from (a) and (b) to calculate total VMT. Model Steps:
   i. Bound AADTT file at town boundary
   ii. Add Field (to AADTT) = Length
   iii. Add Field (to AADTT) = AADM_truck
   iv. Calculate field (Length) = [python expression]
   v. Calculate field (AADM_Truck), expression = Length*AADTT
   vi. Sum Total for average daily VMT then multiply by 365 for total VMT

2. Calculating mt CO\(_2\) – Done in excel worksheet
   a. Calculate mt CO\(_2\) for each vehicle type using equation TR.2.A.1
      i. VMT from calculation
      ii. \(\%_b\) from Table TR.2.1 - Truck Fuel Efficiency
      iii. Average MPG\(_b\) from Table TR.2.1 – Truck Fuel Efficiency
      iv. Emission Factors from Table TR.2.2 Heavy Duty Vehicle Emission Factors
      v. Convert Units

\[ CO2 = \sum_{b,f} \left( \frac{VMT \times \%_b}{Average\ MPG_b \times Emission\ Factor_f} \right) \]

b. Calculate mt CO\(_2\)e for each vehicle for N\(_2\)O and CH\(_4\)
   i. VMT From calculation
   ii. \(\%_b\) from Table TR.2.1 - Truck Fuel Efficiency
iii. EF (PT) from Equation TR.2.A.2 - CH₄ and N₂O Emissions from Freight and Service Trucks
iv. Convert Units

\[(CH_4,N_2O)_{emissions} = VMT \times %_e\]

c. Total yearly Carbon Emissions from Freight Vehicles in Chapel Hill = 291 mt CO₂e

Excel Calculation Table

**TR.3 – Emissions From Freight Rail** - due to data limitations and the small amount of rail within the Town boundary it was determined to be negligible

**TR.4 – Emissions From Transit** - transit emissions were already captured by the Carbon inventory for the Town of Chapel Hill and therefore were not included here.

**TR.5 – Emissions Associated with Inter-City Passenger Rail** - there is no train stop for inter-city passenger rail in Chapel Hill

**TR.6 – Emissions from Air Travel** - As a GHG inventory has not been prepared for either the Horace Williams Airport or RDU International airport, we do not know the percentage of passengers that begin/end in the community, and neither a GA or military airport is located in the community, no emissions are included, as was instructed by the ICLEI protocol. In reality, both airports would contribute, possibly heavily, to the total transportation emissions.

**TR.7 – Emission from Marine Vessels** - due to the size of bodies of water within the Town boundaries it was determined that these would be negligible

**TR.8 – Emissions from Other Off-road Equipment** - due to data limitations and the limited activity, these were determined to be negligible.

**Uncertainties and Assumptions**

The protocol here will provide an underestimate for the CO₂ emissions of the community of Chapel Hill as the NCDOT data only captures the major roads for which the NCDOT collected AADT and AADTT counts. It also only accounts for vehicles travelling directly within the Town boundary and does not account for this being either the destination or the origin of trips that extend outside of the Town boundary. This undercounts either the commute that Town residents make to other towns such as Durham or Raleigh, or the people in other communities that commute into the Town. Given the data limitations that we had, we chose to follow the protocol in the above manner. Similar steps were taken in other nearby communities’ carbon inventories, namely that of Durham’s, the last time that they calculated carbon inventories. We assume that the trips into and out of the Town...
roughly will cancel out, so by cutting the data off at the Town boundary we do not lose too large an amount of accuracy.

Due to finding negligible difference between the state and national average vehicle mixes, and due to the protocol’s cleaner and more easily understandable divisions in vehicle types, we chose to utilize the protocol’s vehicle mixes. Lacking any finer resolution in the vehicle mix to get more specific for the Town, we lost the factor that Chapel Hill may tend to have more environmentally conscious residents, and therefore would have a greater concentration of fuel-efficient, hybrid and electric vehicles.

Our goal, given the data limitations, was to have a precise number with easily repeatable processes for future comparison, while still being accurate enough to inform decisions and recommendations. As far as repeatability, all one would need to do would be to find the most current AADT shapefile from the NCDOT and run our model on it, then plugging the numbers from that into our calculation Excel spreadsheet. While not as accurate as it could have been with a regional transit model, we do have a clear understanding of the data used therefore can consider the systematic undercounting from missing the smaller roads in the Town.

**Recommendations**

Ideally, for the absolutely most accurate inventory of transportation, we would need a clearly developed regional transportation model with which to use the recommended method from the protocol. It would need to include origin and destination data as well as the distances and daily traffic so that one could easily calculate, via ArcGIS manipulation of the map and other calculations, a reasonable estimate of the driving done by the community or attracted by the community. Also, it would be easiest to capture the emissions from air travel if RDU airport had more easily accessible air travel data or simply had an inventory of their own.

If a model was unable to be created, and the same methodology applied in the above calculations was used again, then it would be ideal for a greater number of roads to be included in the AADT study done by NCDOT. This would allow for greater resolution, less of an undercount, and more accurate greenhouse gas emissions calculations to be performed. It is unlikely that NCDOT has the means to track AADT for every segment road and street in Chapel Hill. Also, comparison would be made easier to other towns if they all cut off the transportation section at their boundaries. This would account for all inbound and outbound traffic as they moved between towns and cities as well, making a thorough and easily comparable set of inventories.
Appendix E: Solid Waste Emissions

ICLEI Appendix E outlines methods used to calculate the greenhouse gas emissions resulting from solid waste management and the natural decay of solid waste (includes CO₂, CH₄, and N₂O emissions). The emissions associated with management include emissions from the combustion of fuel in equipment used to transport and process waste or to combust the waste itself. Greenhouse gas emissions resulting from natural decay are associated with landfills, digesters, and compost facilities. Emissions are calculated for solid waste generated by a community (regardless of where it is disposed of) as well as emissions arising from solid waste disposed of inside a community’s boundaries (regardless of where it was generated).

The Solid Waste Planner for Orange County Solid Waste Management, Blair Pollock²¹, was the initial contact for solid waste information. He answered initial questions and offered a tour of the Orange County landfill. Other important contacts were the Solid Waste Services Manager of the Town of Chapel Hill, Wendy Simmons²², and the Recycling Coordinator of the UNC-Chapel Hill Office of Waste Reduction and Recycling, Amy Preble²³.

The methods in Appendix E produce an estimation of all of the emissions (converted to metric tonnes CO₂e) resulting from the production or deposition of solid waste in a community. Each section of the Appendix E are summarized below, and with each method’s data needs outlined. We have included the contacts or websites with the specific data. An MS Excel spreadsheet was created to calculate these values for community-level commercial and residential solid waste.

Methods

Solid Waste Facilities located in the Community

SW.1 – Methane Emissions from Landfills

1. This method applies to emissions from in-boundary landfills, regardless of where the waste was generated. This section includes the emissions from the Orange County Landfill, which is located within the Town of Chapel Hill boundaries. The data for this section is reported by the OC Landfill to the EPA and can be found at this website²⁴: http://ghgdata.epa.gov/ghgp/main.do.

   a. Total facility GHG emissions reported as CO₂e- This information was found on the EPA website - 25,115 mtCO₂e
   b. Fugitive CH₄ emissions from the landfill reported as CH₄- This information was found on the EPA website (using Methane Emissions Equation HH6) - 1195.96 mtCH₄
   c. CO₂, CH₄, and N₂O emissions from combustion sources located at the landfill or on adjacent properties owned and/or operated by the landfill- This was not included in the solid waste emissions calculations, because there are no combustion sources at the OC landfill or that are operated by the landfill.
**SW.2 - Combustion of Municipal Solid Waste**
1. This section provides methods for estimating GHG emissions from combustion of Municipal Solid Waste (MSW) in combustion facilities. This was not included in the solid waste emissions inventory, because there was no combustion of MSW.

**SW.3- Composting**
1. The ICLEI Protocol does not include standardized methods to estimate fugitive emissions from composting due to lack of data.

**Community-Generated Waste Emissions**

**SW.4- Community-Generated Waste Sent to Landfills**
1. This method estimates future emissions resulting from the solid waste deposited in that inventory year.

**SW.4.1- Calculation of Methane Emissions**

a. Mass of waste from the community entering landfills for inventory year: The Solid Waste Services Manager of the Town of Chapel Hill, Wendy Simmons, had the community waste data (residential and commercial-excluding waste from UNC). The Recycling Coordinator of the UNC-Chapel Hill Office of Waste Reduction and Recycling, Amy Preble, had the UNC waste data. Residential - 6553.44 wet short tons; Commercial - 7460.82 wet short tons (excluding UNC); UNC - 5690.52 wet short tons.

b. For each landfill that accepted waste from the community, whether a landfill gas collection and control system was in place for the year: The OC landfill did not have a gas capture system in place until 2013. The Waste Industries landfill (the destination for UNC’s solid waste and the future destination of OC solid waste) does have a gas capture system.

c. Waste characterization: This information can be found on the Orange County Solid Waste Management website, under Statistics, under Waste Sort Data.

**SW.5- Process Emissions Associated with Landfilling**
1. Process emissions come from CO₂ emissions associated with powering the equipment necessary to manage the landfill.

a. Mass of solid waste- Same as SW.4.1, a.

**SW.6- Collection and Transportation Emissions**
1. The method calculates the emissions from transportation of waste from the community to facilities located outside of the community.

a. Mass of solid waste- Same as SW.4.1, a.

b. Transport distance from community center to the waste management facility (miles): The waste from UNC travels a
total of 111 miles (from UNC to the Waste Industries transfer station in Durham, NC to the Waste Industries landfill in Roseboro, Sampson County).

**SW.7- Community-Generated Waste Sent to Combustion Facilities**

1. This method is used for communities that generate waste that is sent to Waste-To-Energy combustion facilities inside or outside of their community boundaries: This was not included in the solid waste emissions inventory, because there was no recorded waste sent to combustion facilities.

**Uncertainties**

The methods outlined in Appendix E should accurately estimate the community-level CO\textsubscript{2} emissions from solid waste. However, there is some associated uncertainty with the given methods. The community generated waste calculation, which accounted for the majority of the community’s emissions from solid waste, and included the default CH\textsubscript{4} emission factor (which was first estimated by the EPA in 2008). The ICLEI protocol claims that the macro-level default emission factor may be appropriate on a national level but may not be suitable to estimate emissions at the facility level, but the carbon equivalent factor for methane (21) was used because there was no better alternative. The values cited in this Appendix to calculate methane generation and the portion of that methane that is released to the atmosphere represent the most reasonable factors available at the time. Another source of uncertainty, which may be underestimating emissions, are the calculations that use the assumed 75% capture efficiency for landfill gas collection systems. There is controversy over this efficiency, with some claiming it to be as low as 15%. Because the prevailing practice for many greenhouse gas inventories has been to use the 75% efficiency and because no other widely accepted rate are available at this time, 75% capture efficiency was used in the calculations of this report.

**Recommendations**

Appendix E of the ICLEI protocol was an ideal method to determine the CO\textsubscript{2} equivalent emissions due to solid waste for the community of the Town of Chapel Hill. The data needs and calculations were adequately explained and straightforward. All of the data was obtainable thanks to the positive and timely communication with the individuals who had access to the needed data.

Our recommendations would be primarily for change within the ICLEI protocol for the values used in calculations (for example, gas capture efficiency). For the next use of Appendix E, analyses should be used to determine the appropriate gas capture efficiency value for the specific landfill. We would also recommend that methods to determine emissions from compost be included in this Appendix. There are many composting operations in Chapel Hill (at UNC’s dining halls, in dorms on UNC’s campus, at the Carolina Campus Community Gardens) that may be producing some emissions that are not accounted for in the Protocol or may be offsetting emissions that would otherwise be produced if the food waste was in a landfill.
### Table 7: Solid Waste Emissions

<table>
<thead>
<tr>
<th>Emission source</th>
<th>Residential (mtCO2e)</th>
<th>Commercial (mtCO2e)</th>
<th>Total (mtCO2)</th>
<th>Total/resident (mtCO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility emissions</td>
<td>-</td>
<td>-</td>
<td>25115.00</td>
<td>0.43</td>
</tr>
<tr>
<td>Community generated emissions</td>
<td>410484.50</td>
<td>556428.10</td>
<td>966912.60</td>
<td>16.55</td>
</tr>
<tr>
<td>Landfill process emissions</td>
<td>107.50</td>
<td>215.70</td>
<td>323.20</td>
<td>0.01</td>
</tr>
<tr>
<td>Collection emissions</td>
<td>131.10</td>
<td>263.00</td>
<td>394.10</td>
<td>0.01</td>
</tr>
<tr>
<td>Transportation emissions</td>
<td>-</td>
<td>88.40</td>
<td>88.40</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>410,723.10</strong></td>
<td><strong>556,995.20</strong></td>
<td><strong>992,833.30</strong></td>
<td><strong>16.99</strong></td>
</tr>
</tbody>
</table>
Appendix F: Wastewater Emissions

The Town of Chapel Hill’s wastewater is treated at the centralized Mason Farm Wastewater Treatment Facility. The centralized nature of the treatment process means that very accurate records are available directly from OWASA for many of the required data.

Methods

**WW.1 - Stationary Methane Emissions from Combustion of Digester Gas**

Summing the emissions released during the wastewater treatment process begins with determining the total quantity of methane gas released because of incomplete combustion of anaerobic digester gas. Organic solids removed from the wastewater stream are removed to anaerobic (no oxygen) digester tanks in which microorganisms produce methane through the reduction of soluble organic carbon. Some of this gas fuels boilers, providing heat to the thermophilic organisms that facilitate the nitrogen removal process during treatment. The remaining gas is flared off on site.

1. Determine the standard cubic feet of digester gas produced per day

   **109,000 ft³/day**

2. Determine the fraction of CH₄ (methane) in the digester gas

   **0.58 or 58% CH₄**

3. Use equation WW.1.a to calculate the mt CO₂e generated via methane release during digester gas combustion

   **1.60 mt CO₂e**

**WW.2 - Stationary Nitrous Oxide Emissions from Combustion of Digester Gas**

Although N₂O itself is not generated in significant quantities within anaerobic digesters, nitrogen-containing compounds are converted to small quantities of N₂O during combustion of the gas. The data used to calculate these emissions is identical to that of WW.2, only the emission factor is changed from methane to nitrous oxide.

1. Determine the standard cubic feet of digester gas produced per day and the fraction of methane (see WW.1)

2. Use equation WW.2 to calculate the mt CO₂e generated via nitrous oxide release during digester gas combustion

   **4.6 mt CO₂e**
WW.7- Process Nitrous Oxide Emissions from Wastewater Nitrification and Denitrification

The Mason Farm Wastewater Treatment facility uses a biological nitrification/denitrification treatment process to reduce the effluent nitrogen concentration to less than 10 mg/L. Nitrification is the two-step process that microbes use to oxidize the ammonium and ammonia in waste to produce nitrate and small amounts of nitrous oxide, a powerful greenhouse gas. During the subsequent denitrification process, additional nitrous oxide is released as nitrate is converted to inert di-nitrogen gas and released into the atmosphere. Through these biologically remediated reactions, nitrogen is removed from the wastewater stream, preventing eutrophication in waters downstream.

1. Determine the population served by the Wastewater Treatment Plant

   **81,000 people**

2. Use equation WW.7 to calculate the total mt CO$_2$e generated by process nitrous oxide emissions during the nitrification/denitrification treatment process

   **177.77 mt CO$_2$e**

WW.12- Fugitive Nitrous Oxide Emissions from Effluent Discharge

Although the biological secondary treatment process removes a great deal of the nitrogen from the wastewater stream, remaining nitrogen compounds can undergo side reactions at the point of discharge, producing fugitive N$_2$O emissions.

1. Determine the average total nitrogen discharged per day (kg N/day)

2. Use equation WW.12 to calculate the total mt CO$_2$e generated by fugitive N$_2$O emissions during effluent discharge

Uncertainties

Large uncertainties are inherent within these calculation methods, largely due to their design for top-down use in large communities using mainly population to estimate emissions. The protocol sites uncertainties of ±42% for methane emission calculations and as much as ±84.5% for nitrous oxide emissions. Calculations based solely on population, including particularly process nitrous oxide emissions should be regarded with some skepticism. Additionally, N$_2$O emissions can vary dramatically between treatment facilities. Generally, higher efficiencies of N removal from the wastewater stream correspond to reduced N$_2$O production. A variety of factors including dissolved oxygen and nitrite concentrations can
significantly alter the quantity of process emissions. It should be noted that because emissions generated through wastewater treatment are such a small portion of the Town’s annual total, the relatively high error of population-based calculations should contribute little to overall error.

**Electricity Requirements of Water and Wastewater Infrastructure:**

The electricity requirements for collecting, transporting, and treating drinking water as well as that required for collection, transportation, and treatment of wastewater is not included in this section, as OWASA purchases 99.6% of its energy needs from Piedmont Energy Collective, emissions from which are included in Appendix C.

To determine if the electricity needed to power pumping stations, the process energy intensity for water collection/treatment/distribution and for wastewater collection, transportation, and treatment were used to calculate these related emissions. We found that less than 11 mt CO₂e were generated as a result of water and wastewater electricity needs. This represents a very small portion of the community’s total electricity related emissions.

**Recommendations**

The quantities of greenhouse gasses emitted directly as a result of the wastewater treatment process represent a very small portion of the 2012 total. The detailed nature of the OWASA records system will make these calculations easy to update as the Town’s wastewater stream grows.
Appendix H: Emissions Associated with the Community’s Use of Materials and Services

Accounting for Trans-boundary Community-Wide Supply-Chains.

The objective of this section is to estimate the upstream and life-cycle carbon emissions associated with the production, transport and sale of consumer goods within the community. However, compiling exhaustive data on community goods consumption is not practical in most cases. Thus the ICLEI protocol focuses on the consumption of certain readily measured goods and provides conversion factors for CO₂ equivalents in the following categories.

SC.1.1. – Food
The life-cycle greenhouse gas emissions associated with the production and distribution of food can often be a considerable portion of community emissions. We use data from the Consumer Expenditure Survey (CES) (BLS, 2011) to obtain annual food dollars spent per household and 2010 Census data for Chapel Hill. There are 19,970 households in Chapel Hill at the 2010 census. The average household spent $4890 for food at home in 2010 and $3216 for food away from home. The estimated emissions from the upstream production and distribution of this food are as follows.

Methods
1. Obtain annual food dollars spent per household at home and away, from U.S. Department of Labor, Bureau of Labor Statistics Consumer Expenditure Survey
3. Obtain total number of households in Chapel Hill, from U.S. Census Bureau
4. Determine total yearly community food expenditure for each category, apply conversion factor, we use 1.6 kg CO₂/2002$ and sum

Table 8: Food Emissions, 2012

<table>
<thead>
<tr>
<th></th>
<th>2012$ / HH</th>
<th>2002e$ / 2012$</th>
<th>mt/ 2002e$</th>
<th>Resident (mt/yr)</th>
<th>Household (mt/yr)</th>
<th>Community (mt/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Home</td>
<td>4890</td>
<td>0.7690</td>
<td>0.0016</td>
<td>2.06</td>
<td>6.02</td>
<td>120152</td>
</tr>
<tr>
<td>Away from Home</td>
<td>3216</td>
<td>0.7690</td>
<td>0.0016</td>
<td>1.35</td>
<td>3.96</td>
<td>79081</td>
</tr>
<tr>
<td>Total</td>
<td>8106</td>
<td>-</td>
<td>-</td>
<td>3.41</td>
<td>9.98</td>
<td>199233</td>
</tr>
</tbody>
</table>
Uncertainties
The Consumer Expenditure Survey is based on a relatively small sample size (<100,000) and cannot fully account for regional and cultural trends that may dramatically change the reported food budget used to make these calculations. Given the unique setting of Chapel Hill as a town with lots of local food availability, it is likely that the nationally averaged food budgets and associated carbon conversions are inconsistent with reality on the ground here. It seems possible that the emissions associated to the average food dollar spent in Chapel Hill are less than for the national average. The protocol suggests that national food expenditures are highly consistent across the country, and the reported values for Chapel Hill indeed fall in the expected range. Therefore, we feel confident that these food-related emissions are reasonably accurate.

Recommendations
Future community assessments would be well served to have local survey data regarding annual food expenditure and consumption. As noted above, the nationally averaged values from the CES may not properly represent Chapel Hill and achieving more than a cursory accounting of carbon emissions from life-cycle food consumption may only be possible with comprehensive local data in any city.

SC.2.1. - Cement
Determining cement-related emissions at the community scale is accomplished by obtaining statewide data for ready-mix concrete, and applying a conversion factor. Ready-mix concrete (NAICS 32732) is used as the proxy variable because it has a short setting time, and so is assumed to be used in close proximity to its origin. Estimated cement-related emissions are calculated as follows.

Methods
1. Obtain State-Wide NAICS 32732 expenditures\textsuperscript{30}:
   a. 2007 expenditures: $1,125,682,000
   b. 2012 equivalent: $1,267,946,330
2. Determine statewide per-capita use and apply to Chapel Hill population (58,424).
3. Apply emission factor, 0.002 tonnes CO\textsubscript{2}e/$

<table>
<thead>
<tr>
<th>Cement $/capita</th>
<th>CO\textsubscript{2}e (mt/$)</th>
<th>CO\textsubscript{2}e /Resident (mt)</th>
<th>CO\textsubscript{2}e/Community (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>0.002</td>
<td>0.26</td>
<td>15,190.24</td>
</tr>
</tbody>
</table>
Uncertainties:
This estimate is on the same order of magnitude as in the example calculation for cement in the ICLEI appendix, and so this estimate is likely to be accurate. However, these numbers represent statewide per-capita averages and so may not accurately reflect cement usage in town for two distinct reasons. First, a large cement operation exists directly over the municipal line in Carrboro, and given such close proximity to a manufacturer, Chapel Hill is likely to have a higher than average portion. However, such close proximity would also bring down the associated upstream emissions of transportation. Second, the Town of Chapel Hill saw respectable amounts of growth and construction over the 2012 calendar year, especially including the University, and likely a good deal more than would be reflected with state-averaged per capita usage.

Ultimately, the reported emissions are most likely on the correct order of magnitude, but represent an underestimate overall.

Recommendations
Explore advanced methods for cataloging cement use within the community. One possible option would be to request and aggregate cement budget from UNC. Another would be to request Chapel Hill sales from the Carrboro based plant, where the vast majority of large-scale cement used in town is likely purchased.

SC.3.1. – Other Materials
Methods
The intention of this approach is to estimate the manufacturing emissions from products that are not produced in the community, but are consumed here. We used managed materials data from Orange County Recycling program, and CO$_2$e conversion factors as provided by the protocol, table SC.3.1. The calculations are as follows.

1. Determine total tonnes managed in the community, by type$^{31}$
2. Apply appropriate conversion factor for upstream CO$_2$e emissions
3. Calculate per community and per resident

Uncertainties
These reported emissions are likely to represent somewhat of an underestimate because we have no good way of determining the aggregate upstream emissions from all other discarded goods, as they are not recycled or are not readily qualified across the community. Likewise, consumable items all experience some sort of a time lag between their purchased and discarded dates. It seems reasonable to assume that more expensive items (TV’s for example) have a higher carbon footprint per tonne than newspaper, and also take longer to be discarded.

There is little uncertainty about the emissions calculated based on the reported managed materials, aside from any errors in the conversion factors themselves. And
despite the underestimate noted above, certain trends are apparent and may provide guidelines for reduction and readily comparable benchmarks for other cities.

Table 10: Other Material Upstream Emissions

<table>
<thead>
<tr>
<th>Material</th>
<th>mt managed, OCR 2012</th>
<th>Upstream emission (mt CO₂e/tonne)</th>
<th>CO₂e (mt/yr)</th>
<th>CO₂e (mt/resident yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardboard</td>
<td>1,464</td>
<td>0.88</td>
<td>1,288.32</td>
<td>0.022051</td>
</tr>
<tr>
<td>Newspaper</td>
<td>5,329</td>
<td>1.94</td>
<td>10,338.26</td>
<td>0.176952</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2,927</td>
<td>7.91</td>
<td>23,152.57</td>
<td>0.396285</td>
</tr>
<tr>
<td>Steel</td>
<td>2,927</td>
<td>2.83</td>
<td>8,283.41</td>
<td>0.141781</td>
</tr>
<tr>
<td>PET plastic</td>
<td>146</td>
<td>2.07</td>
<td>302.22</td>
<td>0.005173</td>
</tr>
<tr>
<td>Tires</td>
<td>1,264</td>
<td>4.34</td>
<td>5,485.76</td>
<td>0.093896</td>
</tr>
<tr>
<td>Lumber</td>
<td>818</td>
<td>0.18</td>
<td>147.24</td>
<td>0.00252</td>
</tr>
<tr>
<td><strong>Total CO₂e</strong></td>
<td></td>
<td></td>
<td><strong>48,997.78</strong></td>
<td><strong>0.838658</strong></td>
</tr>
</tbody>
</table>

SC.4.1. – Long-Distance Freight Methods

This procedure accounts for the exhaustive freight systems that are responsible for delivering so much of the community’s goods, and which are not already accounted for in the transportation section. We do not have in-bound long-distance freight data, so we use the national average of $323 per capita (in 2002$) as provided by the protocol. And we use the conversion factor of 0.0019 tonnes CO₂e/2002$. The calculation for total CO₂e from long-distance freight is as follows.

Table 11: Long Distance Freight Emissions

<table>
<thead>
<tr>
<th>$ per capita (2002$)</th>
<th>CO₂e (mt/2002$)</th>
<th>Population</th>
<th>CO₂e / Resident (mt)</th>
<th>CO₂e Community (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>323</td>
<td>0.0019</td>
<td>58,424</td>
<td>0.6137</td>
<td>35,854.81</td>
</tr>
</tbody>
</table>

Uncertainties

This estimate is assumed to be accurate because it relies on the nationally-averaged per-capita responsibility of long-distance freight. However, there may of course be certain characteristics of Chapel Hill that could cause the true value to be slightly different from the national average. Perhaps the close proximity to I-40 would reduce this estimate slightly.
Appendix I: Consumption-Based Emissions Estimate

The goal of consumption-based accounting is to include a complete life-cycle carbon footprint for everything that is consumed by a household, from regular consumer goods to transportation and home energy use. To conduct consumption-based emissions in the absence of complete survey data and without the use of IMPLAN modeling, ICLEI protocol calls for the Berkeley Cool Climate Calculator to provide a rough estimate of CO₂ emissions at the household level. The calculator makes several basic nation-wide assumptions (e.g. vehicle MPG and individual diet for example), and also uses regional information (average income, home sizes, climate parameters) to provide rough estimates of CO₂ emissions at the household level. The household emissions number is then easily extrapolated out for the entire community.

Methods:
Cool Climate Calculator\(^{32}\):

\textbf{Input:}
- Chapel Hill, Orange County, NC
- 2 people/ HH – (the real average is 2.35)
- $50,000 - $59,000 annual HH income – (the real average is \$51,000)

\textbf{Output:}

\textbf{Cool Climate Estimate of Total Community Carbon Emissions, Chapel Hill 2012:}

\[(46.05 \text{ mt-} \text{CO}_2/\text{HH}) \times (20564 \text{ HH}) = 946,972 \text{ mt-} \text{CO}_2/\text{yr.}\]

\textbf{Uncertainties}

While the Cool Climate Tool indeed provides an estimate for community emissions that is on the right order of magnitude, it may differ somewhat from the actual...
emissions of Chapel Hill. The algorithm in this software has the benefit of aggregating national data to smooth out trends and provide a reasonable estimate of household emissions by applying relative proportions of energy use. However, the software cannot account for enough of the specific characteristics of Chapel Hill (or any city) to make this a highly accurate estimate. Instead, the output provides a baseline against which other, more advanced, emissions inventories may be compared. It should be understood that the Cool Climate Tool is valuable to develop and maintain a baseline for comparison as other more advanced accounting methods are employed.

Additionally, the user-provided input to the model is limited to household size (integer only) and average annual household income. In Chapel Hill, the average household size is 2.4 people, and so we used 2 as the household size input for the model. As such, we expect the tool output to be lower than in reality – potentially by as much as 20% / household.

Table 12: Household Breakdown

<table>
<thead>
<tr>
<th>Source</th>
<th>Source2</th>
<th>??</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other fuels</td>
<td>0.25</td>
<td>Cereals 0.71</td>
</tr>
<tr>
<td>Air Travel</td>
<td>1.78</td>
<td>Produce 0.66</td>
</tr>
<tr>
<td>Car MFG</td>
<td>1.32</td>
<td>Dairy 0.84</td>
</tr>
<tr>
<td>Car Fuel</td>
<td>11.94</td>
<td>Meat 2.19</td>
</tr>
<tr>
<td>Construction</td>
<td>1.63</td>
<td>Other Goods 3.29</td>
</tr>
<tr>
<td>Water</td>
<td>1.29</td>
<td>Furniture 2</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>2.27</td>
<td>Clothing 1.63</td>
</tr>
<tr>
<td>Electricity</td>
<td>6.59</td>
<td>Services 6.46</td>
</tr>
<tr>
<td>Other Food</td>
<td>1.2</td>
<td>Total 46.05</td>
</tr>
</tbody>
</table>

**Recommendations**

In the absence of complete local data, utilizing the Cool Climate calculator every year will provide a continued baseline against which other accounting methods may be compared. Additionally, this standardized tool may be useful to standardize comparisons between cities, and cities using other more advanced accounting methods.
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Ben Poulson, Associate Director, Energy Service at UNC

Dr. Elizabeth Shay, Institute for the Environment, Curriculum for Environment and Ecology

Wendy Simmons, Solid Waste Services Manager, Town of Chapel Hill

Bj Tipton, Solid Waste Manager, UNC Chapel Hill
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17 Personal communication via Brian Calloway, Energy ma


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