A Sustainable University of Delaware®

CARBON FOOTPRINT

Greenhouse Gas Emissions Inventory

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Table of Contents

Executive Summary

Every year, the University of Delaware's senior class elects to fund a project or effort for its alma mater. The 2008 Senior Class chose to support a project that would measure the carbon footprint of the University and create an action plan for reducing emissions. This report presents the results of the project – the first carbon footprint measurement of the University of Delaware.

The inventory of carbon emissions required the efforts of a team of students and faculty from diverse disciplines. Among the disciplines represented are mechanical engineering, civil & environmental engineering, electrical engineering, architecture, economics, and energy and environmental policy analysis.

Data on the University's major carbon-emitting activities were gathered, and total CO_2 emissions were calculated from four sources: building energy use, transportation fuel consumption, waste (including food waste), and emissions associated with landscaping. These sources are standard among universities that have conducted CO_2 emissions inventories.

The University's total 2007-2008 emissions are estimated at 152,542 metric tons of carbon dioxide equivalent ("$MTCO_{2e}$"). This is equivalent to 8.7 $MTCO_{2e}$ per student and 7.1 $MTCO_{2e}$ per university community member (faculty, staff, and students).

In addition to gathering data for calculating emissions, building audits were performed to estimate emissions by activities such as lighting, heating, cooling and transportation to and from campus. The audits create opportunities for projecting conservation and energy efficiency improvements. Sixteen buildings and six utility plants were audited to collect data on mechanical equipment, lighting, HVAC systems and plug loads. The next step of the project is to prepare an Action Plan that offers strategies for reducing the University's carbon footprint. This step will include a detailed evaluation of carbon reduction options for consideration by the University community.

SECTION I
Introduction

On April 23, 2008, Dr. Patrick Harker, President of the University of Delaware, signed the *American College & University Presidents Climate Commitment* ("the Presidents Climate Commitment"). The Commitment requires the completion of a greenhouse gas inventory followed by an action plan to become carbon neutral. President Harker described the University's participation as "another significant step in our effort to become a more sustainable University." The Presidents Climate Commitment recognizes that leadership in higher education is needed to encourage society as a whole to significantly reduce carbon emissions.

Approximately 40 universities across the United States have published their carbon footprints. The reports are available to the general public via the website of the Association for the Advancement of Sustainability in Higher Education (AASHE). Of the 40 universities with completed inventories, 27 are signatories to the Presidents Climate Commitment. Several other universities have prepared emissions inventories and emissions reduction plans, but have not published the results.

Universities and colleges are expected to be early adopters of new ideas and have a special responsibility to educate and motivate young people who will determine our future. This leadership can be used to positively influence other institutions and communities.

The Presidents Climate Commitment calls for U.S. universities to pursue carbon neutrality. By demonstrating national and community leadership in reducing their carbon footprint, universities can accelerate the adoption of carbon neutrality goals throughout society. By integrating action plans with education on environmental issues, the University of Delaware can contribute to a new direction that addresses the significant energy and environmental challenges facing our society.

The Commitment lays out the following plan and timeline for universities to become climate neutral:

- Within a year of signing the agreement, a carbon inventory must be completed.

- Two years after the Commitment is signed, universities must develop an action plan to become carbon neutral.
- This action plan shall include goals to reduce carbon emissions and a time frame for becoming carbon neutral.
- Suggested measures include meeting LEED[1] or equivalent building standards, adopting an energy efficient purchasing policy, providing public transportation incentives and purchasing renewable energy.

Estimating the carbon footprint and adopting an emissions reduction plan will help the University prepare for future carbon reduction regulations and mandates by state and national policies. By being proactive, the University will enable our community to be "ahead of the curve," securing the benefits of action earlier than others, while being able to anticipate future costs and hopefully lower long-term costs.

University research and funding can be targeted to the development of new sustainable technologies and strategies, programs and behavioral changes that are successful in reducing carbon emissions at universities, can be designed for use in other public and private sector initiatives. By reducing energy use and carbon emissions, and by using these actions as part of an education strategy, the University of Delaware will attract students and faculty that share its concern for sustainability and inspire community and alumni participation in moving the wider society toward carbon neutrality.

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[1] "LEED" stands for the Leadership in Energy and Environmental Design. This rating system for building ecological performance was created by the U.S. Green Buildings Council. The LEED ratings cover four categories: Platinum, Gold, Silver, and Certified. The highest awarded rating is LEED Platinum for scores between 52-69; LEED Gold is awarded for a score of 39 to 51; a LEED Silver rating is given for buildings that score between 33-38, and LEED Certified is awarded for scores of 26 to 32.

Scope of the Inventory

Initial Focus

Emissions inventoried in this study address activities at the Newark Campus of the University of Delaware. This includes Laird Campus, the Main Campus, and South Campus. The University's off-campus farm facilities were outside of the scope of this inventory, as were its Dover, Wilmington, Lewes and Georgetown satellite campuses.

Institutional Representation

Institutional data used to build the carbon inventory of the University of Delaware: include the number of students (full time equivalent), faculty and staff; the total building stock (including classrooms, laboratories, offices, sports facilities, libraries, etc.); the University vehicle fleet and the vehicles of its commuting members; the University's waste stream (including food waste); and landscaping services.

During FY 2007-08, the Newark Campus supported 17,631 students, and 3,857 faculty and staff.[2] The total University community membership was 21,488 members. The total building area for the Newark Campus of the University of Delaware in FY 2007-08 stood at 5,235,720 square feet (486,414 m^2). Its vehicle fleet included 37 cars, 135 vans, 15 buses, and 103 trucks and other work vehicles. The campus has 2,613,600 sq. ft. (242,811 m^2) set aside for vehicle parking. The average number of cars driven to campus by students, staff and faculty is 7,000 per day.

Emission Sources

The University's emissions from primary energy sources are mainly from the use of natural gas, with very small amount of heating oil also annually consumed. On-campus stationary sources (utility plants) use fuels to provide space heating and hot water (via central utility plants) for the vast majority of campus buildings. In fact, around three quarters of building square footage at the

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[2] The full time equivalent (FTE) of these population was calculated using the formula:
Full Time Equivalent (FTE) = Full-time count + (Part-time count/3)

Newark Campus is served by utility plants. The University operates utility plants throughout the campus. At these sites, steam is generated and distributed for building heating and hot water. Some also generate chilled water for cooling and underground chilled water distribution for electricity. A portion of the buildings on campus are offline (i.e., they are not connected to utility plants). For these buildings heating and cooling needs are met through the use of smaller, localized equipment.

Fuel used for on-campus transportation is also a significant source of emissions. The burning of gasoline, diesel, and other fuels is needed to power the University fleet, personal vehicles, and other vehicles to transport people and products on behalf of the University.

Solid wastes, including food waste generated by the University and the application of fertilizers are also sources of GHG emissions. Methane is a potent GHG and is released when waste is sent to the landfill rather than composted or recycled. Fertilizers release nitrogen oxide, which is another potent GHG.

Operational Boundaries

Inventoried emissions were categorized into three types:

- Category 1 – *Direct GHG Emissions*
  - Sources include natural gas, University fleet fuel, and fertilizers
- Category 2 – *GHG Emissions from Imports of Electricity*
  - Sources include all electricity consumption
- Category 3 – *Other Indirect GHG Emissions*
  - Sources include student and faculty daily commutes, dorm resident trips to home, and food and other waste sent to landfills

Exclusions

Several sources of University emissions are outside the scope of this inventory. In most cases, these emissions are excluded because of a lack of sufficient data. The omitted activities include:

University related ground travel for which the University fleet was not used; and University related air travel. Although the University has its own travel agency, it is common for individuals to make their own travel arrangements. Obtaining University-related travel data from individuals was deemed infeasible at this time. Emissions from excluded activities, as well as those from satellite campuses, will be considered at a later time.

Base Year

Fiscal year 2007-08 was selected as the base year. This was the most recent year for which complete information was available. Reduction goals in the Action Plan will use 2007-08 as the benchmark year.

SECTION II

Data and Estimation Methods

Essentially, calculating emissions involves applying a CO_2 emissions factor to total fuel usage, waste generation, and fertilizer applications. The degree of accuracy of the data obtained and utilized for the inventory tends to correlate directly with the level of control the University has over the emissions sources, which aligns closely with the scope.

For sources of **Category 1** emissions – which include the burning of natural gas and fuel oil for heating, the application of fertilizer and the use of gasoline and diesel fuel for campus fleet transportation – the data obtained can be assumed to be accurate and calculating the emissions is straightforward.

The University's emissions from primary energy sources are mainly related to its use of natural gas. Relatively small quantities of heating oil are also used. On-campus stationary sources (utility plants) provide heating and chilled water for the vast majority of campus buildings.

Facilities Management provided metering and billing data for natural gas and oil consumption for buildings and other facilities in the University. Data collected for Category 1 emission analysis is for the period 2003-2008.

Transportation services provided data on gasoline and diesel fuel consumption by the University vehicle fleet. Fleet data collected for emission analysis is for the period 2005 to 2008.

Calculating **Category 2** emissions – that is, emissions from electricity consumption – involves an additional estimation. While electricity invoices paid monthly by the University can be assumed to be accurate, transmission and distribution and efficiency losses must also be included in the inventory and require estimation. The emission estimation for electricity use is based upon regional average factors for the quantities of the different fuels used by power plants in the

Delmarva Zone[3] of the PJM Interconnection. Data on CO_2/kWh for the Delmarva Zone is regularly reported by the PJM. The research team gathered data on this factor for 1990–2007.

For **Category 3** emissions – those resulting from food waste and mixed solid waste sent to landfills, as well as emissions associated with student, faculty and staff commuting – calculations involved a number of assumptions. While accurate waste generation data can be obtained from the University, the emissions factors applied to this data must be based on national studies. Emission factors are sensitive to assumptions about waste composition and landfill conditions.

To arrive at an estimation of vehicle miles traveled by commuting students, staff and faculty, a variety of information sources was utilized. A University transportation survey conducted in 2008 for the Newark campus transportation capacity was used to estimate the percentage of student, staff and faculty commuters that traveled to work using a vehicle, the typical commuting distance, and the frequency of trips made. The University's Department of Public Safety provided data on registered vehicle types and vehicle age. This information was used to calculate average fuel efficiencies for each category of commuter (student and faculty/staff).

Trend Analysis

Although FY 2007-08 is the base year, a trend line starting with FY 2002-03 was established in order to better understand the trajectory of University emissions. For natural gas, heating oil, and electricity, data were collected from 2002-03 to 2007-08. For transportation, the number of years of collected data varied. For calculating emissions from daily commuters and on-campus student residents, estimations of emissions per vehicle were made for FY 2007-08 (based on 2007-08 data), and the resulting per vehicle emission was applied to the number of commuting students, faculty, and staff as a constant. For University fleet emissions, fuel consumption data was available from 2003-04 to 2007-08.

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[3] The Delmarva Zone is a spatial area defined by the PJM for purpose of planning electricity capacity and service. It includes the State of Delaware, northern Maryland and a small area of Virginia served by the Delmarva Power Company, the principle load-serving entity of our region.

Data on waste generated by the University was available from 1990-91. However, food waste data covered only 2007 and 2008. Fertilizer use data was only available for FY 2007-08 only.

Emission Factors

To calculate the GHG emissions associated with the activities considered in the inventory, we relied upon emissions factors calculated by official, reliable, and relevant sources. For natural gas, fuel oil, gasoline, diesel fuel and jet fuel, emissions factors were taken from the U.S. Energy Information Administration. The emissions factor applied to nitrogen fertilizer was taken from the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (April 2003). For releases from electricity, the emissions factor was taken from the U.S. EIA database for the "Original PJM Area" (Delaware, Pennsylvania, New Jersey, Maryland and District of Columbia). Given the mix of the resources used to generate electricity in the PJM region, and average transmission and distribution (T&D) losses,[4] the CO_2 emission factor was approximated as 1,278 pounds of CO_2 per MWh of electricity in 2007-2008. Power plants in this region use multiple fuel sources including coal, oil, natural gas, nuclear, biomass, captured methane gas, photovoltaic cells, water, wind, and wood waste. The conversion factor used for electricity was based on the U.S. Energy Information Administration (EIA) database, which offers annual carbon dioxide emissions from power plants for each state. Also available are the average nitrogen oxides (NO_X), sulfur oxides (SO_X), and carbon dioxide (CO_2) emissions for the PJM region. The data change yearly and CO_2 emissions are decreasing slowly due to the steady change in fuel mix created by a decrease in coal use and an increase in natural gas and renewable energy resources as a percentage of the total generation fleet.

For food waste and mixed waste, CO_2 equivalent emission factors were taken from the U.S. EPA's *Waste Reduction Model* (WARM). These emission factors are U.S. national averages for waste sent to landfills without methane recovery. The figures reflect the carbon equivalent of methane

[4] Typical T&D losses in the U.S. are 7% (see http://www.climatetechnology.gov/library/2005/tech-options/tor2005-132.pdf).

emissions from the decomposition of the waste, as well as emissions from transportation of waste to landfills. Emission factors applied to all sources of University emissions are listed in Figure 1.

Figure 1: Emission Factor, Total Consumption and Emission by Sources for 2007-2008

Source	Sector	Category	Emission Factor	Consumption	Emission
Natural Gas	Buildings	1	.0546 $MTCO_2$/mcf	642,625 mcf	35,087 MT
Distillate Fuel #2 (Heating Oil)		1	.01015 $MTCO_2$/gal	154,525 gal	1,569 MT
Electricity		2	.00058 $MTCO_2$/kWh	137,925,068 kWh	79,958 MT
Gasoline	Transportation	1 3	.0088 $MTCO_2$/gal	229,697 gal 3,470,617 gal	2,022 MT 30,558 MT
Diesel Fuel		1	.01015 $MTCO_2$/gal	72,451 gal	735 MT
Jet Fuel		3	0.0096 $MTCO_2$/gal	2,162 gal	21 MT
Mixed Solid Waste	Waste	3	.73 $MTCO_{2e}$/ton	2,937 ton	2,144 MT
Food Waste	Food Services	3	.78 $MTCO_{2e}$/ton	505.65 ton	394 MT
Fertilizer (Nitrogen)	Landscaping	1	.004 $MTCO_{2e}$/lb	13,427 lb	54 MT
Total Emission					**152,542 MT**

Building Audits

The University of Delaware carbon footprint inventory included detailed audits of sixteen buildings, representing ten different building types on the Newark campus. Six utility plants were also subjected to detailed audits. The audits enabled estimations of emissions from activities in buildings such as lighting, heating and cooling, computing and other activities using electronic devices, etc.

Audit Onsite Procedures

The audit procedures adopted for the project are based on the Industrial Assessment Center (IAC) methodology. The U.S. Department of Energy created the IAC program in 1994 to assist small and medium-size companies in finding cost-effective strategies for reducing energy use. The University of Delaware is a DOE-designated IAC site. The program is co-administered by the Department of Electrical and Computer Engineering and the Center for Energy and Environmental Policy.

Each building audit included a comprehensive assessment of four major categories: lighting; heating, cooling, air-conditioning and domestic hot water systems; equipment and appliances; and building envelope. Based on the inventory, a building energy model was established for each site in order to analyze individual building energy performance and behavior. These models will be used to indentify cost-effective energy improvement opportunities during the Action Plan phase of the Project.

1. *Lighting*: A comprehensive lighting inventory was prepared for each audited building. Information was collected on fixture type, wattages and hours of operation, as well as opportunities for installing natural day-lighting or occupancy sensors.
2. *Building mechanical systems including heating, cooling, and domestic hot water equipment: A*n assessment of each building's mechanical systems was conducted and mechanical equipment specifications such as size, model, voltage, amperage, horsepower, and loads (as well as existing energy efficient installations, such as variable speed drives) were documented. Input from facilities management personnel responsible for the audited systems was also recorded. This information will be used to identify opportunities for improving energy efficiency in each building.
3. *Equipment and appliances (classrooms, offices, labs, kitchens, etc.):* An inventory of equipment and appliances was prepared. Plug and process loads for buildings will be based on this inventory. For residence halls, student plug loads were established through an analysis of energy consumption under various seasonal occupancy scenarios.
4. *Building Envelope:* Status of existing glazing, insulation and building envelope infiltration rate was documented and opportunities for improvements will be identified.

Audit Offsite Procedures

In addition to the audit procedures conducted onsite, the following complementary analysis was conducted offsite:

1. *Direct Energy Consumption Analysis*: This step involved allocating the electricity and gas consumption used in buildings to end-use categories. These categories included lighting, plug loads, and mechanical equipment.

2. *Indirect energy consumption allocation and analysis:* This step involved allocating the electricity, natural gas, and heating oil used at the University's central utility plants to produce steam, hot water and chilled water for campus buildings. As part of this process, an allocation methodology was developed by the project team to estimate the portion of indirect energy consumed by each audited building.

For chiller plant allocations, the project team established an allocation methodology, which is based on individual building electricity load characteristics.

To allocate the indirect heating load, the Commercial Buildings Energy Consumption Survey (CBECS) database from the U.S. Energy Information Administration was utilized to estimate heating energy intensity ("EI") for each building type. Based on the EI factor for each building category, heating energy equivalents and adjusted gross square foot allocation factors for all buildings served by central boilers, were calculated and applied to each building.

See Appendix A for allocation factors used to determine indirect energy consumption.

General Observations from Building and Utility Plant Audits

The University's building stock varies widely in age, occupancy, design, energy consumption characteristics, and types of end uses. Considering the entire campus, electricity consumption is dominated by lighting and space cooling. Fuel consumption, mainly natural gas, is driven primarily by space heating during the winter. However, domestic hot water loads and summer reheating are also important.

Among building types, laboratories are typically the most energy intensive in relative and absolute terms. This is because they require large ventilation air flows, which impose large winter heating and summer cooling loads. Morris Library is also one of the most energy intensive buildings on campus. Classroom, office and student housing are less energy intensive, but vary widely depending on age and condition.

In general, the condition of most campus buildings is good. Although each building had unique characteristics, several observations were common in the building audits:

- The University has addressed lighting technology throughout the campus. For the most part, the audited buildings used T-8 fluorescent lamps and fixtures, or similarly efficient technologies. Compact fluorescent lamps (CFLs) were used in most fixtures where they could be applied. Exit lamps were a mixture of CFLs and LEDs. However, the audits showed that some opportunities for lighting upgrades remain (e.g., replacement of incandescent with fluorescents).

- Although lighting technology has been addressed, there are numerous areas where lighting controls can be used to reduce electricity consumption. Hallways, classrooms and other areas were frequently lit when no students, staff, or faculty were present. In other areas, lights were on even though there was adequate day light available. In addition, the audit team frequently received comments about lights being left on when buildings were completely unoccupied.

- The audit team also observed areas, especially common areas and hallways that were significantly over-lit. Fixtures could be de-lamped or removed in these areas.

- The University has upgraded motor technologies in most heating, ventilation and air conditioning (HVAC) systems. Variable speed drives were installed on many of the larger motors used for hot water and chilled water pumps, and air handler fans. Additional opportunities for variable speed drives exist.

- A significant thermal load is imposed by summer re-heating. Re-heating is typically used to control humidity. In this process, chilled water is used to reduce supply air temperatures before it enters the air conditioned space. By "overcooling" the air, additional humidity can be removed. But to avoid uncomfortably cold building temperatures, the air then has to be re-heated. Precise humidity control is rarely needed for conventional space cooling applications, and simultaneous heating and cooling is obviously very energy intensive. Less energy intensive methods of controlling humidity for comfort are available.

- There are opportunities for building shell improvements, such as windows and insulation, especially in classroom and lecture halls on the west side of College Avenue. Single pane glass is used in several of these buildings, and many are deteriorating.

- Approximately 60% of the campus buildings are connected to the existing building management system. Individual electric meters are installed on nearly all buildings, but they are capable of monitoring only total electricity consumption and are not connected to the building management system. The system is primarily used to schedule building equipment operations and to set temperatures. Since the system does not currently collect real-time electricity, chilled water or steam flow to the buildings, it cannot be used to track trends in actual energy consumption which could help to pinpoint energy-related problems.

- One issue noted by Facilities staff is that there is great uncertainty about actual building occupancy and schedules. Although there is some coordination, it is believed that better coordination and scheduling would reduce the amount of time that buildings are operated in the "occupied" mode when they are actually unoccupied. During summer and winter sessions, there are also opportunities to optimize building utilization to reduce utility loads in lightly used areas.

The University has several central utility plants to supply steam, hot water and chilled water. The largest by far is the Central Utility Plant located on Academy Street. The age and condition of boiler chillers and auxiliary equipment varies. In several cases, the equipment is in good

condition, although there are many opportunities to increase production efficiency. These are summarized in greater detail in the appendices, but they include:

- Installing oxygen trim control and heat recovery equipment on boilers
- Installing a back pressure turbine to reduce boiler steam pressure to distribution system pressure
- Reducing blowdown losses by improving boiler water treatment
- Implementing free cooling at the central plant
- Repairing condensate system piping to increase condensate return flow
- Insulating underground piping in access vaults

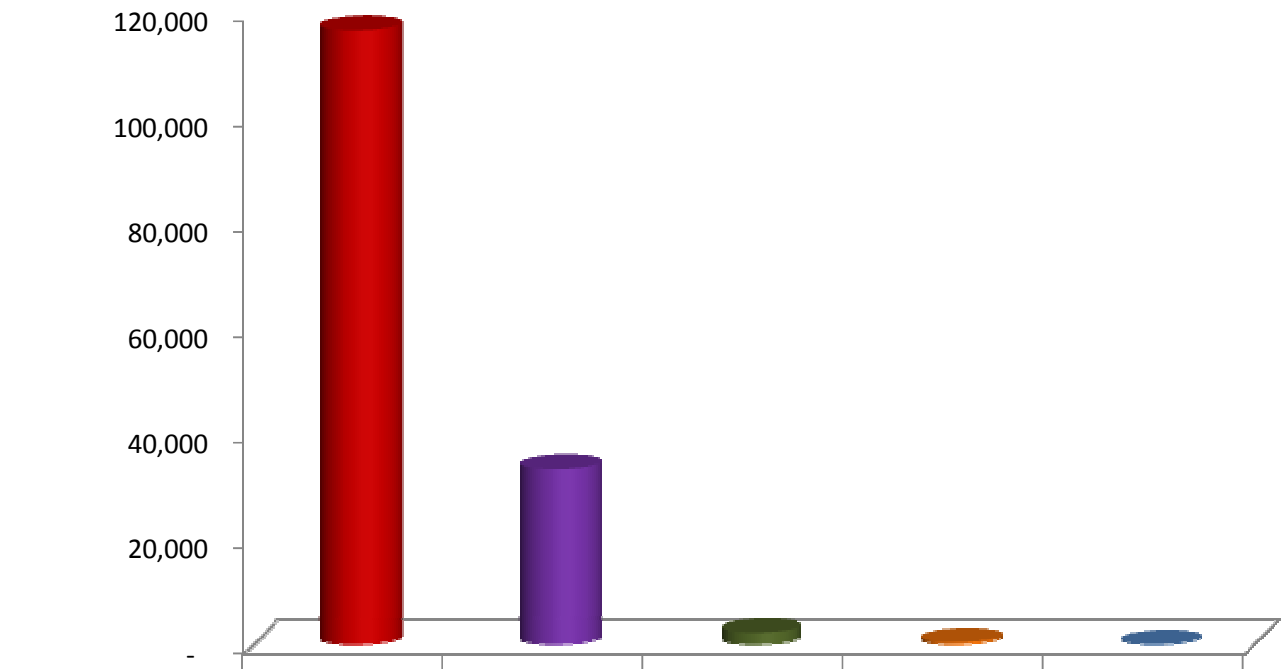
SECTION III

Estimated Footprint

The University of Delaware's total emissions are estimated to be 152,542 $MTCO_2$ for the 2007-08 academic year. This amounts to 8.7 $MTCO_2$ per student and 7.1 $MTCO_2$ per University community member (faculty, staff, and students). For the remainder of this section, emissions will be broken down and discussed by sector.

Total Emissions: 152,542 $MTCO_2$

Figure 2: Total Emissions



	Buildings	Transportation	Waste	Dining Services	Landscaping
Metric Tons of CO2	116,614	33,336	2,144	394	54

Building Emissions: 116,614 $MTCO_2$

Emissions due to energy usage by buildings on campus make up the largest portion of the inventory. Space heating, cooling, producing hot water, lighting, powering appliances and equipment all require energy. The University currently uses electricity, natural gas, and heating oil to meet these energy needs. Energy consumption was categorized by function and these categories were ranked according to energy usage per square foot.

Laboratories, dining facilities, and student centers use substantially more energy per square foot than other types of buildings on campus. More energy is required in these facilities due to factors such as greater ventilation needs and the use of specialized appliances and equipment.

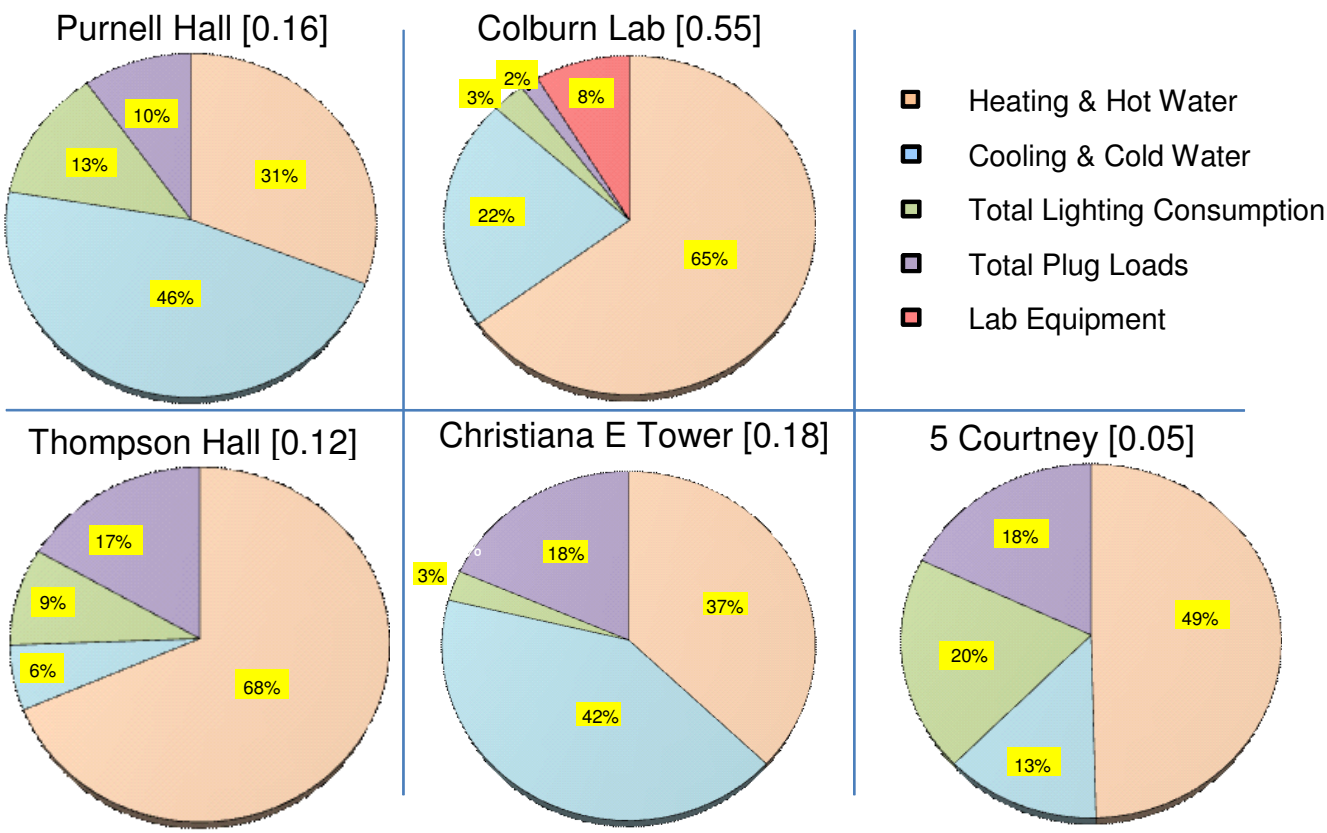
Figure 3: Total Energy and Carbon Intensity by University of Delaware Building Category

Building Type	Total Sq.Ft.(in thousands)	Natural Gas, Electricity, and Heating Oil Consumption (MMBtu)	Percent	Energy Intensity	CO_2 Emissions	Percent of Total Emissions	CO_2 Intensity
Dormitories	1,405	220,607.49	18%	157.02	40,003.05	17%	28.47
Laboratories	1,052	522,174.92	43%	496.36	104,434.99	43%	99.27
Classrooms	813	95,125.75	8%	117.01	19,025.15	8%	23.40
Elevated Parking Garages	595	1,589.13	0%	2.67	317.83	0%	0.53
Sports Buildings	496	78,646.52	6%	158.56	15,729.31	7%	31.71
Offices	386	73,349.73	6%	190.03	14,669.95	6%	38.01
Student Centers	263	93,906.67	8%	357.06	18,781.33	8%	71.41
Libraries	252	47,507.63	4%	188.52	9,501.53	4%	37.70
Cultural Centers	181	37,373.82	3%	206.49	7,474.76	3%	41.30
Dining Halls	165	57,807.52	5%	350.35	11,561.50	5%	70.07

It is also important to note that building energy use by activity can vary significantly. As the charts of energy use for five Newark Campus buildings establishes, there is no simple method for characterizing building energy needs or their associated carbon emissions. This is why building

audits are an essential tool in building an accurate understanding of the carbon footprint of a campus, and in developing an effective Action Plan significantly reduce emissions.

Figure 4: Building Profiles (mmBTU per ft² in brackets)



Transportation Emissions: 33,336 $MTCO_2$

Emissions due to University-related transportation are the second largest contributor to greenhouse gas emissions. The transportation portion of the inventory consisted of all fuel used by the University's transportation fleet, student commuting, faculty and staff commuting, and campus resident trips home (see Figure 5).

Campus resident trips home included trips taken by car and plane by students living on campus. It was assumed that students living on campus take approximately three round trips home per academic year, and that students living greater than 500 miles from campus traveled by air.

Several transportation activities were excluded from this inventory due to non-availability of data.

Fuel Source	Description	Category	Emission Factor	Consumption	Emissions
Gasoline	University fleet	1	.0088 $MTCO_2$/gal	229,697 gal	2,022 MT
	Student and faculty daily commutes	3		3,213,717 gal	28,296 MT
	Dorm resident trips to home by car	3		256,900 gal	2,262 MT
Diesel Fuel	University fleet	1	.01015 $MTCO_2$/gal	72,451 gal	735 MT
Jet Fuel	Dorm resident trips to home by air	3	0.0096 $MTCO_2$/gal	2,162 gal	21 MT
Total					**33,336 MT**

University business related air travel and student activity and athletic travel undertaken in vehicles other than those in the University fleet are also not included in this inventory.

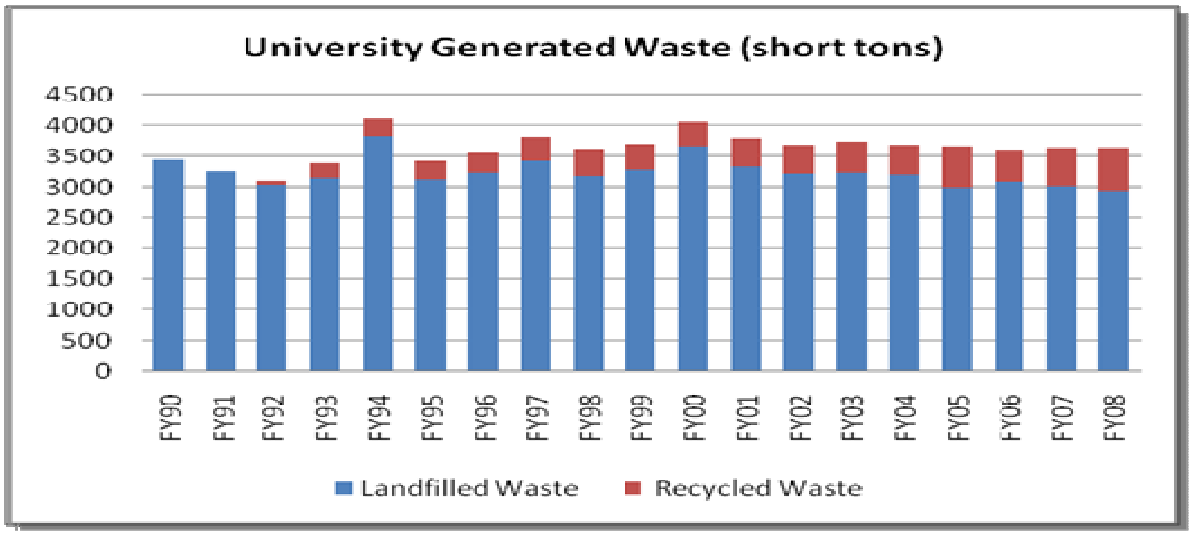
Figure 5: Transportation Emissions

Food Waste, Waste, & Landscaping: 2,592 $MTCO_2E$

Solid wastes, food wastes and landscaping are the smallest contributors to the University's overall GHG emissions. Together, they make up 1.7% of the University's total emissions. Emissions related to food waste and solid wastes include the carbon dioxide equivalent of methane emitted during decomposition of these wastes when they are sent to the landfill. Data on total waste generated by the University was provided along with percentage recycled. Recycled waste was netted out of this total figure, and an emissions factor was applied to the remaining portion of the wastes, shown in Figure 6.

Carbon dioxide emitted during transportation of the wastes to the landfill was also included in the calculations. Although a host of additional GHG emission causing activities could be associated with the University's dining services – such as carbon released while cultivating, harvesting, processing, and transporting food eventually consumed on campus, these activities were not within the scope of this inventory due to a lack of the necessary data.

Figure 6



Emissions by Category

As mentioned earlier, the inventoried emissions were grouped into three categories. This categorization followed a standard reporting method created by the World Resources Institute (WRI) to ensure clear and careful reporting of GHG inventories on a worldwide basis.

A major advantage of the WRI categorization is that it highlights emissions directly controlled by the University (i.e., from sources that are owned and controlled by the University), compared to releases which the University can reduce but does not directly decide (e.g., emissions from

imports of electricity) and finally emissions which the University can endeavor to reduce but has little influence over the result (e.g., landfill waste – if the landfill operator captures methane at some point in time this may reduce attributed emissions but this result is not necessarily directed by the University).

In this report, the WRI categorization offers information in a format that is conducive to the development of Action Plans.

The emissions inventory according to the three categories is described below:

Category 1 – Direct Emissions

The total volume of Category 1 – Direct Emissions is 39,467 $MTCO_2$ (or 25.9% of the campus total). As mentioned earlier, this includes natural gas and heating oil consumed on campus, University fleet fuel, and emissions from fertilizers applied to the grounds of the Newark Campus.

The University's fleet emissions are included in Category 1 because the fuel is purchased for use in University owned vehicles. The fleet transportation component of Category 1 emissions amounted to 2,757 $MTCO_2$ in 2007-2008. Landscaping is also included as a part of Category 1 emissions and equaled 54 $MTCO_{2e}$ in 2007-2008. The remainder – 36,656 $MTCO_{2e}$ derives from the use of natural gas and heating oil at utility plants and by other campus facilities (dining halls, buildings, etc.).

Category 2 – Indirect Emissions from Electricity Imports

The volume of Category 2 emissions in 2007-2008 was 79,958 $MTCO_2$ (or 52.4% of the campus total). CO_2 per kWh generated in the PJM interconnection from which the City of Newark acquires electricity for the University has actually declined since 2000. The release rate in 2007 was 1.278 lbs/kWh, approximately 7% less than in 2000. As the University plans actions to reduce electricity-related emissions, it must consider this trend. The draft Action Plan under

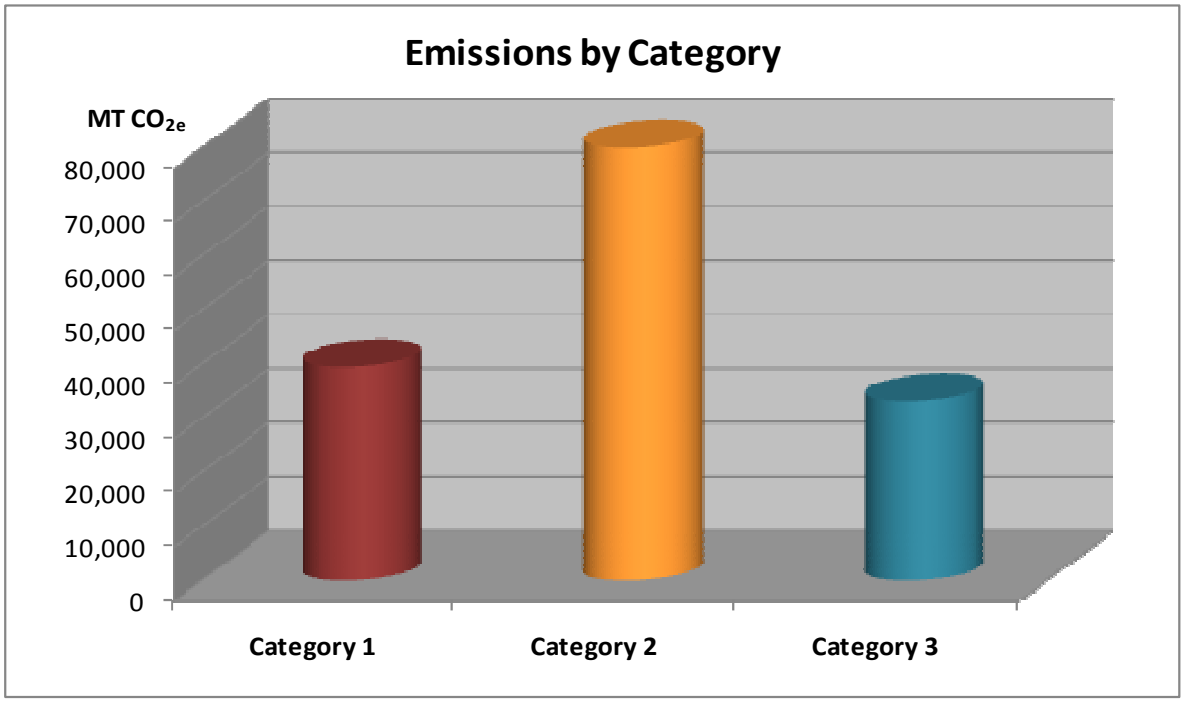
development by CEEP for the University incorporates this trend and includes a scenario where declining emissions in the PJM accelerates.

Category 3 – Indirect Emissions from non-Electricity Sources

The total emissions in Category 3 are 33,117 $MTCO_2$ (or 21.7% of the campus total). This volume includes all indirect emissions other than those from electricity imports. Emissions due to food and solid wastes are considered in Category 3. All transportation emissions from commuting are also included in Category 3. Emissions from commuter transport totaled 30,579 $MTCO_2$ (or 20.0% of the campus total).

Figure 7 summarizes the shares of campus emissions by WRI category.

Figure 7



For action planning purposes, it is evident that the University faces a challenge in reaching carbon neutrality due to the high share of emissions from electricity imports (Category 2) and commuter transportation (Category 3). On one hand, the downward trend in emissions per kWh in the PJM may facilitate University efforts to achieve its goal. On the other hand, this trend is not subject to University design and decisions. In this regard, an Action Plan that significantly lowers electricity

use and obtains a portion of electricity needs from University on-site "clean" generation (such as geothermal heat pumps, combined heat and power facilities, and solar electricity) will improve the institution's ability to control the evolution of its carbon footprint. Similarly, an Action Plan that can lower commuter transportation will further reduce emissions. Finally, actions to sequester carbon – principally through tree planting, landscaping and sustainable land use planning – can improve the University's capacity to lower its carbon footprint over time.

SECTION IV

Peer Comparisons

It is helpful to compare the carbon footprint of the University of Delaware with that of other universities across the U.S. However, there are many challenges and limitations associated with making such a comparison. Institutions differ in physical size, number of students, infrastructure, fuel mix and climate. The methodology used to calculate inventories can also differ in significant ways. Some universities omit certain sources of emissions (such as commuter transportation), while others include sources such as air travel. Some institutions such as MIT and Yale have a significant portion of their building stock dedicated to laboratories with high energy consumption requirements and others focus less on education requiring extensive laboratory use, and unsurprisingly, typically have lower energy consumption. Some campuses house a large share of their student population, while others do not. Some must heat with heating oil, while others have access to natural gas with its lower carbon content per unit of heating energy consumed. Some face cold winters, and others experience warm winters but also warm spring seasons. Clearly caution must be exercised in carrying out such comparisons.

The project team has prepared comparisons of the existing emission performance (FY 2007-08) of the University of Delaware with twelve institutions which have already published their carbon footprint data. The twelve universities are: Tulane University, the University of California at Berkeley, the University of Iowa, Oregon State University, the University of Maryland, the University of Illinois at Chicago, Pennsylvania State University, Harvard, Duke, the University of Pennsylvania, MIT and Yale.

These peer institutions provide a baseline for the variety of factors influencing university emissions, including differences in physical size, climate, student/community population and the purposes for which energy is consumed.

All of the selected peer institutions employed rigorous methods of carbon counting, and many of those detailed measurement approaches were followed for the University's carbon footprint. The

purpose of the comparison is not to gauge the volume of Delaware's releases to those of individual institutions. Rather, it enables a comparison of our footprint to the *range* of U.S. university emissions. A brief overview of each of the peer institution is given below.

1) Tulane University: Tulane estimated its FY2002 carbon footprint to be 52,981 $MTCO_{2e}$ from all three WRI categories.

Its inventory was calculated using a software program called e-Mission from Torrie Smith Associates. The software is designed specifically to calculate greenhouse gas emissions from conventional business activities. This initial Tulane inventory includes only the greenhouse gases emitted as a result of burning fossil fuels. The inventory is limited to its major campus. Emissions due to electricity imported to campus, as well as those from emissions of University power plants and commuter vehicle emissions of Tulane's staff, faculty and students are included. The University does not require heat during winter. The proportion of full-time undergraduate students housed on campus is 48%.

The emission of GHGs per student is 4.1 $MTCO_{2e,}$ while it is 2.8 $MTCO_{2e}$ per community member.

2) University of California at Berkeley (UCB): The University of California at Berkeley has estimated its carbon footprint for the year 2006 as 209,000 metric tons of CO_2 equivalent. Berkeley included a life cycle analysis for its campus carbon inventory which is estimated to be 482,000 $MTCO_{2e}$ for the year 2006. A lifecycle analysis counts greenhouse gas emissions from all stages of a product or service's lifecycle, including mining, manufacturing, transportation, retail, use, and disposal.

The University used Cool Air Clean Planet (CACP) software to calculate its carbon inventory. Berkeley divides its emissions into two parts, Required Reporting and Optional Reporting. The required reporting portion includes emissions due to electricity, steam, refrigerants and the campus vehicle fleet. Emissions from this portion are 160,000 $MTCO_{2e}$, which is about 76.5% of its total emissions. Optional reporting includes emissions due to municipal solid waste disposal, staff, faculty and student commuting, estimated air travel and water consumption. Emissions from this

portion are estimated to be 50,000 $MTCO_{2e}$, about 23.5 % of total emissions. The Berkeley campus has a mild winter and spring and has 35% of its undergraduate population living on campus.

With a total campus community population of 48,000 people, the GHG emission per community member is 4.29 $MTCO_{2e}$ and per student it is 6.0 $MTCO_{2e}$.

3) University of Iowa: Iowa's carbon footprint for the year 2006 was estimated at 230,000 metric tons of CO_2 equivalent. The emission of GHGs per student is 8.1 $MTCO_{2e}$, while the per community member figure is 5.3 $MTCO_{2e}$. It experiences a cold winter and has 30% of its undergraduate students living in dormitories and other campus housing.

4) Oregon State University: Oregon State University has estimated its carbon footprint to be 151,287 $MTCO_{2e}$ for 2007. This figure includes emissions from all three WRI categories, and is an increase of 9.4% from FY 2004. The Clean Air Cool Planet calculator was used to estimate its carbon footprint.

Emissions from the following activities are not included: the University extension service, athletics, chartered travel, recycled materials, incinerated wastes, long distance student travel, purchases and sequestration. Winters are cold and spring semesters mostly involve mild temperatures. The on-campus resident population is 21% of the institution's total enrolled undergraduate population.

The emission of GHGs per student is 8.1 MTCO2, while the per community member figure is 6.6 $MTCO_{2e}$.

5) University of Maryland: The University of Maryland has estimated its carbon footprint to be 352,000 $MTCO_{2e}$ from all three WRI categories.

Its footprint is based only on those University operations that are located within the state. The inventory was calculated using Campus Carbon Calculator version 5.0. Emissions from its vehicle fleet, commuter traffic, air travel, agriculture, refrigerants and solid wastes are all included. Its

winter and spring climates are similar to Delaware. Its resident undergraduate population is 41% of its total enrolled undergraduate population.

Emissions per student are 10.8 $MTCO_{2e}$, while the emissions per community member are 8.6 $MTCO_{2e}$.

6) University of Illinois at Chicago: The University of Illinois at Chicago has estimated its carbon footprint to be 224,852 $MTCO_{2e}$ from all three WRI categories.

Several exclusions apply to the institution's estimate. Emissions due to Rush University Hospital were not included. Also air travel and University farm and refrigeration data were not included. Illinois has cold winter and 22% of its undergraduate population lives on-campus.

Emissions per student are 11.0 $MTCO_{2e}$, while emissions per community member are 7.5 $MTCO_{2e}$.

7) Pennsylvania State University: Pennsylvania State University has estimated its carbon footprint to be 479,245 $MTCO_{2e}$. The institution experiences cold winter and houses 36% of its undergraduate population on campus. Emissions per student are 11.4 $MTCO_{2e}$, while emissions per community member are 6.7 $MTCO_{2e}$.

8) Harvard: Harvard University has estimated its carbon footprint to be 230,616 $MTCO_{2e}$ from all three WRI categories. The University's action plan includes carbon offsets in the amount of 47,641 $MTCO_{2e}$ obtained from renewable energy certificates purchased for output from wind farms in Minnesota. Harvard experiences cold winters and has 98% of its undergraduates living on campus.

Emissions per student are 11.5 $MTCO_{2e}$, while emissions per community member are 7.2 $MTCO_{2e}$.

9) Duke University: Duke University estimated its 2003 carbon footprint to be 380,000 $MTCO_{2e}$. This was 31% greater than its emissions in 1990. The estimated inventory included carbon sequestration services provided by 7,900 acres of Duke Forest, which is estimated to sequester about 8,000 $MTCO_{2e}$ each year. Duke experiences somewhat mild winters and houses 83% of its undergraduates on campus.

Emissions per student are 12.8 $MTCO_{2e}$ while emissions per community member are 9.12 $MTCO_{2e}$.

10) University of Pennsylvania: The University of Pennsylvania estimated its 2006 carbon footprint to be 352,000 $MTCO_{2e}$ emissions from all three WRI categories.

Emissions from the University's vehicle fleet, commuters, University related air travel, agriculture, solid waste, refrigerants and other solid wastes are all included. Its climate is the same as Delaware's. Penn houses 64% of its undergraduates on campus.

Emissions per student are 15.8 $MTCO_{2e}$, while emissions per community member are 7.7 $MTCO_{2e}$.

11) Massachusetts Institute of Technology*:* MIT has estimated its carbon footprint to be 210,000 $MTCO_{2e}$ from all three WRI categories.

Emissions due to air travel by faculty and students, delivery freight travel to and from campus, tourist travel, and business travel related to the MIT campus and its community are not included. Emissions due to refrigerant use are also excluded from the calculations.

A high percentage of MIT's buildings inventory is in laboratories, typically the most energy intensive building type on a campus. Undergraduates are 42% of the total student population, which is lower than many universities. The campus experiences cold winters and has 90% of its undergraduates living on campus.

Emissions per student are 21.1 $MTCO_{2e}$, while emissions per community member are 10.5 $MTCO_{2e}$.

12) Yale: Yale University has estimated its carbon footprint to be 284,663 $MTCO_{2e}$. The calculations include emissions related to waste management and purchased lab gases, as well as sequestration from Yale forest properties (6,291 $MTCO_{2e}$).

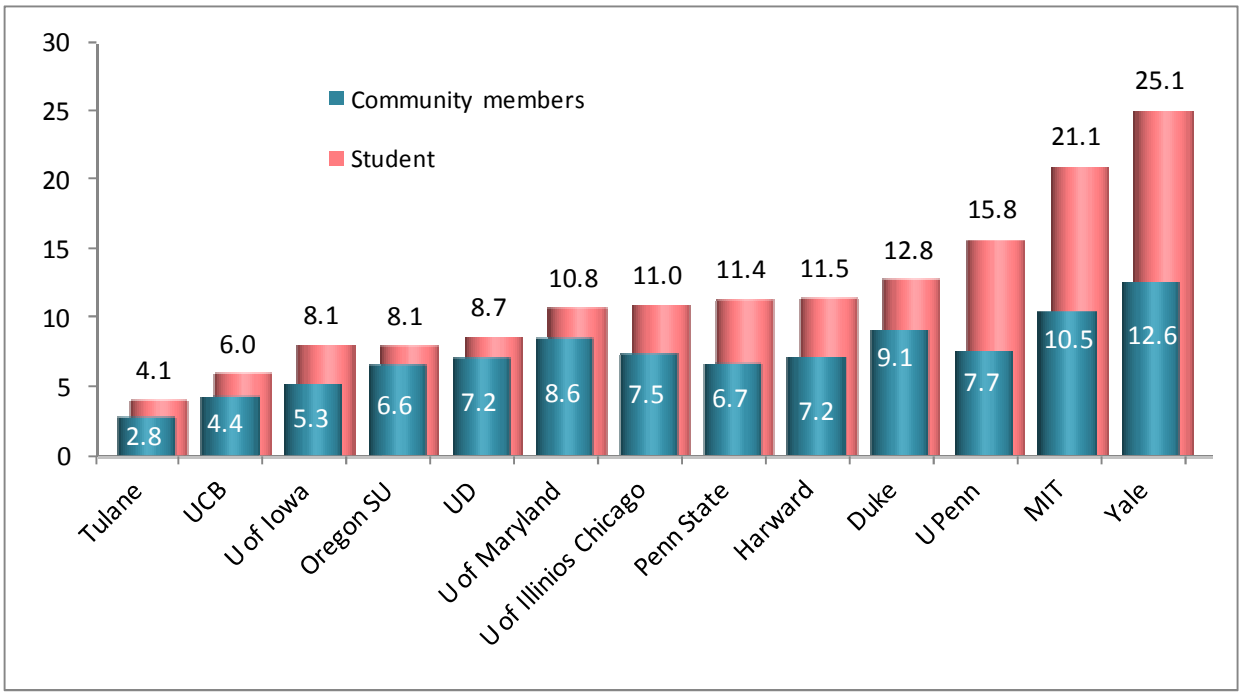
Emissions from the institution's vehicle fleet, commuters, University-related air travel, the University farm, solid waste, refrigerants and other solid wastes are all included in the calculation. 88% of its undergraduates live on-campus.

Emissions per student are 25.1 $MTCO_{2e}$, while emissions per community member are 12.6 $MTCO_{2e}$.

Peer Comparison

The University of Delaware's carbon footprint can be usefully compared to the range of emissions of other institutions on a per student and per community member basis. Figure 6 provides this comparison. The University's per capita emissions fall in the middle range of the institutions for which similar estimates, based on similar methods, are available.

Figure 6: Peer Emissions Comparison



Because the universities represented in Figure 6 encompass climate variations, differences in facilities, higher percentages of students living off campus, and so on, Delaware's mid-range per capita emissions can be understood to mean that its footprint is typical of many academic institutions with significant research portfolios.

While the University of Delaware does not rank among the highest emitters in this comparison, there remains significant room for improvement. Many universities are already pursuing innovative policies to reduce their GHG emissions. The next step for the University of Delaware will be to develop its own GHG reduction plan.

SECTION V
Next Steps

In the next step of this project, the carbon footprint team will use the inventory and the information collected from building audits to develop an array of emission reduction options for the University to consider. It will also propose reduction targets over different planning periods: three years, five years and 10 years. Ideas solicited from the student body, staff and faculty, as well as those developed by the carbon footprint project team, will be analyzed based on several factors: CO_2 reduction equivalent, educational value, economic benefits, social and environmental benefits, financial costs, and other costs.

Recommended actions will fall broadly under two categories. The first is conservation and efficiency actions. These actions reduce the amount of energy used by the University. Conservation and efficiency actions include solutions such as powering down computers at the end of the day, turning off lights when they're not in use and adjusting the thermostat. Efficiency improvements may not always require behavioral changes, but routinely involve improved energy management and technology so that less energy is required in order to meet community needs.

As discussed in Section III of this report, the extent to which the University can control emissions depends largely on the category of the emitting activity. Category 1 emissions (i.e., those generated from campus produced heating and cooling, campus vehicle fleet activity, etc.) are owned and controlled directly by the University and any policies implemented to reduce emissions in these areas can be directly managed. Category 2 and Category 3 emissions, however, depend upon actors such as the PJM and its management of the region's electricity market, the landfill operators and their decisions regarding methane recovery; campus members' decisions regarding mode of transport (e.g., the use of transit, bicycles, or walking versus personal vehicles) and the efficiency of equipment, vehicles, etc. operated while on campus. For Categories 2 and 3, University policy can partially influence outcomes.

For all three categories, the decisions and actions of University members will be critical in significantly reducing the community's footprint. For this reason, education will play a vital role in achieving emissions reduction goals.

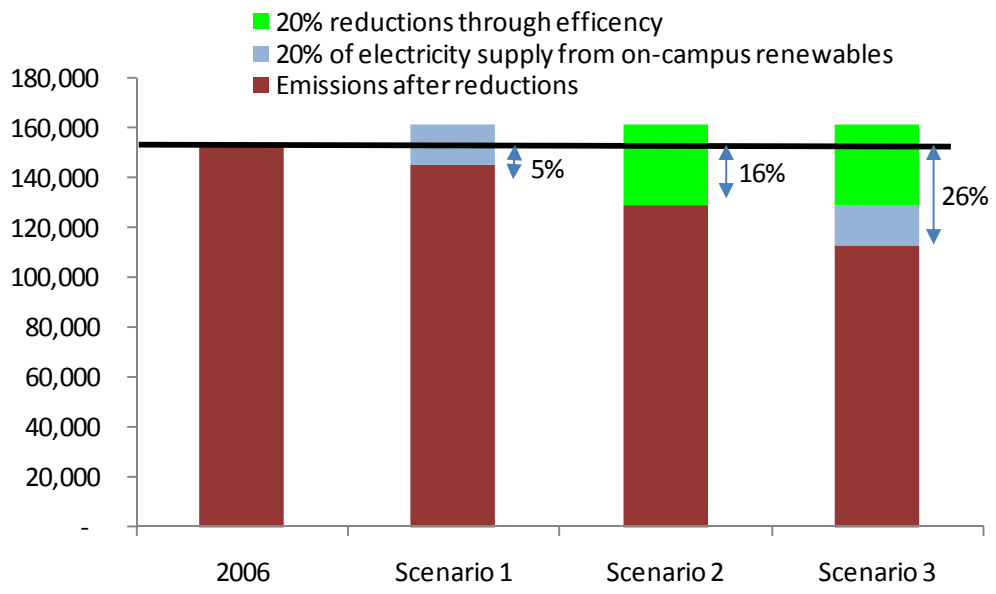
Figure 7: Emissions Reduction Process

Reducing the University's emissions to a net zero level will be a continuously evolving process (See Figure 7). After the creation of an Action Plan, recommendations must be implemented, monitored, improved upon and continually enhanced. Reaching carbon neutrality will require a long term commitment. It is impossible for the University to reach this goal in a few years. In the case of this challenge, there are no "magic bullets." Technology improvements and greater use of renewable resources, while key to a sustainable future, cannot in themselves accomplish carbon neutrality. Through their use, we can slow future emissions and we can replace existing, carbon intensive methods of energy supply with low or no-carbon alternatives. However if demand for energy and other resources remain constant; carbon neutrality will elude our community.

Reductions in the use of energy and resources are required for the campus to significantly downsize its carbon footprint.

Using fewer resources more efficiently and from a renewable perspective can help UD achieve a carbon-neutral campus. To illustrate, Figure 8 measures impacts of University commitments separately to lower energy use by 20%in 10 years, and to purchase the same 20% reduction in carbon in 10 years by installing renewable energy systems on campus. Importantly, if those actions are combined in a thoughtful, well-planned manner, the impact is *greater* than the simple addition of the two separate approaches.[5]

Figure 8: Emissions Reduction Scenarios



[5] The comparison is intended to illustrate the synergistic effects of coordinated actions. The relative costs of reducing carbon by, say, energy efficiency improvements and campus installation of renewable energy systems, should also be considered. The example excludes so called "carbon offsets" – in which the University would buy a share of, for example, a renewable energy plant not directly tied to University buildings. In this instance, the carbon impacts do not include a reduction in emissions. University emissions are unaffected (other than a possible slowing of the rate of increase of emissions from PJM electricity supply). Offsets can be used to "buy time" as the University plans new actions. But without further action, offsets transfer the burden to other actors to actually reduce emissions and, therefore, are restricted by many national and international policies to modest percentages for compliance purposes.

Finally, leadership and cooperation across UD's campus is essential in pursuit of carbon neutrality. A common commitment among the University's administration, faculty, staff and students to sustainability is vital. Ultimately, UD's carbon footprint will be successful if and only if the entire campus community actively participates in the effort.

Appendix A

	Building type	CBECS Average BTU/Sq Ft	CBECS Equivalent Factor
1	Classroom	20.39	3.110
2	Office	51.09	1.241
3	Entertainment/Culture	45.33	2.759
4	Lab	154.40	9.398
5	Recreation	23.84	1.451
6	Entertainment/Culture	45.70	2.782
7	Public Assembly	70.96	4.319
8	Library	45.70	2.782
9	Dorm	16.43	1.000
10	Dining/Restaurant	105.95	6.449

Source: CBECS - Commercial Buildings Energy Consumption Survey (CBECS) database from the U.S. Energy Information Administration.

Appendix B

Part 1. Energy and Carbon Intensity by University of Delaware Building Category for Electricity Use

Building Type	*Total Sq.Ft.(in thousands)*	*Electricity Consumed (kWh)*	*Electricity Consumed (MMBtu)*	*Electricity Intensity (MMBTU/SqFt)*	*CO_2 Emissions (Metric Tons)*	*Percent of Total Emissions*	*CO_2 Intensity (Emissions/SqFt)*
Dormitories	1,405	22,303,809	76,101	54.16	12,929	17%	9.20
Laboratories	1,052	54,396,848	185,602	176.43	31,533	41%	29.97
Classrooms	813	15,906,430	54,273	66.76	9,221	12%	11.34
Elevated Parking Garages	595	465,747	1,589	2.67	270	0%	0.45
Sports Buildings	496	12,750,927	43,506	87.71	7,392	10%	14.90
Offices	386	5,979,198	20,401	52.85	3,466	5%	8.98
Student Centers	263	7,106,501	24,247	92.20	4,120	5%	15.66
Libraries	252	6,521,134	22,250	88.29	3,780	5%	15.00
Cultural Centers	181	2,925,044	9,980	55.14	1,696	2%	9.37
Dining Halls	165	3,869,244	13,202	80.01	2,243	3%	13.59

Appendix B (Continued)

Part 2. Energy and Carbon Intensity by University of Delaware Building Category for Natural Gas and Heating Oil Use

Building Type	Total Sq.Ft.(in thousands)	Natural Gas Consumed (1000's cu ft.)	Heating Oil Consumed (gal)	Natural Gas and Heating Oil (MMBTU)	Energy Intensity	CO_2 Emissions (Metric Tons)	Percent of Total Emissions	CO_2 Intensity
Dormitories	1,405	134,005	26,731	144,507	102.85	27,074	19%	19.27
Laboratories	1,052	312,114	62,259	336,573	319.94	63,058	43%	59.94
Classrooms	813	37,884	7,557	40,853	50.25	7,654	5%	9.41
Elevated Parkig Garages	595	0	0	0	0.00	0	0%	0.00
Sports Buildings	496	32,587	6,500	35,140	70.85	6,584	5%	13.27
Offices	386	49,101	9,794	52,949	137.17	9,920	7%	25.70
Student Centers	263	64,597	12,885	69,659	264.86	13,051	9%	49.62
Libraries	252	23,422	4,672	25,258	100.23	4,732	3%	18.78
Cultural Centers	181	25,403	5,067	27,394	151.35	5,132	4%	28.35
Dining Halls	165	41,364	8,251	44,606	270.34	8,357	6%	50.65

Sources: University of Delaware monthly electricity and natural gas bills by the City of Newark, for 2007-2008 FY

University of Delaware building inventory to determine square footage

PJM CO_2/kWh estimates for the four states commonly known as "PJM original" – Delaware, Maryland, New Jersey, and Pennsylvania.

Appendix B (Continued)

Part 3. Total Energy and Carbon Intensity by University ofv Delaware Building Category

Building Type	Total Sq.Ft.(in thousands)	Natural Gas, Electricity, and Heating Oil Consumption (MMBtu)	Percent	Energy Intensity	CO_2 Emissions	Percent of Total Emissions	CO_2 Intensity
Dormitories	1,405	220,607.49	18%	157.02	40,003.05	17%	28.47
Laboratories	1,052	522,174.92	43%	496.36	104,434.99	43%	99.27
Classrooms	813	95,125.75	8%	117.01	19,025.15	8%	23.40
Elevated Parkig Garages	595	1,589.13	0%	2.67	317.83	0%	0.53
Sports Buildings	496	78,646.52	6%	158.56	15,729.31	7%	31.71
Offices	386	73,349.73	6%	190.03	14,669.95	6%	38.01
Student Centers	263	93,906.67	8%	357.06	18,781.33	8%	71.41
Libraries	252	47,507.63	4%	188.52	9,501.53	4%	37.70
Cultural Centers	181	37,373.82	3%	206.49	7,474.76	3%	41.30
Dining Halls	165	57,807.52	5%	350.35	11,561.50	5%	70.07

*These charts represent the targeted building categories. They do not include utility plants, farm buildings and maintenance and operations facilities.

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