UNC GREENHOUSE GAS INVENTORIES 2016 & 2017

ENEC 698 Capstone - Fall 2018

DISCLAIMER: THIS REPORT WAS PREPARED AS A STUDENT PROJECT AND DOES NOT REPRESENT AN OFFICIAL UNC INVENTORY

Heyward Lathrop, David Herskowitz, Emma Tobin, Eric Fitch, Jintong Wu, Kojo Minta, Matt Bravante, Shalini Sharma

Faculty Advisor: Dr. Léda Van Doren

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Summary:

The goal of this study was to collect data on greenhouse gas emissions created directly and indirectly by the University of North Carolina at Chapel Hill in 2016 and 2017 and consolidate this data into a comprehensive inventory. Emissions were found to have increased slightly from 2016 to 2017, but total emissions are down since 2013. The inventories compiled from this data were requested by UNC's Three Zeros Environmental Initiative and UNC's Energy Services in order to find where campus emissions can be reduced. Members of the research study also analyzed some compensation and mitigation measures in response to the data to suggest ways to reduce emissions. The total emissions in 2017 were 419,530.47 metric tons of CO_2 equivalent, with the largest sources being the university's cogeneration power facility and purchased electricity.

Introduction

Launched in 2016, the University of North Carolina at Chapel Hill's Three Zeros Environmental Initiative has the goal of getting to water neutrality, zero waste to landfill, and net-zero greenhouse gas emissions. The initiative involves many aspects of campus life including transportation, energy, water management, and waste management. Part of the net-zero greenhouse gas (GHG) emissions aspect of the initiative is conducting an annual emissions inventory for UNC. An inventory has not been fully completed since 2013. The goal of this research paper is to convey the results of the greenhouse gas inventories for 2016 and 2017, and to propose mitigation measures for the university to explore.

A greenhouse gas inventory is composed of three types or "Scopes" of emissions. Scope 1 emissions are directly emitted on UNC's campus. They include emissions from electricity produced by UNC from the Cogeneration plant, on-campus generators, and the Manning Steam Plant. Scope 1 also accounts for fugitive emissions from lab gases and mobile emissions from the on-campus vehicle fleet. Scope 2 emissions come from purchased electricity, which UNC gets from Duke Energy and Progress Energy. Scope 3 emissions are all other indirect emissions and come from the value chain of UNC, excluding purchased energy. This scope includes commuting, solid waste, air travel, urban forestry, landscaping, paper usage, and food from Carolina Dining Services.

After these emissions were collected, they were organized by type of emission and converted into Carbon Dioxide equivalent or CO_2e. CO_2 has a global warming potential (GWP) of 1 because it is what the final calculations are measured in. Methane has a GWP of 25, meaning that over the span of 100 years, 1 kg of methane will cause 25 times more warming than 1 kg of CO_2. The amount of methane produced in kilograms is multiplied by 25 to convert it to CO_2e. For Nitrous Oxide, the global warming potential is 298 times as potent as Carbon Dioxide. Each different greenhouse gas has its own GWP that was used to find the total emissions for the inventory. These numbers were consistent with past inventories performed by the university.

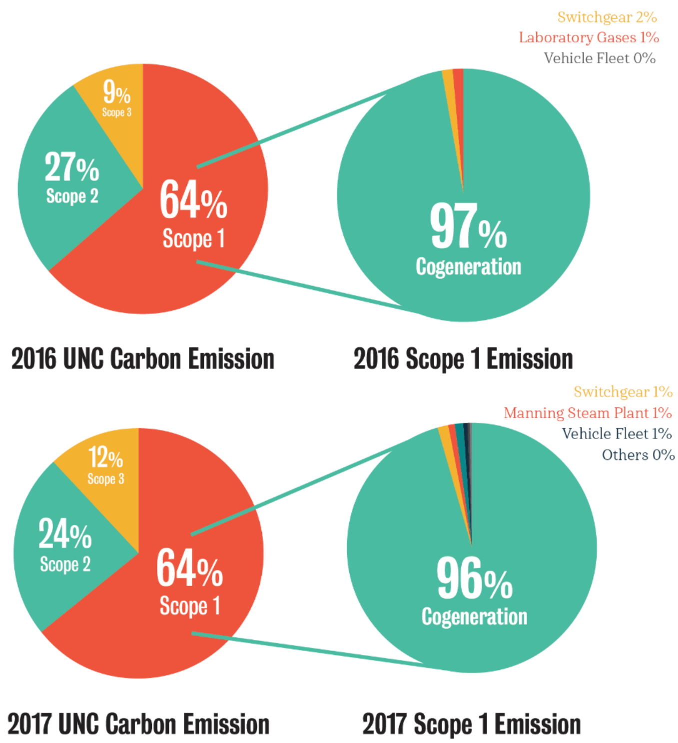
In this paper, we will analyze and describe the calculations for each scope of the inventory. Then, we will examine key differences and trends between emissions in 2016 and emissions in 2017. In the last section, we will discuss mitigation measures, and recommendations for future inventories.

2016 and 2017 Inventories

Results and Trends

Total emissions for UNC were 418,265.93 metric tons of CO_2 equivalent (MT CO_2e) in 2016, and 419,530.47 MT CO_2e in 2017. 64% of emissions came from Scope 1, 27% from Scope 2, and 9% from Scope 3 in 2016. In 2017, Scope 1 had the same percentage while Scope 2 created 24% of emissions and Scope 3 created 12%. The following sections will discuss each scope in detail.

There were certain trends that are important to highlight year over year. The scope 1 emissions went up by approximately 12,000 metric tons, scope 2 emissions went down approximately 10,000 metric tons, and scope 3 emissions went down approximately 600 metric tons. The summed up to a net increase of a round 1,500 metric tons year over year. The main explanation for the increase overall is weather. The calendar year in 2016 was warmer overall than that of 2017. This caused the cogeneration facility to produce more emissions. This was partially outdone by the lower carbon intensity of Duke Energy. Even with this slight increase, the university has reduced total emissions by 16% since 2013.



Scope 1

Cogeneration Plant and Manning Steam Plant

The bulk of the scope one greenhouse gas (GHG) emissions comes from the cogeneration facility located just off UNC's campus. The cogeneration plant produces steam for the hospitals and campus, as well as energy for the university. The cogeneration facility burns coal, natural gas, and fuel. Oil. While it is far more efficient than most fossil fuel plants, it still creates a large amount of emissions that are hard to avoid. We gathered data on the emission factors and tonnage of burned fuel from the 2017 Annual Air Emissions Inventory prepared for the University (Lawrence 2017). In 2017, the Cogeneration facility produces over 250,000 metric tons of CO_2 equivalent (MT CO_2e). This was 95% of the emissions in scope one, and over 60% of the total emissions attributed to the university. The Manning Steam Plant, which is used as a backup to the cogeneration facility, produced 2,629 MT CO_2e in 2017, which accounted for about 1% of scope 1 emissions.

Blackstart Generators, Emergency Generators, and Building Boilers

For reliability and resiliency purposes, the university also has a campus-wide network of blackstart generators, emergency generators, and building boilers. The emissions data for these is also in the 2017 Annual Air Emissions Inventory. In 2017, these three sources emitted a total of 1,484 MT CO_2e, which accounts for 0.55% of scope 1, and 0.35% of total emissions.

Lab Gases

The University also uses an array of laboratory gasses at the hospital and in scientific research. These gasses range from Carbon Dioxide to Methane to Sulfur Hexafluoride. These gasses either leak or get vaporized through their various functions, and the university needs to account for the emissions. Each gas has a slightly different global warming potential, ranging from carbon dioxide with a global warming potential of 1 to Sulfur Hexafluoride with a global warming potential of 23,900. These gases have a large range, and it is important to look at the substitutes of the gasses with higher potentials. Total lab gas emissions for 2017 were 1,250 MT CO_2e.

Vehicle Fleet

To calculate emissions from the university vehicle fleet, we obtained fuel purchase records from Adam Long. UNC purchases four different kinds of fuel: Diesel, biodiesel, E10, and E85. We used the sum of the fuel purchases for each year, and emissions factors for each fuel type to calculate total emissions. The emissions factors for E10, E85, and biodiesel were taken from the 2013 inventory, and the diesel emissions factors were taken from an EPA mobile emissions report (Greenhouse Gas Inventory Guidance, 2016). Total emissions were 2,931.42 MT CO_2e and

2,591.62 MT CO_2e for 2016 and 2017, respectively. The decrease in 2017 is mostly due to lower fuel use in 2017.

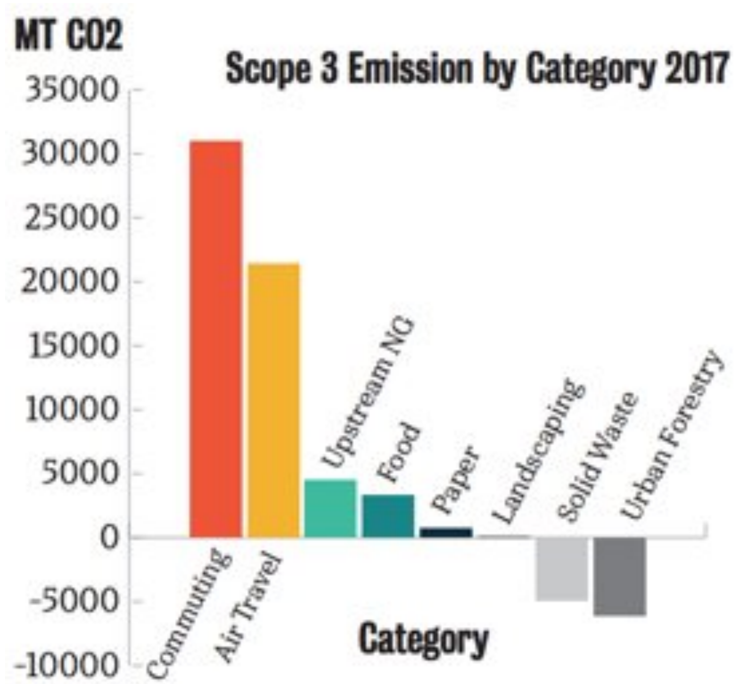
Scope 2

Electricity Purchased

Scope 2 emissions are from electricity use on UNC campus. Electricity purchase data for 2016 and 2017 was provided by Adam Long. In 2016, UNC purchased a total of 421,767,090 kWh of electricity from Duke Energy Progress and Duke Energy Carolinas. Out of these purchases, UNC sold 88,405,491 kWh to UNC hospital. Because UNC hospital's GHG emissions are not included in this report, the total purchased electricity was calculated by subtracting the UNC hospitals purchase amount from the total purchase. The net electricity purchase for 2016 and 2017 calendar year is 333,361,599 kWh and 320,133,243 kWh, respectively.

The carbon intensity of electricity generation of Duke Carolinas and Progress is 0.33 MT CO_2 per kWh in 2016 and 0.31 in 2017 generated (Historical and Projected Carbon, 2014). After multiplying the carbon intensity by the effective UNC campus electricity purchase, the result of total GHG emission due to electricity purchase of UNC campus is 11,009 MT CO_2 in 2016 and 99241 MT CO_2 in 2017. Scope 2 emissions accounted for 23.65% of total emissions in 2017, down from 26.3% in 2016.

Scope 3



Air Travel:

UNC is a major research university with partnerships with other universities and institutions across the United States and the world. Its students, professors, and administrators are often travelling on university sponsored flights. These flights also contribute to the carbon footprint of the university. To calculate the GHGs attributable to air travel, we analyzed data from the university's Central Airfare Billing System and the Study Abroad Office. Both datasets contained logs of each airport travelled to during a person's trip for 2017. For example, the first row of the raw data file reads:

RDU-CLT CLT-MSY MSY-CLT CLT-RDU

This line indicates that the traveler went from Raleigh to Charlotte to New Orleans and back during their trip. We wrote a MatLab script which read in all 30,000 trip itineraries and determined the total distance of each person's trip and the distances between each stop on the trip. Then, using emission factors for airplane emissions provided by Adam Long, we related the total distances travelled for all of UNC to a corresponding amount of carbon dioxide emissions.

In 2017, the total emissions from UNC Study Abroad Travel were 5,984 MT CO_2e, and total emissions from flights booked through the Central Airfare Billing System were 16,887 MT CO_2e. Air travel accounts for about 44% of scope 3 emissions. These emissions came from a total traveled distance of 64,674,585 passenger-kilometers.

Upstream Natural Gas:

Upstream Natural Gas emissions refers to GHG emissions generated in the production system of the natural gas. It results from activities in the process of natural gas production such as venting and flaring of methane during well completion and leaks in the transportation system (Scull, 2017). The method this report used to calculate UNC campus upstream natural gas emission is to multiply the total campus natural gas consumption by the upstream natural gas GHG emission factor. The emission factor is a percentage of GHG emission resulting from the production divided by the total production of Natural Gas. The emission factors are calculated separately for CH_4 and CO_2 emissions. To calculate the emission factors of natural gas, we used the numbers for total US domestic production of Natural Gas in 2017 (U.S. Dry Natural Gas, 2018), and divided this number by the total CH_4 and CO_2 emissions in 2016 associated with upstream processes in the production of natural gas (Inventory of U.S., 2018). This calculation is further explained in the appendix.

We obtained an emission factor of 0.96 MT CO_2 per million cubic feet. The emission factor of Upstream NG CH_4 emission is 1.08%, meaning the amount of upstream CH_4 emission in the natural gas production system is equal to 1.08% of the total Natural Gas production. Natural gas is used on campus in the cogeneration facility, and for the Manning Steam Plant. Total NG consumption was 721 Million Cubic Feet and 626 Million Cubic Feet in 216 and 2017. Using the emissions factors, we calculated that total upstream natural gas emissions were 5,124 MT CO_2e and 4,452 MT CO_2e for 2016 and 2017, respectively.

Paper:

The paper consumption data used in this report includes paper purchase from both Staples and Mini Store. The university buys paper that is composed of different percentages of recycled paper. Our method for these calculations was to sort the paper by recycled percentage and then multiply the weight of paper by the emissions factor for the recycled content. These emissions factors were maintained from the 2013 inventory.

The paper consumption data comes from two sources, Staples and Mini Store purchases. The data from Staples provides information such as the unit weight of a certain paper product, recycled content, selling unit and purchased quantity. A small portion of raw data received from Staples was missing the unit weight value. In order to fill in the missing value, the average unit weight of the paper was calculated from existing data according to the sell unit (for example, pack). The unit weight of the paper product that was missing a value for weight was assumed to be the average unit weight of that unit type. 0.31% of paper purchases in 2016, and 0.2% of paper purchases in 2017 were missing unit weight values. There were also some products in the Staples purchase data that were missing the recycling percentage. All the product that was missing the recycle % value is assumed to be 0% recycled paper. The paper products from Staples were later grouped by their recycle content, 0%, 1%, 10%, 30%, 50%, 75%, and 100%. The total amount of paper purchased for each recycle percentage was calculated by multiplying the units purchased by the unit weight.

The paper purchase data from Mini Store gives the amount of paper in the unit of cases. Each case is assumed to be 20 pounds in the calculation. All paper purchased from Mini Store were assumed to all have a 30% recycled content and thus been added to the 30% recycled weight.

The final emission amount for each recycle percentage was calculated by multiplying the emissions factor for that specific recycle percentage by the total weight of paper of that recycle percentage. The final total emission value is 733 MT CO_2 in 2016 and 723 MT CO_2 in 2017.

Commuting:

Emissions from commuting make up the largest portion of scope 3 emissions with about 55% of scope 3, and about 7% of all emissions on UNC's campus. Commuter data is collected in a survey every other year and includes mode of transportation, distance traveled, and frequency of travel. Chapel Hill Transit provided their own data about diesel and unleaded fuel use for their vehicles. We used this data along with emissions factors data from the EPA to calculate the total emissions for 2016 and 2017 (Greenhouse Gas Inventory Guidance, 2016). Unleaded and diesel fuel emit 99% CO_2 with some CH_4 and N_2O.

For Chapel Hill Transit emissions, we decided to keep the assumption from the 2013 greenhouse gas inventory that 62% of CHT emissions are attributable to UNC employees and students. By using the fuel use data and the same emissions factors from the EPA, we calculated the total greenhouse gas emissions from Chapel Hill Transit.

For the rest of the commuters, we used the data from the campus commuter survey. Since the survey is only conducted every 2 years, we averaged the 2015 and 2017 values to find the 2016 values. There were three main parts to this calculation. The first part was calculating the average distance traveled to campus for students and employees. The commuter survey asks respondents how far they live from campus, and offers 5 choices: Less than 2 miles, 2-5 miles, 6-10 miles, 11-20 miles, and over 20 miles. For these categories, we assumed average distances of 1 mile, 3.5 miles, 8 miles, 15.5 miles, and 25.5 miles, respectively. The survey data shows what percentage of people live in each distance category for each transit mode. We used the assumed distances and these percentages to calculate a weighted average distance for each transit mode.

The original survey data had 11 categories, but for simplicity's sake, we condensed the data into drive alone, bike, carpool, walk, and bus. We added half of park and ride to drive alone, and the other half to bus. We added "motorcycle" and "dropped off" to the drive alone category. Carpool and vanpool were combined into one carpool category. Finally, the telework from home and the "other" categories were excluded from the final calculations, because they are assumed to be produce no emissions. To get the average distance of the combined categories, we calculated another weighted average based on the number of survey responses for each transit mode.

The second part of the calculation was to calculate the number of commuters who use each transit mode. We started by looking at the percentages of students and employees that commute by each transit mode. Because we obtained fuel use data directly from CHT, we factored out the students and employees who take local buses. We did this by first multiplying the transit split percentages for students and employees by the total number of students and employees. We assumed that the transit splits for full and part time students were the same. We then subtracted 9% from both the total number of employees and the number of employees who take the bus. We did the same for the students using the assumption that 35% of students take CHT. The assumption that 9% of employees and 35% of students take CHT was taken from the 2013 inventory. In addition to factoring out the commuters who take CHT, we added half of park and ride to the bus category, and the other half to the drive alone category. This assumes that when a commuter uses a park and ride lot, about half of their commute is them driving alone, and the other half is on a bus. After these calculations, we were left with the total number of students and employees who take each mode of transit.

The third part of the commuter calculations was to use the average distance calculations, the number of commuters using each transit mode, and the number of trips per year for each type of commuter to calculate the number of vehicle miles traveled, and the number of bus miles traveled. We then assumed an average of 25 mpg for passenger vehicles, and 40.9 passenger miles per gallon for buses, and used these factors to get the total unleaded gallons and total diesel gallons. We calculated CO_2, CH_4, and N_2O using the same emissions factors used previously.

The total greenhouse gas emissions attributable to commuters for 2016 and 2017 are 31,545 MT CO_2e and 31,000 MT CO_2e, respectively.

Waste

One part of UNC's goal with the three zeros initiative is for the campus to have zero waste-to-landfill. Through the introduction of composting programs in the dining and residence halls, increased number of recycling bins around campus, and other initiatives in labs and academic buildings, the campus has significantly decreased the amount of solid waste that is produced annually. Lenoir and Chase dining halls, for instance, now use plastic to-go containers which can be washed and reused after each student's use, and they introduced compostable items such as cups, napkins, and utensils. Eleven million pounds of food waste has also been composted since 2000 in the dining halls and other dining facilities on campus (Food Waste Composting). The University of North Carolina at Chapel Hill Office of Waste Reduction and Recycling also works to decrease the amount of waste on move-in and move-out days by running a program focused on donating used goods, as well as recovering items such as cardboard and Styrofoam for recycling.

When looking at waste calculations for the 2016 and 2017 Greenhouse Gas Inventories, we based our template on the 2013 inventory. We used the same categories as provided in the spreadsheet: bottles and cans, corrugated containers, office paper, textbooks, food scraps, yard trimmings, mixed paper, mixed metals, mixed recyclables, mixed municipal solid waste, concrete, coal ash, and tires. Glass, personal computers, mixed plastic, mixed organics, residential paper, and bottles and cans were not included in the calculations. This is because the Office of Waste Reduction and Recycling annual reports did not have data on these categories. Also, when referencing the 2013 inventory, these categories did not have a significant impact on the total amount collected.

Annual trend reports account for all the measurable solid waste produced by the university. The trend reports are organized by fiscal year, which runs from July 1st to June 30th. To determine the amount of landfilled, recycled, and composted waste produced in the calendar year of 2016, we used the 2015-2016 and 2016-2017 year-to-date values. Similarly, we used the 2016-2017 and 2017-2018 Trend Reports for the 2017 calendar year. We were then able to find the values for each of the waste categories (in tons) collected in the fiscal year. The amount year-to-date value for July, for example, would be the total amount of tons collected from January to July. So, to find the number of tons for each section for the 2016 calendar year, the year-to-date value for June 2016 were subtracted from the year-to-date tons for December 2015 in the 2015-2016 report, thus giving us the year-to-date tons for the first half of the year. To find the value for the whole year, we took the year-to-date tons from December 2016 in the 2016-2017 report and added this to the total we found previously. This procedure was used for all 13 categories in 2016 and 2017. All categories were counted as being recycled, besides mixed municipal solid waste, which was landfilled, and food scraps and yard trimmings which were composted. Version 14 of the WARM database was utilized to procure the emissions factors for each category, converting the amount in tons to megatons of CO2 equivalence. The emissions factors varied for each category, and whether the material was recycled, landfilled, or composted.

We summed all categories and found that in 2016, 2254.75 tons were recycled, 5931.27 tons were landfilled, and 2576.89 tons were composted, giving off -7432.34 MT CO_2e, 2444.11 MT CO_2e, and -407.44 MT CO_2e, respectively. In 2017, 1947.91 tons were recycled, 5651.52 tons were landfilled, and 2719.24 tons were composted, giving off -6380.84 MT CO_2e, 2347.65 MT CO_2e, and -430.81 MT CO_2e, respectively. Recycling and composting were counted as negative emissions because they are credited as such by the university. By recycling, the university can reduce the emissions attributed to raw materials in product production. According to the data, it seems that the tons of landfilling still exceed the tons recycled and composted combined, although the emissions for completely offset the emissions from landfilling. This is likely because the emissions factors for recycling were much more than those for landfilling.

Urban Forestry :

Urban forestry has historically been counted as a carbon credit because of the amount of carbon sequestered by trees on campus. This amount was studied in a previous capstone at UNC in 2012 and for the purpose of the inventory, we assumed that the amount of green space at UNC had not changed (ENST). The 2012 capstone class calculated that 6,120 metric tons of CO_2 were sequestered every year by the trees on campus, and that this was a carbon sink (ENST). We used this same number in both the 2016 and 2017 inventories.

We recommend that, in future inventories, UNC not count our urban forests as a carbon sink. It is true that forests absorb carbon, but the forests that are a part of UNC's campus existed before the Three Zeros Initiative was developed. Therefore, it is not right to count the forests as a carbon offset because the trees aren't something that the university planted for that purpose. For this number to be accurate, the university would have to keep track of every tree planted and removed on campus and adjust the number accordingly.

Landscaping:

In order to create an inventory for landscaping, we obtained data from Adam Long regarding what kind of fertilizer and how much was applied around UNC's campus in 2016 and 2017. We only calculated emissions for the pesticides and not herbicides because, with an herbicide, there is no nitrogen that will go into the atmosphere as emissions. There may be nitrogen molecules in the herbicide, but they will stay fixed in the environment and will not be released into the air. Therefore, the emissions for herbicides were considered to be zero.

In the product name, the composition of each fertilizer is listed, with the ratio of nitrogen that is contained within each. In order to convert nitrogen emissions to CO_2 equivalent emissions, we obtained an equation from the EPA.

The equation is:

$$N_2O\ Emissions = FC * EC * \frac{44}{28}$$

FC is the fertilizer consumption, in tons of nitrogen applied. This value is found by multiplying "nitrogen content by weight" by tons of fertilizer. EC is the emission coefficient, which is stated by the EPA as 0.0117 tons N_2O-N/ton N applied. In the equation, $\frac{44}{28}$ is the molecular weight ratio of N_2O to N_2O as N (N_2O/N_2O-N) (Emissions).

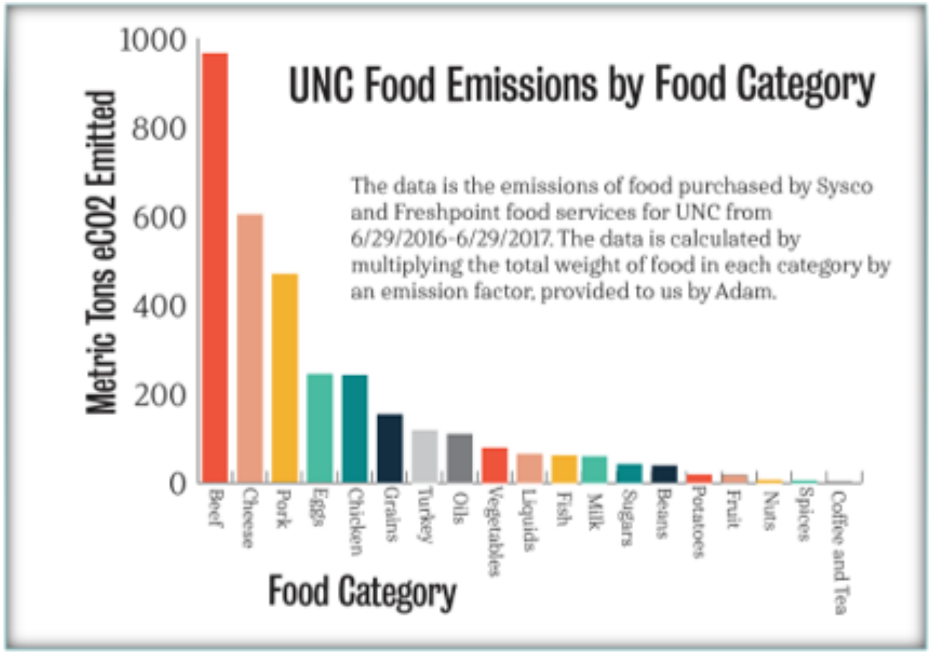
Like the equation indicates, for each type of fertilizer, we multiplied the tons of fertilizer by nitrogen weight by content to get total nitrogen content in tons, which was the FC value. We then plugged this FC value into the equation each time to calculate total N_2O emissions in tons, using 0.0117 as the EC variable, per the EPA's direction. After making the calculation for each pesticide and getting the final N_2O emissions, the N_2O emissions in tons needs to be converted to metric tons, so these values were then multiplied by 0.907185 because 1 ton = 0.907185 metric tons. Each of these were then multiplied by 298 to convert from nitrogen emissions to CO_2e.

The result for the 2016 inventory was that Proscape 16-0-8w.38 Barricade fertilizer created 7.16 metric tons of CO_2 equivalent, Woodace 14-14-14 Nursery created 1.04 metric tons, and 18-24-12w/50%XRT MICROPK created 8.95 tons. For the 2017 inventory, we discovered that, out of the fertilizers that contributed emissions, Proscape 16-0-8w.38 Barricade created 0.8 metric tons of CO_2 equivalent and 18-24-12w/50%XRT MICROPK created 13.42 metric tons. This accounts for 0.03% of Scope 3 emissions.

Carolina Dining Services:

Carolina Dining Services (CDS) feeds most UNC students and many of its faculty and staff members. As a result, CDS purchases large amounts of food every year, which emits thousands of metric tons of carbon dioxide. All raw data used for the calculation were provided by Adam Long. In making our calculation we used Velocity Reports from Sysco and Freshpoint Foods and carbon emission factors, also provided by Adam Long, for production of each major food category (i.e. beef, pork, vegetables).

Velocity reports spanned from June 29, 2017 to June 27, 2018. Each line of the Excel report included a description of a single food item and an associated quantity of that item, purchased by Carolina Dining Services. In order to calculate the carbon emissions from the Sysco reports, we ran a MatLab script which was able to identify key words from each row of the report and determine the food category to which each row belonged. After running through the data, we then multiplied the calculated quantity of food in each category by the corresponding emissions factor to arrive at the total carbon dioxide emissions. For Freshpoint Foods, we manually scanned the data, determined quantities of food by category, and multiplied by emission factors. We then summed the data from the two sources and divided our final emissions values by .7 to account for the fact that Freshpoint and Sysco comprise 70% of the food consumed on campus. Total emissions from food purchases were MT 4,706.87 CO_2e. We assumed this number to be the same for 2016 and 2017 since we were only able to obtain data for 2017.



In the process of calculating the total carbon emissions from Carolina Dining Services, we were also able to identify which food categories were most at fault for the large number. The top three categories in terms of carbon dioxide emissions were beef, followed by cheese, followed by pork. It was not surprising that these categories were the larger contributors. The process of farming cows, which are used to produce beef and cheese results in much greenhouse gas emissions. Accordingly, before extrapolation to account for the remaining 30% of campus food, beef contributed 966 and cheese 603 metric tons of carbon dioxide to the atmosphere. In our mitigation measure section of the report, we will calculate the potential carbon emission savings by a minimally disruptive alteration to the UNC campus diet.

Mitigation Measures:

Scope 1

Cogeneration facility:

Currently, coal is being used as the main fuel source in the Cogen plant, with natural gas and oil as the backups. Our recommendation for mitigating the emissions from Cogen is to make biogas our primary fuel source. However, biogas is significantly less energy dense than coal, so it would take much more biogas than what would be produced on campus to make enough energy for the entire campus. It is possible to still replace the coal by either obtaining an anaerobic generator to produce biogas from campus biomass or installing a gas pipe line that runs from a hog farm to campus, though both options would be very expensive. A plan for a potential biogas generator is described below. In order to have zero greenhouse gas emissions for the Three Zeros Initiative, the fuel source would most definitely have to be replaced. For now, campus groups should lobby for a change in legislation so that the state government can install a biogas pipeline somewhere close by in North Carolina. Another alternative is using biodiesel, like vegetable oil, animal fats, or recycled grease. Princeton University successfully used soy-based biodiesel in their cogeneration power plant in a trial run, so the switch is feasible (Cogeneration Plant Tests, 2007).

UNC Vehicle Fleet:

The vehicle fleet is bought and managed by each separate department, but we recommend a centralized incentive for switching to electric or high efficiency vehicles. This incentive could be monetary or could be a special privilege like parking location. Any way to increase the amount of EVs in UNC's fleet would be beneficial.

Switchgear:

We highly recommend switching the switchgear gas from Sulfur hexafluoride (SF6) to General Electric's new G3 gas. SF6 has a GHG warming factor of 23,900 and switching to G3 gas would reduce the GHG emissions of the switchgear 98%. This alone would have a larger impact that the solar farm planned for Horace Williams Airport.

Scope 2

Biogas Generator at OWASA Plant:

OWASA currently manages biogas at its waste water treatment plant, but most of is flared off at gas. The Mason Farm road plant which treats Orange County's sewage currently captures methane to power its onsite-boilers (Rouse, 2017). The remaining 46 percent of the methane is what is burned off into the environment as carbon dioxide and water vapor (Rouse, 2017). With the UNC's goal to reduce its emissions, it may want to consider utilizing some of OWASA's biogas to power its campus.

A biogas generator can convert tons of organic waste, mainly food waste, into biogas—a mixture of methane and carbon dioxide. Using an anaerobic biodigester, the creation of methane produced for biogas and biosolids for fertilizers are possible (Battiste, 2016). Also, the energy produced from organic waste in sewage water is 10 times the amount needed to treat it (United States, 2012). Seemingly, it makes sense to incorporate a combined heat and power (CHP) biodigester to reduce the electricity purchases from Duke Energy. According to the National

Association of Clean Water Agencies, if all Waste Water Treatment Plants (WWTPs) in the United States had a biogas generator, 12 percent of the nation's electricity demand would be met. To put this statistic into perspective, the University of North Carolina at Chapel Hill (UNC-CH) in 2017 consumed 1.126 x 10^12 BTUs of energy. The power potential of WWTPs would amount to 1.172 x 10^16 BTUs of energy, which is enough to power the university 10,000 times.

Food waste is the most efficient source of organic waste that can be utilized for biogas fuel. It can produce as much as 3 times the amount of energy that biosolids can produce (United States, 2012). In Orange County, 2700 tons of organic matter —mainly food waste — is composted (Karidis, 2018). If OWASA can maximize collection of food waste to 2700 tons, 486 MTCO2 would be offset and 5349 BTUs would be produced annually.

In the United States, biogas generation for a university campus in not a foreign idea. Michigan State University has an exemplar an exemplar biogas plant on campus that uses more than just food scraps from campus. By collecting feedstock from local restaurants and farms, the university has been able to produce 1.365 x 10^6 BTUs that can power up to 10 campus buildings (Kirk, 2016). Even though the generator does not work with a WWTP, it is sustained by a university fund (Kirk, 2016). This model may be intriguing to the UNC-CH, but the greater student population of Michigan State and potentially larger feedstock resources may play unique roles in the program's success.

Financially, the implantation of the CHP certain associated costs. From 1.1 to 8.3 cents per kilowatt hour to install the generator, there can be an optimal production of 21 cents per kilowatt-hour of energy pricing for WWTPs (United States, 2012). Still, the cost of installing an anaerobic digester-powered biogas generator may cut significantly into the university's fiscal budget. By setting up a fund with OWASA to power the university, UNC-CH may be able to contract the WWTP to purchase energy at a more affordable price.

There have been several case studies that were performed on the implementation possibilities of a biogas generator at OWASA. In fact, there are 7 different plans under consideration, but the feasibility of each are still under study. Things that OWASA must consider include the financial responsibility, the realistic nature of using a co-digestion of food waste, and the timeframe of regional collaboration with related energy services (Rouse, 2017). Once a plan is determined to have the right balance of actionable results and viability by state consultants, biogas-to-energy on OWASA property can be considered.

Building Efficiency:

An area that UNC can make significant improvements in efficiency is by transitioning to LED lights in as many buildings as possible. LED lights have only been put in locations where an easy switch of compatible bulbs is possible. Currently, there is no inventory of where LEDs are on campus, and there is no list of buildings where it is possible to switch more out. We are aware that Energy Services is considering having an intern do an inventory of the LEDs on campus in 2019 so that UNC can better understand what the current status of LED lighting is. We highly recommend going forward with this plan, and then from there taking steps to convert every bulb possible to LED that isn't already, and, where possible, we suggest LED motion sensor lighting. We understand that there are limitations in converting everything over to LED due to some buildings being extremely old. However, especially in new buildings being built, LEDs need to be mandated, and systems need to be in place where LED lights are not value engineered out. By value engineering out LEDs in new buildings being built, UNC is merely moving around costs. The cost not spent up front on installing LEDs is merely moved to the maintenance budget, and more is spent later on to maintain old, less efficient lighting systems. Creating an LED inventory, retrofitting all existing buildings with LEDs where possible, and making sure LEDs cannot be value engineered out would make a big impact in energy usage on campus.

Our second energy efficiency recommendation is that Energy Services work to automate the 5% of buildings that are not currently part of the building automation system. It's imperative that we get off of pneumatic controls and have full view of what is occurring inside all buildings on UNC's campus energy-wise. We understand that this type of change is very expensive, but it should be prioritized in the budget because it will maximize the ability of the campus to make more universal changes, increase transparency, and decrease the labor needed to deal with the 5% of buildings not part of the universal automation system.

Another great system that is already in place is "events to HVAC". We recommend that UNC expand this program to reach beyond just the Union because it would certainly save energy and costs. Other buildings where this program would be effective include Memorial Hall, Playmakers, Global FedEx, the Alumni Center, and any other building that has event-type use. This is a low-lift solution with great impact on campus and is very feasibly implemented.

In terms of residential halls, we recommend starting a "green-certified" dorm room program. This can be implemented by having a certain list of things each room must have or that the residents must do to make their room "green-certified". Several other colleges, including Duke University, use a questionnaire detailing the residents' daily living habits and those residents who meet all the requirements for their rooms win a prize (Duke Green Dorm, 2018). These can include conditions such as not buying a fridge and installing LED lights in desk and floor lamps. Specifically, for UNC, each student could be given a water bottle or other sustainable prize, as well as a chance to be entered into a raffle for a chance to meet the basketball team.

Rooftop Solar:

Rooftop Solar can be expanded on campus to help offset purchased electricity. With the help of policy incentives and a tax credit, solar projects are subsidized and can be a cost-efficient way to cut carbon emissions. Non-profit organizations such as UNC are eligible for a rebate of 75 cents per watts up to 75000 dollars from Duke Energy (Henderson, 2018). Although rooftop solar projects require a huge upfront cost for installation, they require minimal maintenance. The cost of rooftop solar is often covered by the long-term savings from the decrease in electricity purchases.

The average capacity factor of a solar panel in North Carolina is 19.8%, which means a panel in North Carolina can produce 18% of its maximum output. (Andrews, 2016) The average space requirement of solar in 2018 is about 15 watts per square feet. (Zientara, 2018) Since space needs to be reserved for inverters and walking area, the usable area is about 2/3 of total area, which result in about 10 watts per square feet for a rooftop solar project. A lot of buildings on UNC campus have enough roof space and the right structure for installing rooftop solar projects.

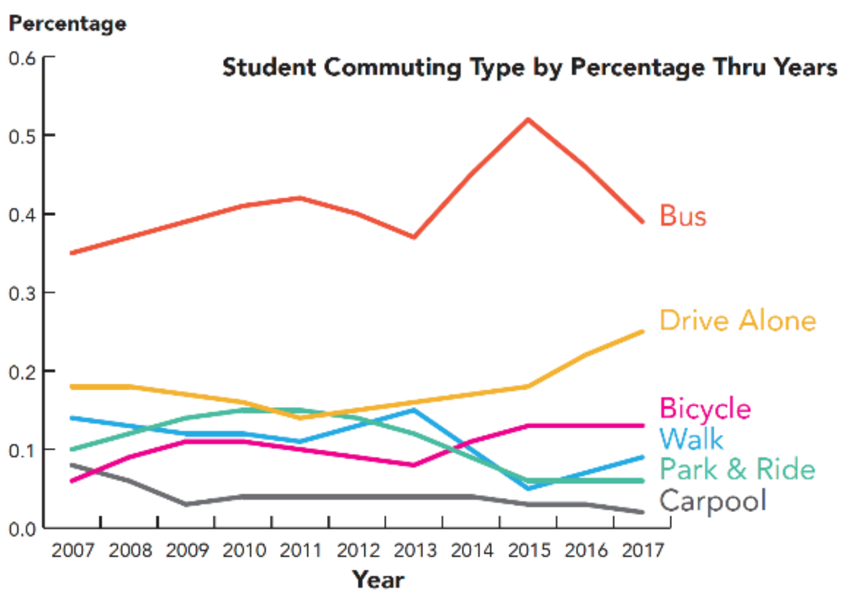
This image, taken from Google Project Sunroof, shows the solar potential on buildings around campus. Take Davis Library for example: as of right now the rooftop is made from cement and has nothing on it. According to Google Project Sunroof, Davis library has 55,410 square feet available for solar panels (Google). If all the space is used to install solar panels, it could have a capacity of 55410*10 = 0.55 MW. Since the cost of solar installation is about 3000 dollars per kWh, the upfront estimated cost of this project is about 1.5 million dollars. (Google, 2018) However, in one year of full operation, it could generate 0.198*0.55*8760 hours = 954 MWh, which can cover 0.29% of UNC 2016 total electricity bill and reduce 314 MT of carbon emission in one year. If this project is used for Duke Energy rebate, it could get a rebate of 412500 dollars.

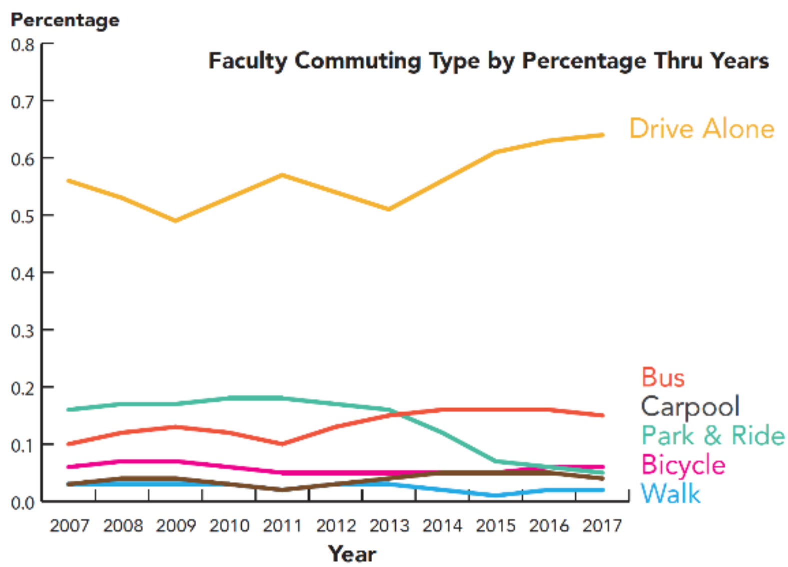
Besides Davis Library, there are several other buildings on central campus such as the Undergraduate Library, Woollen Gym, and Paul Green Theater that have potential for rooftop solar. These buildings have flat rooftops and get great sunlight throughout the year, according to Google Project Sunroof and Google Maps. Overall, Rooftop Solar project is an option for UNC to consider that could save money and cut down carbon emissions in the long term.

Scope 3

Transportation:

Our first recommendation to cut transportation emissions is to reduce the cost of Park and Ride. Ever since Park and Ride required a fee back in 2012, usage has decreased from 17% to 5% for employees and from 13.5% to 6% for students (2017 UNC Commuter Survey, 2017). Driving alone has increased from 15% to 25% for students and from 54% to 64% for employees, as shown in the graphics below. We calculated that Park and Ride creates 30% fewer emissions than driving alone. This is based off of the emissions created per passenger in buses and in cars from diesel and unleaded fuel, dividing the average distance in half, and finding the emissions created from those distances by vehicle type. It is understandable that Park and Ride costs money in order to pay for upkeep of the sites and buses, but if transportation services offered a discounted park and ride rate for students and faculty and it was well advertised, it could offset some of the increase in driving alone. UNC Transportation and Parking already offers parking passes for the academic year in addition to the calendar year ([Park and Ride] Pricing, 2018). One solution could be offering parking by semester. Another possibility could be to offer special discounts around holidays or for back to school, or just offering an overall percentage decrease in fees for UNC students and employees.





Our second recommendation for reducing commuter emissions is establishing a program to incentivize employees to purchase electric vehicles. In 2015, the Union of Concerned Scientists published a report that found, when all lifecycle emissions are considered, battery electric vehicles produce half of the emissions of conventional gas vehicles (Cleaner Cars, 2015). The case for electric vehicles has gotten even better since 2015, as North Carolina continues to add solar capacity and transition away from coal. Right now, the average rate of electric vehicle adoption in the US is 1.75% (EV Market Share, 2018). If we consider that there are approximately 8,500 employees who either drive alone or carpool to work and assume that the average person buys a car every 10 years, there will be 15 employees buying an electric vehicle each year. With a proper incentive, this rate could double to 30 employees per year.

The average employee driving alone to UNC commutes 12 miles to campus and makes about 490 trips per year. This results in 5,580 vehicle miles per year. If we assume an average fuel economy of 25 mpg, then the average employee uses 235 gallons of gas, and emits just over 2 MT CO_2e per year. If an EV emits under half of the emissions of a gas vehicle, then this number would decrease to under 1 MT CO_2e per year for every commuter who switches to an EV. If the incentive is responsible for an additional 15 people switching annually, on top of the 15 who would have switched anyway, then the program will reduce emissions by about 15 MT CO_2e per year. In the scope of UNC's emissions, this is a very small reduction. However, emissions from commuters have increased from .69 MT CO_2e per commuter in 2013, to 0.74 MT CO_2e per commuter in 2017. This recommendation will help to reverse this trend and set commuter emissions on a declining path.

Our recommendation is to give a one-time discount on a parking pass to employees who purchase an electric vehicle and drive it to campus. The discount would only apply for the first year that the employee owns the car. In addition, we recommend that some desirable parking spots be designated "EV only" parking spaces. The cost to the university would be in the form of lost parking revenue for UNC Transportation and parking. However, with an EV adoption rate of only 30 per year, the cost would be minimal. This program will only have to run for a few years, until EV prices have come down more and there are more EV options for consumers. Finally, UNC may have to invest in some additional charging infrastructure. However, studies have shown that 65% of EV charging sessions happen at home, while only 32% happen at work (Menser, 2018).

Air Travel:

Air travel is one of the most difficult categories to mitigate because there are no great alternatives. We came up with a compensation measure that could also serve as an indirect mitigation measure. We recommend that the university charge a greenhouse gas fee to all flights taken on university business. The revenue from this fee could go towards reducing greenhouse gas emissions in other areas on campus. This would also mitigate flying to a certain degree because the increase cost would encourage university departments to organize more video conferences or other alternatives to traveling by air.

Food:

We analyzed three different possible emission reduction strategies. In these scenarios we make the following changes to the food category quantities, which Carolina Dining Services could potentially strive for. Scenario 1 is business as usual, in which case emissions would not change. Scenario 2 assumes that Carolina Dining Services reduces beef consumption by half and distributes the weight on a weighted basis between chicken, turkey, and pork. Scenario 3 assumes that Carolina Dining Services reduces cheese consumption by half. Scenario 4 assumes both modifications from scenario 2 and scenario 3. These modifications were chosen for analysis because the beef and cheese food categories were two of the largest emitting categories identified in the initial analysis

We found that 4,706.9 metric tons of carbon dioxide were emitted under the Scenario 1. Scenario 2 reduced emissions from the current situation by 11.37%. Scenario 3 reduced emissions by 9.15%, and Scenario 4 reduced emissions by 20.52%. We recommend that Carolina Dining Services implement one of these scenarios to cut emissions.

Conclusion:

According to our calculations, total emissions went up from 2016 to 2017 by 1,288.33 MT CO_2e. Despite this slight increase, total emissions are down almost 16% compared to 2013 levels. This change reflects an overall trend towards the university's goal of zero net greenhouse gas emissions by the year 2050. However, considering that total emissions are still almost 420,000 MT CO_2e per year, there is still a long way to go. We recommend that UNC further study the mitigation and compensation measures described in this report. By implementing these measures, the university can continue to reduce its greenhouse gas emissions long term.

References:

"2017 UNC Commuter Survey."*UNC Transportation and Parking.* Nov. 2017. https://move.unc.edu/files/2018/10/commuter-survey-report-2017.pdf.

Andrews, Roger. "Solar PV Capacity Factors in the US – the EIA Data." *Energy Matters.* 15 Sept. 2016, http://euanmearns.com/solar-pv-capacity-factors-in-the-us-the-eia-data/.

Battiste, Micaela, et al. "University of Michigan Waste to Energy – Feasibility Study for an OnCampus Biodigester." *Planet Blue- University of Michigan.* 2016. http://sustainability.umich.edu/media/projects/Biodigester_Dow-Masters-2016.pdf

"Cleaner Cars from Cradle to Grave". *Union of Concerned Scientists.* 2015. https://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.XAUlvuJG2M9

"Cogeneration Plant Tests Sustainable Biodiesel Fuel." *Princeton Weekly Bulletin.* 22 Oct. 2007. https://www.princeton.edu/news/2007/10/22/cogeneration-plant-tests-sustainable-biodiesel-fuel

"CO2 Equivalents." *Climate Change Connection*, *Manitoba Eco-Network.* 2018. climatechangeconnection.org/emissions/co2-equivalents/.

"Duke Green Dorm Room Certification." *Duke Office of Sustainability.* 2018. https://sustainability.duke.edu/action/certification/dorm

Edwards, Rebecca. "How Much Electricity Does a Solar Panel Produce?" *Solar Power Authority.* 2018. https://www.solarpowerauthority.com/rooftop-solar-vs-solar-farms/.

"Emissions from Soils - Greenhouse Gases." *United States Environmental Protection Agency*, www3.epa.gov/ttnchie1/ap42/ch14/final/c14s01.pdf.

ENST 689 Capstone. "Carbon Sequestration in UNC Chapel Hill's Urban Forest." *UNC Chapel Hill Three Zeros Initiative.* 14 Dec. 2012, https://threezeros.unc.edu/files/2016/01/UNC-Chapel-Hill-Carbon-Sequestration_Final-Report.pdf

"EV Market Share". *EVAdoption.com.* 2018. http://evadoption.com/ev-market-share/

"Food Waste Composting." *UNC Facilities Services*.facilities.unc.edu/operations/building-services/waste-reduction/campus-recycling/food-waste-composting/.

Google. *Project Sunroof.* 2018. https://www.google.com/get/sunroof#a=208%20Raleigh%20St,%20Chapel%20Hill,%20NC%2027514&p=1.

"Greenhouse Gas Inventory Guidance: Direct Emissions from Mobile Combustion Sources." *United States Environmental Protection Agency.* Jan. 2016, https://www.epa.gov/sites/production/files/2016 - 03/documents/mobileemissions_3_2016.pdf.

Henderson, Bruce. “NC Regulators Just Made It Cheaper to Install Solar Panels on Your Roof. Here’s How.” *Charlotte Observer*, 16 Apr. 2018, https://www.charlotteobserver.com/news/local/article208992734.html.

“Historical and Projected Carbon Intensity of Generated Electricity.” *Duke Energy Carolinas.* 2014. http://www.energy.sc.gov/files/view/2014DukeEnCarIRP.pdf

“Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016". *United States Environmental Protection Agency.* 12 Apr. 2018. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Karidis, Arlene. “How Orange County, N.C., Has Made Food Scrap Collection a Tradition.” *Waste360*, 6 Mar. 2018, www.waste360.com/food-waste/how-orange-county-nc-has-made-food-scrap-collection-tradition.

Kirk, Dana. “The Largest Biogas Plant for an American Campus Is at the Michigan State University.” *Biogas Channel*, 20 Apr. 2016, www.biogaschannel.com/en/video/anaerobic-digestion/8/largest-biogas-plant-american-campus-michigan-stat/1138/.

Lawrence , J. “UNC Title V 2017 Annual Air Emissions Inventory.” 28 June 2017.

Marsh, Jacob. “Solar Farms: What Are They, and How Do You Start One?” *Energysage: Smarter Energy Decision.* 27 June 2017. https://news.energysage.com/solar-farms-start-one/.

Menser, Paul. “Large National Studies Analyze EV Infrastructure Needs”. *Idaho National Laboratory.* 2018. https://www.inl.gov/article/charging-behavior-revealed-large-national-studies-analyze-ev-infrastructure-needs/

“[Park and Ride] Pricing.” *UNC Transportation and Parking. 2018.* https://move.unc.edu/about/pricing/.

“Program Results.” *Facilities Services*, facilities.unc.edu/operations/building-services/waste-reduction/campus-recycling/program-results/.

Rouse, Ruth. “December 5, 2017 NRTS Committee Meeting.” *Orange Water and Sewer Authority.* 30 Nov. 2017, www.owasa.org/Data/Sites/1/media/about/committees/agendas-committees/nrts/2017/20171205_nrts_agenda.pdf.

Scull, B. D. et al. “Upstream Emissions of Coal and Gas”. *Columbia University, School of International and Public Affairs.* 2017. 2017. http://mpaenvironment.ei.columbia.edu/files/2014/06/UpstreamEmissionsReport_SIPA_REVISED.pdf

United States, Congress, Sinicropi, Patricia. "Biogas Production at Wastewater Treatment Facilities." *Biogas Production at Wastewater Treatment Facilities.* National Association of Clean Water Agencies. 16 May, 2012. www.americanbiogascouncil.org/pdf/briefing15may12_nacwa.pdf.

"U.S. Dry Natural Gas Production". *U.S. Energy Information Administration.* 30 Nov. 2018, https://www.eia.gov/dnav/ng/hist/n9070us2A.htm.

"Versions of the Waste Reduction Model (WARM)." *United States Environmental Protection Agency.* 13 Mar. 2018. www.epa.gov/warm/versions-waste-reduction-model-warm.

"Waste Reduction and Recycling." *Sustainability @ UNC.* 2018. sustainability.unc.edu/initiatives/operations/recycling/.

Zientara, Ben. "How Much Electricity Does a Solar Panel Produce?" *SolarPowerRocks.com.* 2018. https://www.solarpowerrocks.com/solar-basics/how-much-electricity-does-a-solar-panel-produce/.

Appendix:

Emissions Factor Calculation for Upstream NG

Total US natural gas production in 2016 was 26,592,115 million cubic ft. (U.S. Dry Natural Gas). We used the following calculation to find production in metric tons.

$$26{,}592{,}115\ million\ ft^3 * .05\ \frac{lb}{ft^3} * \ (4.5359 * \ 10^{-4}\ \frac{Metric\ Ton}{lb}) \ = 603\ million\ metric\ tons$$

Total methane emissions in the U.S. Natural Gas production system in 2016 was 163.5 Million MT CO_2e, which is 6.54 Million Metric Tons of CH_4 (Inventory of U.S., 2018). The emission factor of Upstream NG CH_4 emission is equal to the CH_4 emission divided by the total production of natural gas:

$$\frac{6.54\ million\ metric\ tons}{603\ million\ metric\ tons} * 100\% = 1.08\%$$

The total CO_2 emission in the Natural Gas Production system is 25.5 Million Metric Tons in 2016. The emission factor of Upstream NG CO_2 emission is equal to the total CO_2 emissions divided by total natural gas production:

$$\frac{25{,}500{,}000\ metric\ tons\ CO_2}{26{,}952{,}115\ million\ ft^3} = \ 0.96\ \frac{MT\ CO_2}{million\ ft^3}$$