The Morris Arboretum of the University of Pennsylvania
Carbon Footprint

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Executive Summary

In 2007, University of Pennsylvania President Gutmann signed the American College and University President's Climate Commitment (ACUPCC). This pledge committed Penn to developing plans for reducing its emissions of climate-altering greenhouse gasses over time to achieve climate neutrality. This report summarizes the initial effort to develop and analyze the carbon footprint of the Morris Arboretum of the University of Pennsylvania in Chestnut Hill. The Morris Arboretum Carbon Footprint is a part of a larger effort to account for the carbon produced beyond the main University of Pennsylvania campus, which will also include carbon footprints for the University of Pennsylvania Health System University City campus and Penn Vet's New Bolton Center. Carbon footprints are important tools in developing strategies to achieve carbon reduction goals.

The T.C. Chan Center was commissioned to prepare the University of Pennsylvania main campus carbon footprint in cooperation with the Department of Facilities and Real Estate Services and has provided annual updates to this work along with expanded analyses since 2007. A carbon calculator was developed to facilitate the ongoing tracking of carbon emissions at Penn based on the World Resources Institute (WRI) Greenhouse Gas Protocol, which is widely utilized at universities and other organizations including Energy Star's Portfolio Manager. This calculator was used to organize data for the Morris Arboretum and to calculate the carbon footprint for the most recent full fiscal year, FY15. For historical context, the carbon footprint was also calculated for fiscal years 2013-2014.

The gross emissions during this year were **700 MTCDE**, but subtracting the credits gained due to the growth of wooded areas, reduces the net emissions to **407 MTCDE**. As with most organizations with a significant physical campus, the majority of the emissions were associated with energy use in the buildings. For the Morris Arboretum campus, consisting of several sizable structures and numerous smaller buildings, this is represented by the use of electricity, natural gas, propane, and fuel oil. Commuting also accounts for a significant portion of the footprint.

The Morris Arboretum Carbon Footprint presents a snapshot of the carbon emissions for the arboretum, and forms the basis for any action plan to reduce emissions. It identifies the patterns of consumption and activity that produce greenhouse gas emissions, with some examination of the trajectory over the last few years. As anticipated, the majority of the emissions are associated with energy used in the built environment and further studies of the buildings and their operation could help to identify means of reducing energy use.

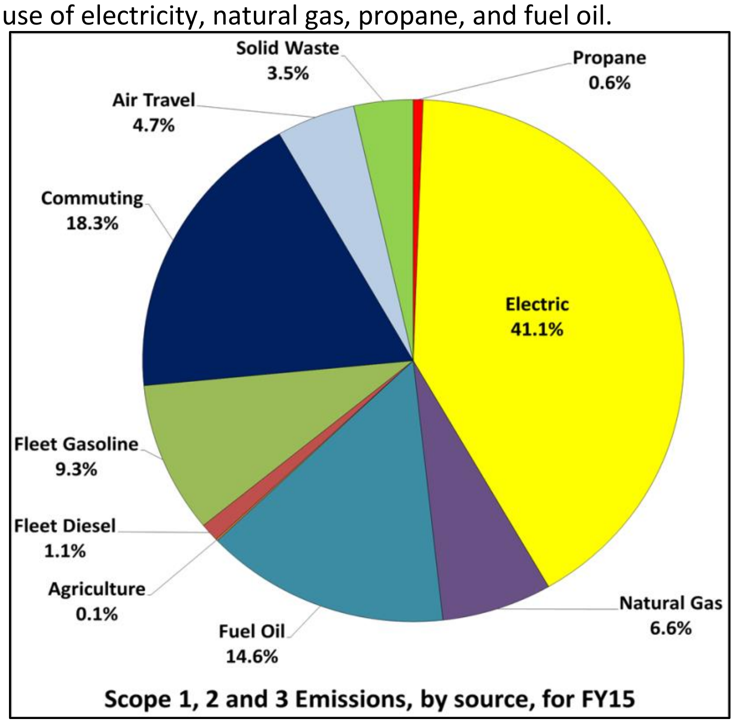

Figure 1- Morris Arboretum Carbon Footprint FY15

Introduction

This report presents the first greenhouse gas inventory, or carbon footprint, for the Morris Arboretum of the University of Pennsylvania. The project grows out of the carbon footprints and Carbon Action Plans prepared for the University's main campus since 2009, which fulfill the terms of the climate neutrality pledge signed by President Amy Gutmann in February of 2007. The pledge was organized by the Association for the Advancement of Sustainability in Higher Education (AASHE), and among its terms, it required "a comprehensive inventory of all greenhouse gas emissions and an update of the inventory every other year thereafter," leading to "an action plan for becoming climate neutral." This report concludes with a preliminary action plan.

This report was commissioned by the Morris Arboretum as part of the President's commitment to extend the Carbon Action Plan too all the units of the University of Pennsylvania.

1.1 The Morris Arboretum

The Morris Arboretum of the University of Pennsylvania began as Compton, the summer home of John and Lydia Morris in 1887. Local industrialists who grew wealthy in the iron business, the Morris's were dedicated philanthropists and plant enthusiasts. Under their initial direction and in the 140 years since, this site has been developed into a center for research and education as well as a fixture in the community. Consisting of 167 acres of grounds and with more than 12,000 labelled trees, plants, and flowers Morris Arboretum serves as a historic public garden as well as the official arboretum of the Commonwealth of Pennsylvania, in which capacity they conduct research and outreach for state agencies. The Morris Arboretum has displayed significant consciousness regarding the environmental impact of their operations and remains dedicated to the reduction of energy usage and minimizing activities which could contribute to environmental degradation. Demonstrative of this is the recently certified LEED Platinum Horticultural Center, which showcases these efforts.

A carbon footprint is utilized in many different ways. Initially it may be little more than a snap shot that shows the climate impact for a single year, but this allows the identification of the activities which are the greatest contributors to climate change and which may be the most productive targets for reduction. By considering historical data and by continuing to produce annual reports, over time the footprints provide a standardized measure for the effectiveness of efforts to reduce climate change impact and can be used to inform projections of what future emissions levels might be. In addition to providing a standardized mean for analyzing an organization's climate change impact over time, if the same protocols are used in the calculation of the footprint then different organizations can more easily compare their emissions. This allows for the creation of better benchmarks to gauge the relative impact of an organization or facility compared against peers. Finally, a carbon footprint facilitates goal setting by providing a consistent measure over time and insight into realistic expectations for reductions in each sector.

1.2- Action Plan for University of Pennsylvania Main Campus

The T.C. Chan Center has been involved in the environmental initiatives of the University of Pennsylvania efforts since 2005, when the first Sustainability Plan was prepared. Beginning in 2007, the Chan Center prepared the first carbon footprint for the main campus (Figure 2) and provided most of the data analysis and research that was used as the basis for the Climate Action Plan 1.0. This analysis has followed many different paths, including the updating of the carbon footprint and the projection of carbon emissions into the future under a variety of envisioned scenarios. In the initial action plan the campus was examined as an aggregated whole and the reductions possible from each category were estimated over the course of a 30 year scenario. This method was used to set initial targets for reductions in the 5 year timeframe following the enacting of the plan and to estimate the scale of reductions that would be possible before 2042. The built environment of the University of Pennsylvania accounts for approximately 85% of the carbon produced by the main campus, and so improvements to building energy performance have been a central feature of the plan.

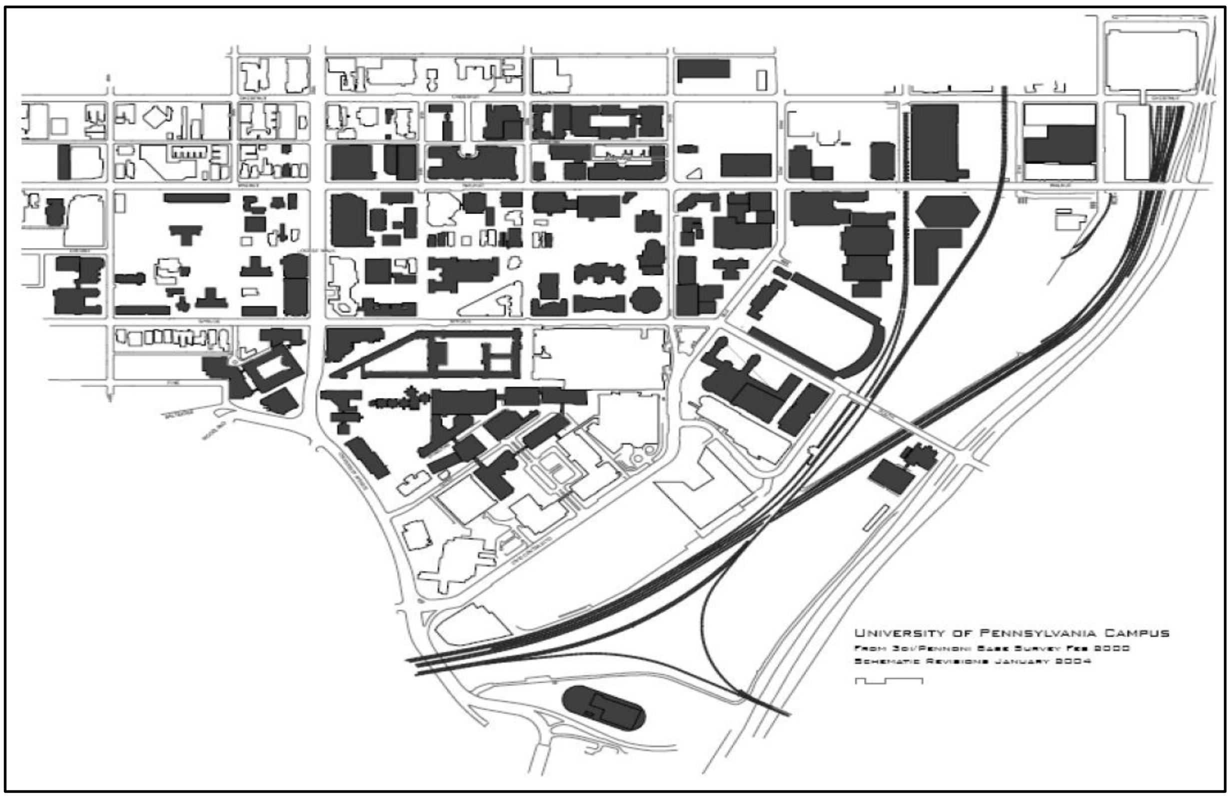

Figure 2- Map of UPenn Carbon Footprint Buildings

After 2009, the T.C. Chan Center developed a framework for more accurate projections of carbon reductions once building energy meters were installed. In 2012 a financial calculator was added to the individual carbon projections. This tool estimates the cost of renovating individual or sets of buildings to a certain performance level by assuming a cost per square foot. The combination of these individual building worksheets and financial calculators allows for a more detailed examination of the potential for carbon reductions in the built environment and the relative costs, in absolute cost and cost per unit of carbon reduced, of pursuing specific scenarios of renovation across the UPenn campus.

All three tools were used together in 2013-14 to develop a more grounded Carbon Action Plan 2.0, though this was still based primarily on estimates of individual building energy consumption. The 2.0 scenarios considered a range of options for the renovation of campus buildings focused around Century Bond projects, and the potential improvements that could be achieved by bringing the worst performing facilities up to a contemporary standard. The Century Bond projects are funded by $300 million in bonds that were sold by the University in 2012 with interest only payments and repayment of the principal in 100 years. The funds are to be used to support projects that combine deferred maintenance and energy efficiency, with the saving accrued feeding back to fund further energy saving projects.

As additional metered data for both the overall campus and individual buildings has become available new techniques have been developed to provide greater insight into the consumption patterns of buildings and the campus. Consumption data by the campus or individual buildings has been examined and compared to national benchmarks and historical performance, facilitating both the assessment of facilities and fault detection. (Figure 3)

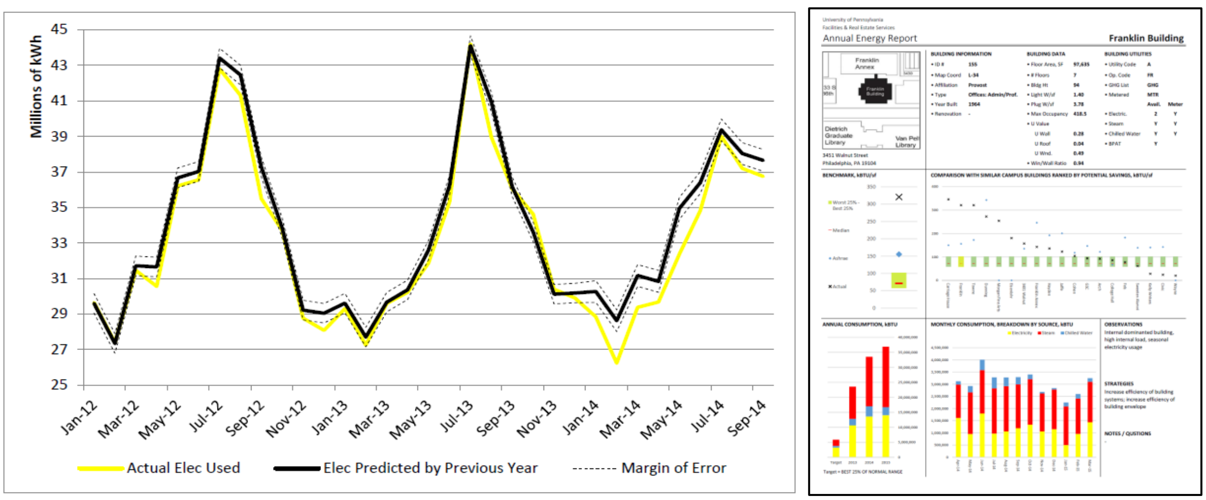

Figure 3- A. Prediction of campus electrical use using historical data, B. Annual Energy Report

The carbon footprint for the University of Pennsylvania is now actively being extended to University affiliated entities and facilities beyond the core campus starting with the University of Pennsylvania Health System, the Morris Arboretum, and the New Bolton Center.

1.3 What is a carbon footprint?

The preparation of greenhouse gas inventories has become an increasingly formalized and recognized procedure for evaluating the impact of institutions and their operations on global climate change. The purpose of this kind of inventory is to establish goals and identify strategies for the reduction of greenhouse gas emissions. The Kyoto Protocol established a level 7% below the emissions level of 1990 as an initial target for capping emissions, and many of our peer institutions have established reduction targets in relation to that standard, for example 10% or 30% “below Kyoto.” Such targets have increasingly been set as a first step to climate neutrality with initiatives such as the 2030 Challenge, and the President’s pledge, and the new targets being negotiated at COP21 this year in Paris.

Climate Neutrality or "Net Zero." The Morris Arboretum will continue to need and use energy in a variety of forms, so the goal of climate neutrality is to achieve "Net Zero" climate impact. In simple terms that means radically reducing the consumption of fossil fuel based energies and/or switching to carbon neutral sources of energy, and producing or purchasing carbon "offsets" until fossil fuel sources can be completely eliminated. The concept and validity of offsets is discussed later in the report, but the trading of carbon credits can only be a tertiary strategy for achieving climate neutrality.

The challenging questions raised by such an ambitious goal are how soon can net zero be accomplished, and at what cost?

Scopes of Effect. Institutional sources of greenhouse gas emissions are conventionally divided in three different scopes. These distinctions identify operational boundaries for institutions to "scope" their sources of emissions and to provide accountability for prevention of double counting or conversely, double credits. There are three basic scopes, numbered in degrees of removal from institutional control.

Scope 1 includes all direct sources of Greenhouse Gas (GHG) emissions from sources that are owned or controlled by an institution, including: production of electricity, heat, or steam; transportation of materials, products, waste, and community members; and emissions from unintentional leaks.

Scope 2 includes indirect GHG emissions from imports of electricity, heat or steam – generally those associated with the generation of imported sources of energy. The indirect nature of these emissions makes carbon accounting slightly more complex, though standardized procedures are rapidly being developed.

Scope 3 - includes all other indirect sources of GHG emissions that may result from the activities of the institution but occur from sources owned or controlled by another entity, such as: business travel, the commuting habits of community members, outsourced activities and contracts, and emissions from waste generated by the institution when the GHG emissions occur at a facility controlled by another company, e.g. methane emissions from landfilled waste. Credits included in Scope 3 also include carbon "offsets" purchased from other institutions or companies, such as wind or green electricity credits.

To assess the Morris Arboretum carbon footprint, data gathering focused on the following eight categories, going back to FY13. Where data was not immediately or completely available, conservative estimating procedures were used (and are documented) to complete the inventory.

Scope 1 and 2

1. Energy consumption through the use of electricity, fuel oil, propane, and natural gas.
2. Gasoline and Diesel use in Morris Arboretum's owned and operated cars, trucks, and equipment.
3. Agriculture, including fertilizer and agricultural waste
4. Solid Waste disposal
5. Refrigerant replacement

Scope 3

6. Commuter Travel by car, train, bus, bike, and walking.
7. Air Travel by faculty and staff
8. Offsets, such as green electricity credits or from biomass growth

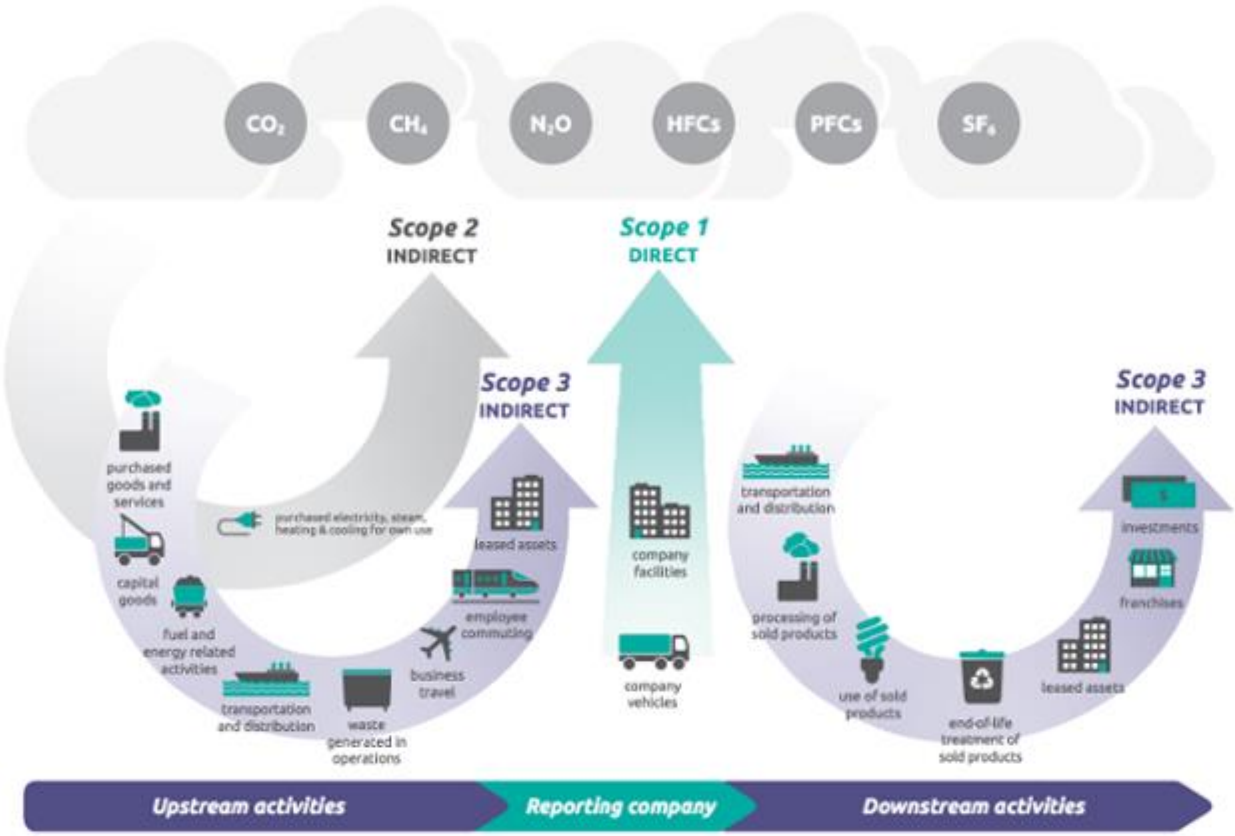

Figure 4- WRI diagram of "scopes" of carbon accounting

The current report has gathered data for all three scopes, but scopes 1 and 2 represent the largest sources of emissions and the ones most directly affected by Morris Arboretum policy or operation.

Scope 3 emissions are significantly more difficult to assess precisely or to certify for any kind of reduction. Also, one institution's scope 3 emissions can be another organization's scope 1 or 2 emissions, leading to double counting. The WRI/WBCSD GHG Protocol considers the Scope 3 emissions to be optional when preparing an overall GHG inventory, as do similar protocols such as the U.S. Environmental Protection Agency's Climate Leaders program. A number of our peer institutions have decided to only target scope 1 & 2 emissions. Nevertheless, employee commuting and air travel are generally considered a direct extension of institutional operations, so have been included in Penn's carbon footprint.

1.4 What is Carbon?

Since the Kyoto Protocol of 1990, greenhouse gas emission efforts have focused on the reduction of six atmospheric gases with a recognized greenhouse effect on the global climate: CO_2, CH_4, N_2O, HFC and PFC, and $SF_{6.}$ While each of these gases has a different Global Warming Potential (GWP), they are commonly indexed to an equivalent amount of Carbon Dioxide, called $eCO_{2,}$ eCarbon, or simply carbon, so that simple comparisons and evaluations can be made. In common usage and in this report "carbon" is referred to as the emission to be reduced, though the reduction applies to the whole range of gases.

The carbon equivalencies of the different greenhouse gases are shown in the table below, reporting the 2007 values. As the science has developed, the equivalencies have become more precise, but these are estimates used for the purposes of standardizing the accounting of effects.

Carbon Equivalents	
Gas	**2007 IPCC GWP**
Carbon Dioxide	1
Methane, CH_4	25
Nitrous Oxide, N_2O	298
HFC-23	14,800
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
Perfluoromethane (CF4)	7,390
Perfluoroethane (C2F6)	12,200
Sulfur Hexafluoride (SF6)	22,800

Figure 5- Carbon Equivalency Factors for Gasses; Source- IPCC Fourth Assessment Report, 2007.

1.5 Emission Factors

An emission factor is a normalized measure of the amount of carbon that can be attributed to the consumption of a single unit of energy in a particular process. This can actually vary quite a bit for different fuels and processes, reflecting both the efficiencies of conversion and transmission, and the inherent "dirtiness" of different fuels. Because of the international nature of the climate agreements, carbon is typically reported in metric tons (MT) of carbon equivalent, which is 1,000 kg or 2,205 lbs. For calculations and analysis, emission factors are normalized to the appropriate units of energy, kWh or MWh for electricity, and MMBtu for thermal sources, for example in "tons eCO2/MMBtu" or "MT eCO2/kWh." For comparisons and summaries, this report will convert emission factors to "MT eCO2/MMBtu" to make immediate evaluations possible. In some cases, the amount of eCO2 per MBTU is sufficiently small, that it will be reported in kilograms, "kg eCO2/MMBtu," which is simply 1/1000 of a ton. The basic emissions factors used in this report are normalized to MBTU and listed in the following table for comparison purposes.

Energy Source		MT eCO2/MBTU site energy	kg eCO2/MBTU site energy
Utilities			
Electricity	PECO Electric	0.135	135
Steam (heat)	Distillate Oil in CHP plant	0.0498	49.8
Natural Gas	Site Boiler	0.054	54
Diesel (Distillate) Oil	Generator	0.0727	72. 7
Transportation			
Gasoline	Car and light Truck	0.067	67
Diesel	Truck and Bus	0.0725	72.5
Jet Fuel	Air Travel	0.197	197

Figure 6- Emissions Factors for Energy Sources

As mentioned previously, the eCarbon emission factors for direct scope 1 sources are relatively precise, and largely derive from the physics of combustion of different fuels. Indirect, Scope 2 emission factors, however involve estimates of the mix of fuels or processes involved in the energy imported through centralized utilities. This is especially complex with purchased electricity that draws from a regional grid that includes multiple power plants, each with unique emissions patterns, and is itself interconnected with other regions. Similar questions occur even with the steam that the University purchases from a single provider, who produces steam in a multi-step process with standby equipment that can substituted or added as needed.

This report has used the protocols developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) to organize and calculate the emission factors. The World Resources Institute Greenhouse Gas Protocol is the standard for carbon calculations and the same source of emissions factors used by the Energy Star Portfolio Manager. This protocol has been used by many companies and institutions across the country, and has been incorporated in a Penn Carbon Calculator to standardize the calculations across the University. Nevertheless, choices have to be made in the identification of local fuel mixes or efficiencies, and for steam, which is not used at the Morris Arboretum but which provides heat to the University City campuses, the actual values from Veolia are used. Currently the emissions factor for electricity is derived from the RFCE grid supply mix reported by the EPA's eGrid, however recently changes in the GHG Protocol will require emissions factors derived from the specific power purchasing agreements made by organizations rather than regional averages. Protocols for this new method are currently being developed.

1.6 Site and Source Emissions

An important distinction in the tracking of energy usage and emissions is the difference between the energy consumed "on-site," delivered to building or end-use itself, and that consumed at the "source." The utility reports and charges for energy delivered on-site, but emissions are a product of the fuels burned at the plant, or source, to provide the delivered energy. Although greenhouse gas emissions occur at the source, energy use is reported and understood in terms of site or delivered energy, so emissions factors convert site energy to source emissions.

The difference between site and source energy can be considerable and is caused by both the inefficiencies of conveying power, whether it is through wires or pipes or conveyed in vehicles, and the inherent inefficiencies of combustion and conversion. Electricity, in particular, involves an inefficient conversion process, losing 60-75% of the initial fuel value to waste heat. With respect to greenhouse gas emissions, this means that for every unit of electricity used, roughly three units of emissions are produced. There are similar conversion and transmission inefficiencies for each of the centrally distributed fuels.

2.0 Scope of Morris Arboretum Carbon Footprint

This initial Carbon Footprint of the Morris Arboretum of the University of Pennsylvania examines the main campus in Chestnut Hill and primarily considers consumption at the campus level, rather than that of the individual facilities. Completing a regular carbon footprint for the Morris Arboretum campus will identify the origin of emissions and allow future work to curtail or control emissions.

The main site of the Morris Arboretum includes all the facilities and activities associated with the operation of the 167 acre Chestnut Hill site and its buildings. While the carbon footprint focuses on the emissions associated with the entire campus, sufficient information was gathered to enable a preliminary assessment of most of the individual buildings. As the built environment represents the largest contributor to greenhouse gas emissions, this more detailed look at the individual buildings will better allow the identification of those specific areas that might be performing poorly compared to other buildings. These can reveal opportunities for emissions reductions and help prioritize the areas targeted for remediation efforts. The buildings examined individually were: Gates / Carriage House, the Horticultural Center, Widener / Wagon House, the Greenhouses, Bloomfield Farmhouse, Bloomfield Farm Miller Cottage, the Grist Mill, the Seven Arches, the Gardeners Cottage, the Mechanics Garage, the Pavilion, the Studio, the Barn, and the Pumphouse. Energy consumed by the Morris Arboretum that was not used by these structures was included in the overall footprint. The facilities outside of this campus are not included, though they can be added using the same protocols.

Each of the factors contributing carbon emissions is reviewed below, and the source of the data is identified, as is the primary contact.

2.1- Utilities

Electricity- Electrical consumption was gathered for all facilities in kWh. This data was derived from PECO bills and collected on a monthly basis. Electricity use is a major contributor to carbon dioxide emissions and is used for many different purposes across the Morris Arboretum: lighting, equipment, fans, and including the energy used for on-site cooling. Electricity falls within Scope 2, as it is used on campus, but the emissions are produced offsite. The emissions factor for electricity varies from year to year as the mix of electrical generation supplying the PJM grid changes over time. The current emissions factor for electricity supplied by the RFCE grid is 0.1352 MTCDE/MMBtu.

Steam- Due to its distance from the main campus in University City, the Morris Arboretum is not connected to the university steam loops, and instead generates heat on-site using natural gas or fuel oil. As a result there is no steam utilized on the Morris Arboretum site. If used, steam would fall within Scope 2, as it is used onsite, but the emissions would be produced offsite. The emissions factor for steam used by the UPenn main campus varies over time as Veolia makes improvements to their facilities and improves efficiency. The current emissions factor of steam supplied by Veolia is 0.0498 MTCDE/MMBtu.

Figure 7- Map of facilities included in FY15 Morris Arboretum Carbon Footprint

Chilled Water- The chilled water used for cooling on the main University of Pennsylvania campus is produced using electricity provided by PECO. As with steam, the Morris Arboretum is located at too great a distance from the main campus to connect to the district loop. Instead, cooling is generated on site by each facility using electricity. As a result, no chilled water was used by Morris Arboretum. Chilled water falls within Scope 2, as it is used on the campus, but the emissions are produced offsite. Most of the cooling is produced on-site using electricity, though it is not metered separately, and so it is reported in the total amount of electricity used. The emissions factor for cooling in any given year is equal to that for the electricity and is currently 0.1352 MTCDE/MMBtu.

Natural Gas- A significant amount of natural gas is utilized by the Morris Arboretum facilities, mostly for the production of space heating but a smaller amount for cooking and water heating as well. The natural gas is provided by PGW and the monthly consumption is reported in hundreds of cubic feet of natural gas (ccf). Natural gas falls within Scope 1, as it is used on campus and the emissions are produced onsite.

The carbon dioxide emissions from a ccf of natural gas are constant and do not vary over time. This emissions factor is 0.0540 MTCDE/MMBtu.

Fuel Oil #2- A significant amount of fuel oil is utilized by the Morris Arboretum facilities for the production of space heating. The fuel oil is provided by Dwyer Oil and the monthly consumption is reported in gallons (gal). Fuel oil falls within Scope 1, as it is used on campus and the emissions are produced onsite. The emissions factor is 0.001427 MTCDE/MMBtu.

Contact: Thomas Wilson, Morris Arboretum Director of Physical Facilities; wilsonth@upenn.edu

2.3- Commuting

Commuting by employees is a significant contributor to the greenhouse gas emissions for the Morris Arboretum. Only the emissions arising from employee travel is considered, while the travel by visitors and other guests is excluded. The emissions from visitors could be considered in Scope 3 of the University of Pennsylvania Morris Arboretum carbon footprint, however, they are more appropriately considered to be the Scope 1 and 2 emissions of the visitors. The emissions from commuting to the Morris Arboretum Chestnut Hill campus originate primarily from travel via personal vehicles, as the location is inconvenient for large scale use of public transportation such as bus or train lines. The emissions for personal vehicle travel are based on the gasoline and diesel used. The emissions factors for gasoline and diesel are 0.0088 MTCDE/gal and 0.0102 MTCDE/gal, respectively.

Car Commuting- Employees commuting to work by car is a major contributor to greenhouse gas emissions for the Morris Arboretum. The gallons of gas used for car commuting are not directly tracked by Morris Arboretum and so were estimated from employee data. This is accomplished by using a list of all the employees of the Morris Arboretum and their distance from their residences to the Arboretum, provided by the finance office. For each employee this distance was multiplied by the number of days a year they work and then doubled to reflect travel to and from the Arboretum. The annual miles driven by each employee were then summed and divided by the average fuel economy for U.S. vehicles (23.4 mi/gal) in order to determine the total amount of gasoline consumed by commuting employees. The average fuel economy of the vehicles being used was obtained from the EPA for the year 2014.

Train Commuting- It is believed that almost no commuting occurs by train on a regular basis due to the remote nature of the site and typical distance traveled.

Bus Commuting- It is believed that almost no commuting occurs by bus on a regular basis due to the remote nature if the site and typical distance traveled.

Contact: Karen Owens, Morris Arboretum Financial Manager; owenska@upenn.edu

2.4- Air Travel

Air travel is also a significant contributor to Morris Arboretum's greenhouse gas emissions, though it is a scope 3 emission. Conferences, business meetings, seminars, etc. all lead to the accumulation of air miles travelled, producing more carbon per mile than terrestrial transport options. This data is collected and was reported by the finance office. It is reported in two sets of data, one of which is a report from the Concur system which tracks those flights reimbursed to personal or corporate cards. The second set was manually compiled by the Financial Manager from e-mails generated during the approved process for those flights direct billed to the Morris Arboretum.

Contact: Karen Owens, Morris Arboretum Financial Manager; owenska@upenn.edu

2.5- Fleet Fuel Usage

The Morris Arboretum operates a small fleet of vehicles for maintenance, material management, and other purposes. Additional consumption of gasoline and diesel results from the operation of fuel powered equipment used in the maintenance of the site. The resulting emissions form a significant fraction of the overall greenhouse gas footprint for the Morris Arboretum. The amount of gasoline and diesel used is tracked by individual orders to fill the onsite tanks, which was aggregated into monthly, then annual data. Both gasoline and diesel are provided by Cardinal USA. This information was provided by the Director of Physical Facilities.

The gasoline and diesel totals are multiplied by their emissions factors (as described in Section 2.3) in order to determine the emissions produced by the fleet vehicles.

Contacts: Thomas Wilson, Morris Arboretum Director of Physical Facilities; wilsonth@upenn.edu

2.6- Solid Waste

The disposal of solid waste can be a significant contributor to greenhouse gas emissions. The level of emissions from solid waste disposal is determined by the tons of solid waste that are disposed and the method of disposal used at the locations where waste is sent. Solid waste may be placed in a variety of landfills. Some allow methane emissions to vent to the atmosphere; others may flare the methane, while others will use the methane to generate electricity. Additionally, some solid waste may need to be incinerated. The solid waste from Morris Arboretum is currently sent to a landfill without any methane controls, which leads to the highest level of emissions per ton of waste disposed. The level of waste disposed is recorded in short tons, however this info is not directly tracked and had to be estimated based on the scheduled pickup of trash and size of containers removed. Additionally, composting of food scraps was considered for their potential benefits but the amounts sent for composting were too low to make a significant difference in the overall carbon footprint.

Thomas Wilson, Morris Arboretum Director of Physical Facilities; wilsonth@upenn.edu

2.7- Agriculture

The usage of artificial and organic fertilizers for agriculture and landscaping contributes to greenhouse gas emissions. These emissions are calculated based on the weight of the fertilizers used over the course of the year and the level of nitrogen that is found in those fertilizers. While a significant amount of fertilizer is used in the operation of the Morris Arboretum, then emissions per unit are low, resulting in an overall low emissions impact from this sector.

Contact: Anthony Aiello, Morris Arboretum Director of Horticulture and Curator; Aiello@upenn.edu

2.8- Refrigerants

Accidental release of refrigerants is not believed to be a significant portion of the carbon footprint and the data for this sector is not directly tracked.

Contact: n/a

2.9- Carbon Offsets

One final factor to consider are carbon offsets, which are actions taken by an organization to reduce the overall impact of their GHG emissions. There are many ways to offset carbon, such as by planting new trees, geological sequestration of carbon, or producing renewable energy. Another means of offsetting GHG emissions is through the purchase of credits, in which other organizations offset carbon production, but do not take credit for that reduction and instead sell the credits for those avoided emissions to another organization. This is often expedient and efficient when an organization does not have the ability to directly offset emissions themselves or for whom it may be less expensive to buy the credits rather than directly offsetting the emissions.

The UPHS and UPenn campuses currently purchase renewable energy credits (RECs) to partially offset their electrical consumption by buying carbon offsets created by wind energy producers, however Morris Arboretum does not receive any of those credits. Instead the Morris Arboretum achieves substantial greenhouse gas emissions offsets for the carbon sequestered by their growing trees. As an arboretum, a detailed inventory of the individual trees found on the site is maintained. Details such as species, age, DBH, and diameter were recorded. Each species was classified as Hardwood or Coniferous and Fast, Medium, or Slow growing. This classification was then used along with the age of each tree to determine the amount of carbon sequestered annually due to the trees growth.

Contact: Anthony Aiello, Morris Arboretum Director of Horticulture and Curator; Aiello@upenn.edu

3.0 The Morris Carbon Footprint

The Morris Arboretum of the University of Pennsylvania Carbon Footprint consists of the carbon contributions (or their equivalence) from the usage of utilities, commuting, air travel, fleet services, refrigerant leakage, fertilizers, solid waste, and the sequestration of carbon in the growing stock of trees found on the arboretum's site, which reduce the impact of the produced emissions on a one-to-one basis. While the previous section described the methodology which was used to calculate each of these contributions, this section will discuss the specific approach utilized to calculate the carbon produced for each activity as well as the combined overall footprint for the Morris Arboretum. For most sections an attempt was made to gather historical data in addition to the information for FY 2015 so that the carbon footprints for previous fiscal years could be estimated for comparison. However, for some of the components which accounted for less than 1% of the overall footprint this was not necessary, as even drastic changes in these values would be unlikely to lead to substantial shifts in the carbon footprint. Additionally, other components did not have historical data available, therefore they were held constant for previous years. Of the seven categories that have significant contributions to the footprint (electricity, natural gas, fuel oil, commuting, fleet gasoline, air travel, and solid waste), annual data going back through FY 2013 was obtained for all utilities and fleet gasoline and diesel consumption. As the commuting data was based purely on the list of employee zip codes, which would be relatively stable in the short term, it was held constant for historical data. Future reports should update this figure annually. Solid waste was estimated and so no historical data was available, in future reports better accounting methods for solid waste disposal should be developed. Finally, data for air travel was only available for most of FY15, and so could not be determined for previous years.

Figure 8, below shows the carbon footprint for the Morris Arboretum in FY2015. The gross emissions during this year were **700 MTCDE**, but subtracting the carbon sequestered by the growing trees on the site reduces the net emissions to **407 MTCDE**. The bulk of the emissions, 62%, are created through the provision of utilities to buildings on site. Electricity accounts for 41%, natural gas is 6.5%, fuel oil is 14%, and propane is 0.7% of gross emissions. The remaining 38% is mostly accounted for by commuting, the use of gasoline and diesel for fleet and equipment, air travel, and solid waste (18%, 10%, 5.5% and 3.5% respectively). Emissions associated with fertilizer use and propane were less than 1%. The only sector of emissions that were not calculated were those associated with the release of refrigerants as the data could not be easily determined, but it is believed that these contributions would be on the same scale as fertilizer use, and will have minimal impact on the overall footprint. This pattern of emissions matches expectations, with building utilities accounting for the bulk of emissions, followed by travel associated with work and then by emissions from solid waste.

This is very similar to the breakdown of the University of Pennsylvania Main Campus Carbon Footprint. However, some dissimilarity exists. Most notably, while the use of energy in the built environment still dominates the carbon footprint, the percentage is reduced compared to that seen in the main campus (62% as compared to approximately 85%). This difference is also reflected by significantly larger shares of the footprint being accounted for by solid waste, commuting, and gasoline and diesel usage by the fleet. Given the prevalence of car commuting and the distances of the employees from their worksite, it is unsurprising that carbon from commuting accounted for a larger percentage of the carbon footprint.

Additionally, due to its nature as an arboretum, it is also unsurprising that the use of gasoline and diesel for maintenance vehicles and equipment would play a larger role in the carbon footprint. The greater portion associated with solid waste is harder to explain as the data was estimated. Many reasons could explain the emissions being proportionally higher, or it could be due to an over estimation of the amount of waste being generated.

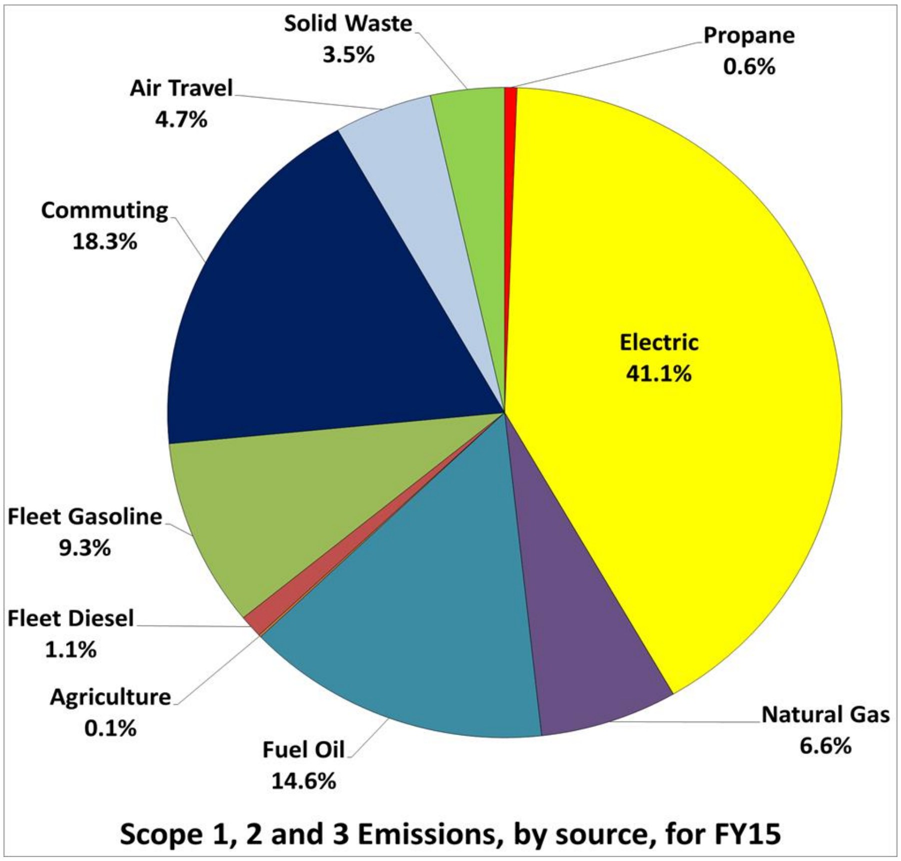

Figure 8- The Morris Arboretum 2015 Carbon Footprint, by source of emissions

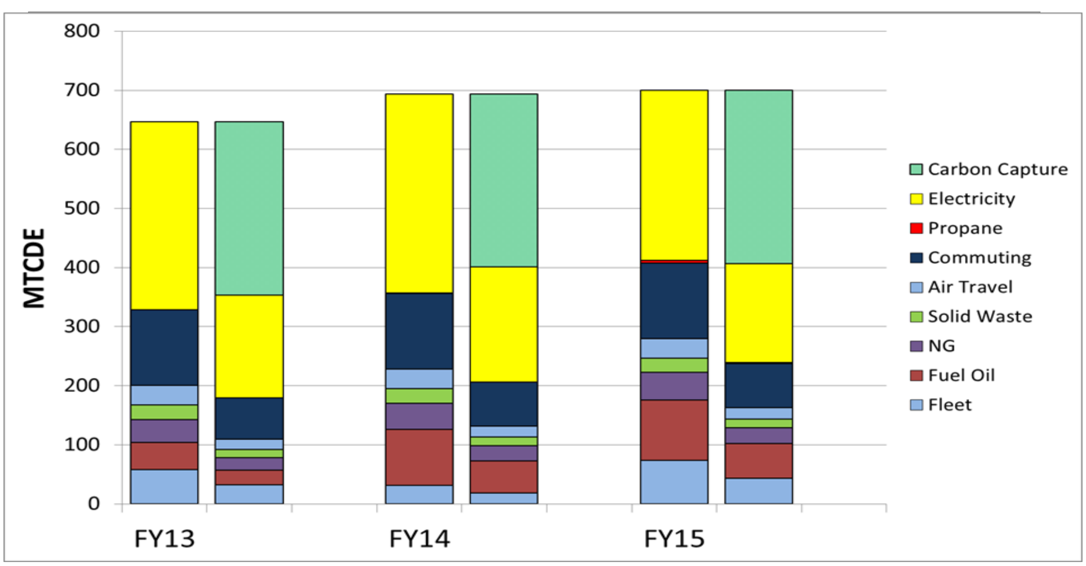

Figure 9- Carbon Footprints for FY 2013-2015, by source of emissions, with and without Sequestration Credits

Figure 9 shows the Morris Arboretum carbon footprint over time, including FY 2013 through FY 2015. This shows a carbon footprint that has increased in each year, most substantially between FY 2013 and FY 2014, which is largely due to a reported increase in the use of fuel oil. If this is not a reporting error then this would indicate that fuel oil consumption doubled in that time frame. Small deviations from year to year may indicate a trend of carbon intensification from FY13-FY15, but it is impossible to determine the cause of these changes without further consideration of external factors which may have impacted carbon production, such as the scheduled use of facilities or average weather patterns in each year. Future studies using regression analysis could determine the impact of these external factors and allow for an accurate comparison of emissions in each fiscal year, but this is beyond the scope of this project.

1- UTILITIES

MTCDE	Annual		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
288	623,344	Electricity (kWh)	52,113	47,092	52,575	42,987	48,401	76,590	67,909	64,784	53,991	36,457	34,008	46,437
102	10,077	Fuel Oil (gal)	0	148	1,870	0	317	1,045	2,617	1,243	2,309	368	161	0
46	8,134	NG (ccf)	117	139	146	172	880	1,115	1,616	1,925	1,139	633	205	47
4	65,001	Propane (kBtu)	11,439	6,943	21,376	0	0	0	0	0	0	0	25,243	0

2- Fleet

	Annual	
65	7,425	Gasoline (gal)
8	780	Diesel (gal)

3- Refrigerants

Annual (lbs)	
	HFC-134a
	HFC-404a
	HCFC-22
	HCFE-235da2
	Others
	HG-10

4- Commuting

128	14,530	Gasoline (gal)
0	0	Diesel (gal)
0	0	Electricity (kWh)

									Electric	Gasoline	Diesel
	44	# 5 day/week employees									
	0	# 2 day/week employees							kWh/mi	gal/mi	gal/mi
Train	0	% trips	0	trip/yr	0	mi/trip	0	mi/yr	0.14468		0.00756
Bus	0	% trips	0	trip/yr	0	mi/trip	0	mi/yr			0.02521
Car	100	% trips	22,000	trip/yr	15.45	mi/trip	340,000	mi/yr		0.04274	

5- Solid Waste

25	25	Solid Waste to Landfill (short tons)

6- Air Travel

33	42,440	Annual Air Miles

7- RECs

293	293	Trees Growth (MTCDE)

8- Fertilizer

0.8	200	lbsN

Figure 10- Tabulated Inputs and MTCDE for Morris Arboretum

3.1 Carbon from Utilities

The consumption of utilities was collected as monthly aggregations in the units of consumption. The primary contributors were electricity, fuel oil, and natural gas, which provide the bulk of energy services to the buildings on site at the Morris Arboretum. Propane was also used as an energy source within buildings on site, however for limited usage such that its contribution to the overall carbon footprint was minimal. Many of the buildings at the Morris Arboretum have cooling systems; however, these are all local space cooling units powered by electricity. The majority of the energy used for cooling is thus incorporated into the totals for electrical consumption. Separate metering of the electricity used for cooling was not available and so it will be difficult to distinguish between power consumed for cooling versus power consumed as a part of a facility's normal internal load. Fuel oil and natural gas, which are used mostly for space heating in addition to some other services, also represent a large portion of the carbon produced.

Annual		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
623,344	Electricity (kWh)	52,113	47,092	52,575	42,987	48,401	76,590	67,909	64,784	53,991	36,457	34,008	46,437
10,077	Fuel Oil (gal)	0	148	1,870	0	317	1,045	2,617	1,243	2,309	368	161	0
8,134	NG (ccf)	117	139	146	172	880	1,115	1,616	1,925	1,139	633	205	47
65,001	Propane (kBtu)	11,439	6,943	21,376	0	0	0	0	0	0	0	25,243	0

Figure 11- Utility Inputs

3.2 Carbon from Fleet

The fleet consists of those vehicles and pieces of equipment which are fueled with gasoline and diesel provided by the Morris Arboretum. This includes a handful of trucks and other vehicles, in addition to numerous pieces of equipment utilized in the maintenance of the Morris Arboretum grounds. The fuel for the fleet is purchased in bulk and stored on site. At this time no effort was made to distinguish between fuel used for equipment rather than vehicles and it is unclear if sufficient information exists to determine the division of the usage. The usage of gasoline and diesel for these purposes represented a significant portion of the overall carbon footprint, which was expected given the nature of the site and the maintenance required.

Annual	
7,425	Gasoline (gal)
780	Diesel (gal)

Figure 12- Fleet Inputs

3.3 Carbon from Refrigerants

Refrigerants are typically a very small component of a carbon footprint for this type of facility, however no data was collected for the annual release of these chemicals and so their contribution could not be determined. Future carbon footprints may estimate the annual release of refrigerants by examining purchase orders over a sufficiently long period of time if believed to be a significant contributor of emissions.

3.4 Carbon from Commuting

Determining the carbon emissions associated with commuting can be very complicated for a large organization, which may have hundreds or thousands of employees coming to work via a variety of methods and from indeterminate distances. For the Morris Arboretum, however, the number of employees was relatively low and the mode of transportation singular, by personal vehicle. Using employee zip codes enabled Google Maps to estimate the distance each employee would drive if commuting to work using the fastest route option. Using the zip code does not give the exact mileage for each employee as it is not a precise address for their home, but the errors introduced are assumed to be relatively small in scale compared to the distance traveled and random in nature such that their individual effects average out. Each employee was assumed to drive to and from work from their home five days a week, fifty weeks a year. Commuting is the second largest source of carbon emissions after electricity by emissions source. Further, if the electricity used for space cooling were accounted for separately, then emissions for commuting would be essentially equal to emissions for all other electric use as well as the carbon emitted for space heating, represented by the combination of natural gas and fuel oil emissions.

14,530	Gasoline (gal)
0	Diesel (gal)
0	Electricity (kWh)

	44	# 5 day/week employees							Electric	Gasoline	Diesel
	0	# 2 day/week employees							kWh/mi	gal/mi	gal/mi
Train	0	% trips	0	trip/yr	0	mi/trip	0	mi/yr	0.14468		0.00756
Bus	0	% trips	0	trip/yr	0	mi/trip	0	mi/yr			0.02521
Car	100	% trips	22,000	trip/yr	15.45	mi/trip	340,000	mi/yr		0.04274	

Figure 13- Inputs for Commuting

3.5 Carbon from Solid Waste

Solid waste is the largest contributor to greenhouse gasses for the Morris Arboretum that does not involve the direct consumption of energy and the associated release of carbon dioxide. Instead the emissions from solid waste derive from their decomposition in a landfill and the methane produced by the anaerobic decomposition of organic materials. While the quantities of methane produced are significantly lower compared to the mass of carbon dioxide released in other sectors, the global warming potential of methane compared to carbon dioxide is much higher, about 50 times more impactful. The Morris Arboretum currently sends all of its solid waste to a landfill without methane control, which leads to the highest possible emissions per ton of waste produced.

Currently, the weight of the solid waste sent to landfills is not directly reported. As a result the magnitude was estimated based on the frequency of pickup and the size and number of the containers collected. As we were unable to determine the actual amount of trash in each container when collected, it was assumed that each was 75% full. Further study should be done to refine this calculation.

25	Solid Waste to Landfill (short tons)

Figure 14- Inputs for Solid Waste

3.6 Carbon from Air Travel

Emissions from air travel were determined from accounting data and few enough flights were undertaken that each could be considered and included. Two sets of data were used to compile the list of flights taken. The first was a report from the Concur system for those flights purchased with personal or corporate cards that were reimbursed. The second set of flights were those direct billed by the Morris Arboretum, which were manually compiled by Karen Owens, Financial Manager at Morris Arboretum. The second set only recorded data for the second half of FY 2015 and so these miles were doubled to estimate the travel that was unrecorded in the previous half of the fiscal year.

42,440	Annual Air Miles

Figure 15- Inputs for Air Travel

3.7 Carbon from Fertilizer

The use of fertilizers is associated with a release of emissions based on the type and concentration of fertilizers being used. Substantial amounts of fertilizer were consumed but due to the low carbon intensity of this sector, the overall impact was very low.

200	lbsN

Figure 16- Inputs for Fertilizer

3.8 Carbon Sequestration in Woody Biomass

The final component of the footprint to be considered is the carbon sequestration credits earned by the Arboretum for the growth of its wooded areas. By maintaining most of their land in a natural state and by purposefully cultivating trees of numerous species, the Arboretum is responsible for the carbon dioxide take up by the trees each year which is captured as a part of their biomass and sequestered out of the atmosphere. Previously conducted carbon footprints for the University of Pennsylvania main campus and for the University of Pennsylvania Health System have not attempted to calculate the carbon sequestered by their trees, but the unique nature and purpose of the Morris Arboretum ensured that the effect of biomass sequestration in their 4,700 trees would be more significant than it would be for the other footprints. Finally, as an arboretum, excellent records were already being maintained describing the tree stock down to the individual tree, in both cultivated and natural areas.

The amount of carbon sequestered by the trees was estimated using a method developed by the EPA in their guide *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings*, 1998. This classifies each tree as Hardwood or Coniferous, and Slow, Medium, or Fast growing and provides a table that combines that classification with the age of the tree to estimate the amount of carbon it sequesters each year. These values ranged from less than a pound a year for the youngest trees of the slowest growing species to more than 100 pounds a year for the oldest trees of the fastest growing species. Most of the more than 4,700 trees inventoried by the Morris Arboretum had a known or estimated age. A significant portion of the trees in the natural area only had information relating to the diameter of the trees, but this information was utilized to estimate age as well. The provided tables were used along with the age and classification for each tree and to determine to summed magnitude of the carbon sequestered

The effect of the biomass sequestration is very pronounced, roughly equal to 40% of the carbon produced by the Morris Arboretum. In FY 2015, the carbon sequestered by trees on the Morris Arboretum site completely negated the emissions arising from electrical use for cooling and internal loads combined. Future footprints for the Morris Arboretum should continue to utilize the most current tree inventory available in order to determine the credits earned from biomass sequestration of carbon. Further, following these experiences, the issue of determining the impact of tree growth on carbon footprints of other sectors, such as the University of Pennsylvania main campus and the New Bolton Center, should be reexamined.

293	Trees Growth (MTCDE)

Figure 17- Inputs for RECs

3.9 Energy Consumption by the Built Environment

As the consumption of energy in buildings accounts for 62% of the total carbon footprint for the Morris Arboretum, this section will more closely examine how and where this energy is being consumed and how the level of consumption compares to similar buildings and facilities. It is important to consider both the magnitude of the consumption in each facility as well as the intensity of that consumption, which is normalized to account for the scale of the facility or the activities within. Determining the magnitude of the energy consumption in each facility allows the targeting of the largest energy users within a group of buildings, which would be one criterion for determining where to focus efforts towards remediation of emissions associated with energy consumption.

Figures 18 and 19, below, show how energy is consumed at the Morris Arboretum month by month. These include the energy consumed by the combination of all the individual facilities as well as the gasoline and diesel consumed by vehicles and equipment. Gasoline, diesel, and fuel oil were not reported in terms of monthly consumption, instead they were reported by purchase date. Because of this the actual consumption of these sources may take place in the months following the month recorded. Even so, the larger pattern displayed is as would be expected, with consumption peaks in the winter for electricity, fuel oil, and natural gas as space heating is required and, to a lesser extent, summer peaks for electricity for space cooling. However this level of analysis does not do much in terms of identifying those buildings which are performing poorly and so cannot lead to specific plans for improvement. The remainder of this section will consider the individual buildings.

The magnitude of energy consumption by itself does not provide any information about how effectively that energy is being utilized to accomplish the goals associated with that facility. Assume Building A uses twice as much energy as Building B, but it contains ten times as many offices. Even though Building A uses twice the energy, Building B may be the better target for remediation. While many metrics have been utilized to determine the energy intensity of a facility, the standard factor used for normalization is the area of the facilities. The energy intensity is most often shown in units of kBtu/sqft and a large amount of data has been published regarding the energy intensity of different building types in different areas that allows for the comparison of an individual facility against national statistics for performance.

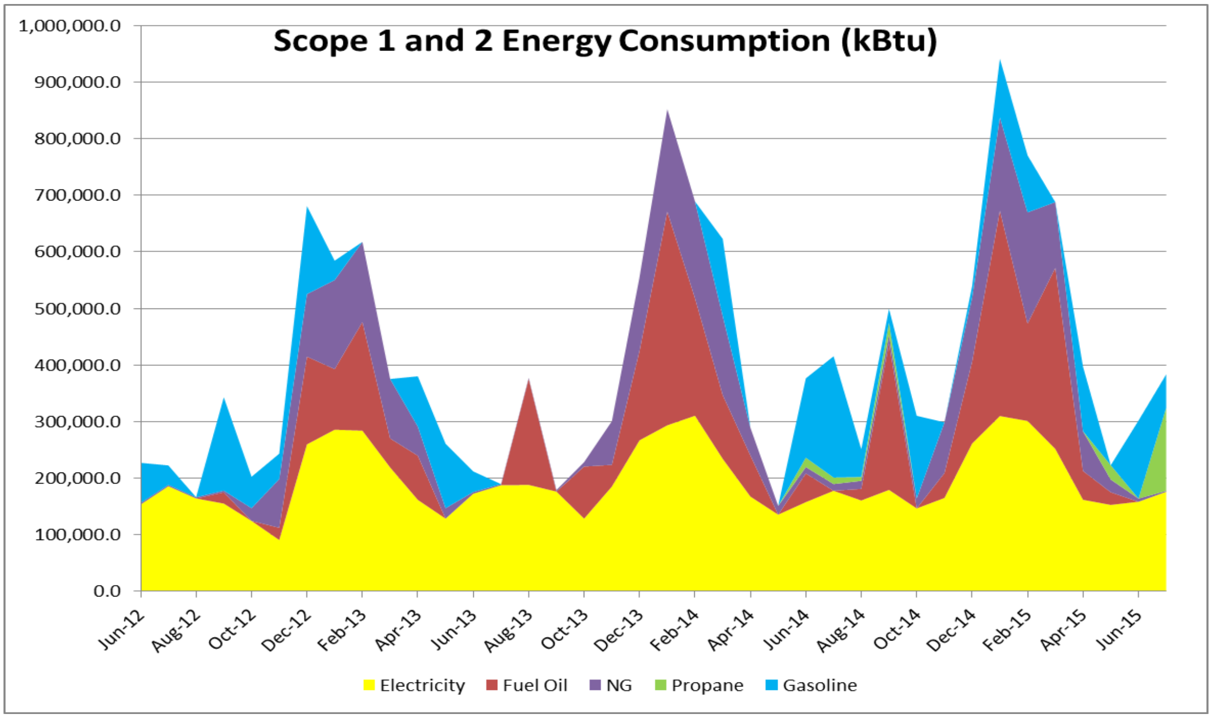

Figure 18- Scope 1 and 2 Energy Consumption

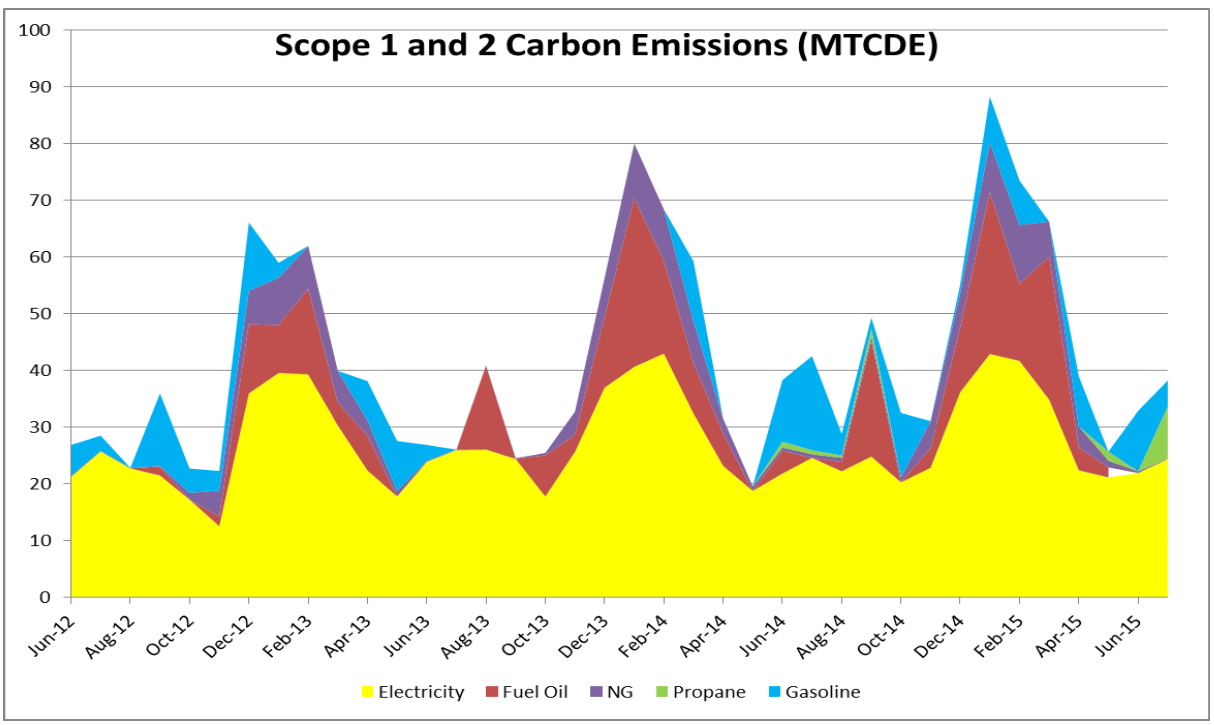

Figure 19- Scope 1 and 2 Carbon Production

For this report, energy data was collected for facilities or facility groups. All facilities for which utility usage was independently metered were considered individually, while some facilities which shared electric were considered as a group. The units considered were: 1) Gates and the Gates Carriage House; 2) Widener and the Widener Wagon House; 3) the Horticultural Center; 4) Greenhouse 1; 5) the Fernery and the remaining greenhouses; 6) Gardener's Cottage; 7) Bloomfield Farm Miller Cottage; 8) Bloomfield Farmhouse; 9) the Studio; 10) Hillcrest Pavilion; 11) Mechanic's Shop and Garage; 12) 7 Arches; 13) the Pumphouse; 14) the Barn; and 15) the Gristmill.

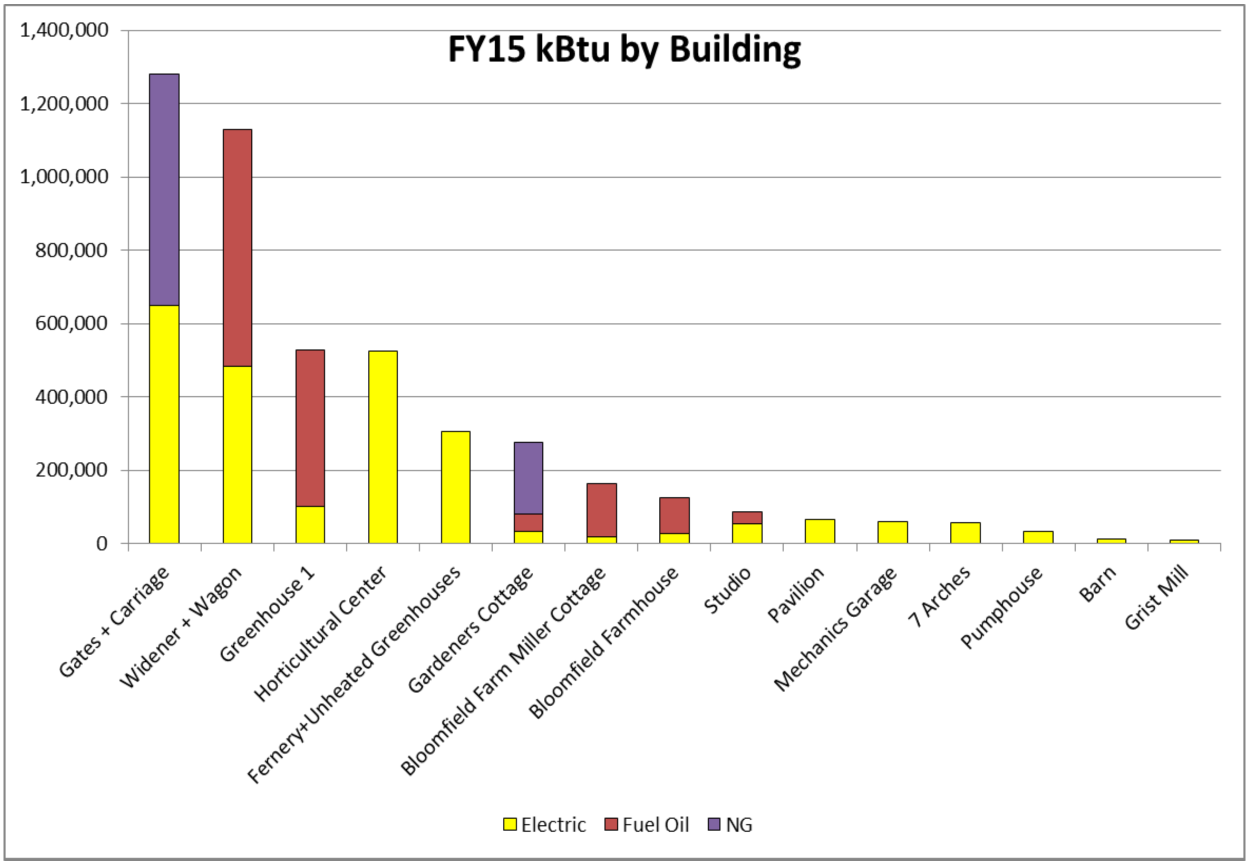

Figure 20- FY 2015 Energy Consumption by Facility, in kBtu

Figure 20, above, shows the energy consumption in each of the fifteen facilities in units of kBtu, which allows for the direct comparison of the consumption of electricity, fuel oil, and natural gas, all of which are reported in different units. This graph shows that for most facilities energy consumption was related to area, with the largest buildings being the largest consumers of energy. There were some outliers, notably Greenhouse 1, the Barn, and the Grist Mill. The Barn and the Grist Mill are utilized in very different fashions from the office and lodging buildings, which simply lead to much lower energy usage despite a large area.

The two largest consumers of energy were the Gates / Carriage House and Widener / Wagon House facilities, using 1,281,652 kBtu and 1,129,781 kBtu respectively. The energy use in the Gates / Carriage House facility was 51% electricity and 49% natural gas. The energy use in the Widener Wagon House facility was 43% electricity and 57% fuel oil. The next largest consumer is Greenhouse 1, consuming 526,773 kBtu. This facility appears to use a large amount of fuel oil for heating, accounting for 80.6% of energy usage, but this may heat more square footage than initially assigned if some of that heat is utilized in other greenhouse sections. The final large consumer is the Horticultural Center, which utilized 524,220 kBtu of electricity in FY 2015. These four facilities account for 75% of the energy consumed by buildings at the Morris Arboretum.

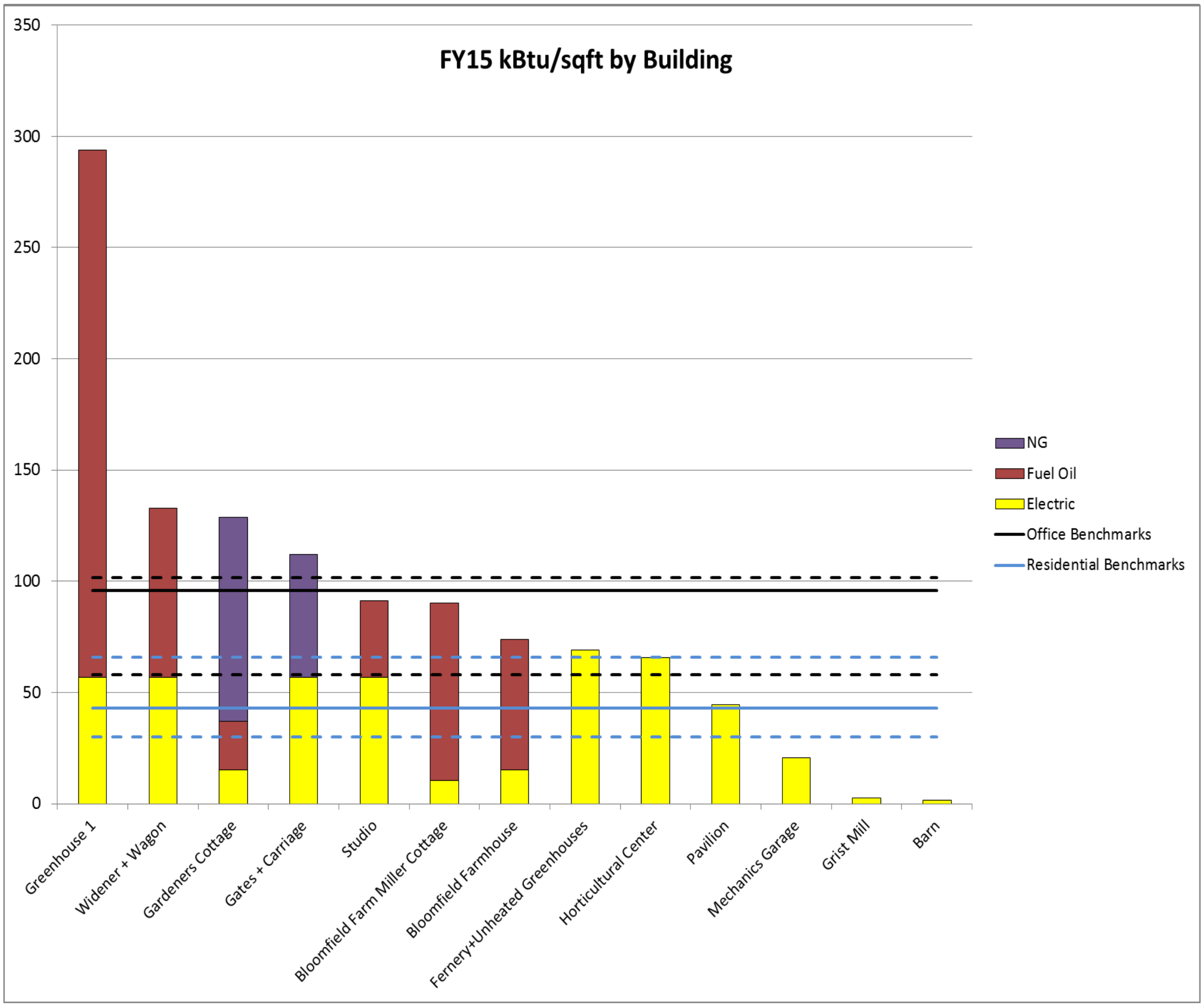

Figure 21- FY 2015 Energy Intensity by Facility, in kBtu/sqft

Figure 21, above, shows the same data as Figure 20 except it has been normalized by the area of each building to provide the energy intensity. Energy intensity is a better means of comparing the relative performance of buildings as it accounts for scale, in this case the physical size of the facilities. In addition to the normalized consumption values in this figure, two sets of benchmarks were added showing the typical range of performance for office and lodging buildings. Each benchmark consists of a mean performance for that building type as well as the performance of the 25th and 75th percentiles. The office benchmarks are based on national data derived from the Building Performance Database, by the U.S. Department of Energy, and the Commercial Buildings Energy Consumption Survey, by the Energy Information Administration, and the residential benchmarks are from the 2009 Residential Energy Survey, which is also produced by the Energy Information Administration.

The facility with the highest energy intensity was Greenhouse 1 at 294 kbtu/sqft. This is primarily due to the large amount of fuel oil used for heating. This consumption may be explained by a higher rate of heat transfer through the structures envelope due to the greater proportion of the envelope consisting of glazing, which has lower insulation values compared to solid wall construction. However, it is also possible that some of this heating energy is used in other greenhouse structures. If so, considering this additional area would lower the energy intensity of Greenhouse 1 and raise the energy intensity of those other areas. If accurate, Greenhouse 1 has an energy intensity more than twice as high as the next group of facilities, which are lodging and office buildings. Accurate benchmarks for greenhouses have not yet been developed for this report, but this level of energy consumption would be comparable to that seen in medical or laboratory buildings, though they would likely present a more balanced mix of consumption between electric and heating.

The Widener/Wagon House and Gates/Gates Carriage House buildings are the two largest office / mixed use structures on the Morris Arboretum site ad they use 133 kbtu/sqft and 112 kbtu/sqft respectively. Both buildings present a fairly even split between energy used for electric and heating, as would be anticipated in these types of facilities. Benchmarks for office / mixed use buildings have been well developed using national data for similar buildings, providing a range of energy consumption that is considered to be normal (an average, bounded by the 25th and 75th percentiles). Both Widener and Gates fall above this normal range of energy intensity (the mean is 96 kbtu/sqft and the 75th percentile is 101.6 kbtu/sqft), which indicates there may be substantial room for improvement and energy savings, especially as these are larger buildings where the magnitude of energy consumed is also high compared to other structures. As such an improvement in energy intensity will lead to large decreases in total energy consumed.

One other building exceeds the benchmarks for what would be considered normal energy intensity and that is the Gardener's Cottage. Unlike Widener or Gates, Gardener's cottage is residential and so the benchmarks for comparison are different than those used for offices. With an energy intensity of 129 kbtu/sqft, this building significantly exceeds the mean and 75th percentile benchmarks for residential structures, which are 43.0 kbtu/sqft and 65.7 kbtu/sqft respectively. This is entirely due to the level of natural gas consumed, which accounts for 71% of the energy consumed in this building. Unlike Gates, Widener, or Greenhouse 1 (all of which have high energy intensity as well as a high magnitude of energy consumed), the magnitude of the energy consumed by this structure is relatively low, meaning that even substantial improvements in energy intensity will have a smaller impact on the magnitude of energy consumed by the Morris Arboretum as a whole. The Studio and the Horticultural Center all fall within the normal range of energy intensity designated by the benchmarks.

The Bloomfield Farmhouse and the Bloomfield Farm Miller Cottage both exceed national averages in terms of energy intensity, as well as the 75th percentile. Again, while it is possible this energy intensity could be improved, the scale of the buildings and magnitude of the energy consumed are quite low, indicating that improvements would have less of an impact on the overall Morris Arboretum carbon footprint. While these structures have an energy intensity above the 75th percentile for residential structures, the magnitude of consumption is comparatively low, so it is also unlikely that improvements to these structures would yield substantial improvements in overall energy consumption.

The final building in this group is the Horticultural Center, which also has an energy intensity lower than the national averages for this type of structure. However, unlike the previous few structures discussed the Horticultural Center is tied with Greenhouse 1 as the 3rd largest consumer of energy amongst the structures at the Morris Arboretum. So while there may not be as much room for improvement in terms of energy intensity as some of the smaller structures, the overall magnitude of consumption means that even a small improvement may have a greater impact on overall energy consumption that a large improvement in a smaller building. Additionally, energy used at the Horticultural Center is actually higher than reported as solar panels have been installed. Due to net metering, the electricity produced by the panels is not recorded, only the additional energy required from the grid.

Facilities by kBtu				
Location	**Electric**	**Fuel Oil**	**NG**	**Total**
Gates + Carriage	648,844	0	632,808	1,281,652
Widener + Wagon	481,989	647,792	0	1,129,781
Greenhouse 1	101,495	425,278	0	526,773
Horticultural Center	524,220	0	0	524,220
Fernery+Unheated Greenhouses	306,185	0	0	306,185
Gardeners Cottage	32,844	46,467	196,860	276,171
Gutowski-Millers Cottage	19,090	143,583	0	162,673
Meyer Farmhouse	26,020	99,318	0	125,338
Studio	54,372	33,282	0	87,654
Pavilion	64,224	0	0	64,224
Mechanics Garage	58,236	0	0	58,236
7 Arches	56,042	0	0	56,042
Pumphouse	32,697	0	0	32,697
Barn	12,969	0	0	12,969
Grist Mill	7,878	0	0	7,878

Facilities by kBtu/sqft					
Location	**Area**	**Electric**	**Fuel Oil**	**NG**	**Total**
Greenhouse 1	1,792	56.6	237.3	0.0	294.0
Widener + Wagon	8,510	56.6	76.1	0.0	132.8
Gardeners Cottage	2,145	15.3	21.7	91.8	128.8
Gates + Carriage	11,456	56.6	0.0	55.2	111.9
Studio	960	56.6	34.7	0.0	91.3
Gutowski-Millers Cottage	1,805	10.6	79.5	0.0	90.1
Meyer Farmhouse	1,700	15.3	58.4	0.0	73.7
Fernery+Unheated Greenhouses	4,438	69.0	0.0	0.0	69.0
Horticultural Center	7,970	65.8	0.0	0.0	65.8
Pavilion	1,440	44.6	0.0	0.0	44.6
Mechanics Garage	2,810	20.7	0.0	0.0	20.7
Grist Mill	3,104	2.5	0.0	0.0	2.5
Barn	8,138	1.6	0.0	0.0	1.6
7 Arches	n/a	-	-	-	-
Pumphouse	n/a	-	-	-	-

Figure 22- Tabulated energy consumption. Magnitude and intensity by facility and type, FY2015

The remaining buildings to consider are the Pavilion, the Mechanics Shop, the Grist Mill, and the Barn. These structures are fundamentally different than the previous ones discussed as they are not fully occupied and utilized in the same manner as office or lodging buildings. Because of the limited use of these buildings both the energy intensity and the magnitude of energy consumed is quite low. This leaves little room for improvement and it is unlikely that substantial energy savings could be accrued through renovations or usage changes in these structures. A low level of electrical consumption was also reported at the Seven Arches and the Pumphouse, but the nature of these sites does not allow for energy intensity to be calculated with any meaning.

One final means of comparing individual facilities is to consider not the magnitude of energy consumption or the energy intensity of each, but rather to consider the resulting emissions from that consumption. Since electricity, fuel oil, and natural gas have different emissions factors, one building may consume more energy than another but still produce fewer emissions, depending on the breakdown of that energy use by source. Typically, fuel oil and natural gas produce fewer emissions per kBtu compared to electricity, so buildings where a large proportion of the energy consumed is from these sources will have lower emissions than buildings consuming a greater proportion of their energy in the form of electricity. When the mix of energy used in different buildings adheres to similar breakdowns between electricity, natural gas, and fuel oil, the order of buildings in terms of energy consumption will match the order of the buildings in terms of carbon produced

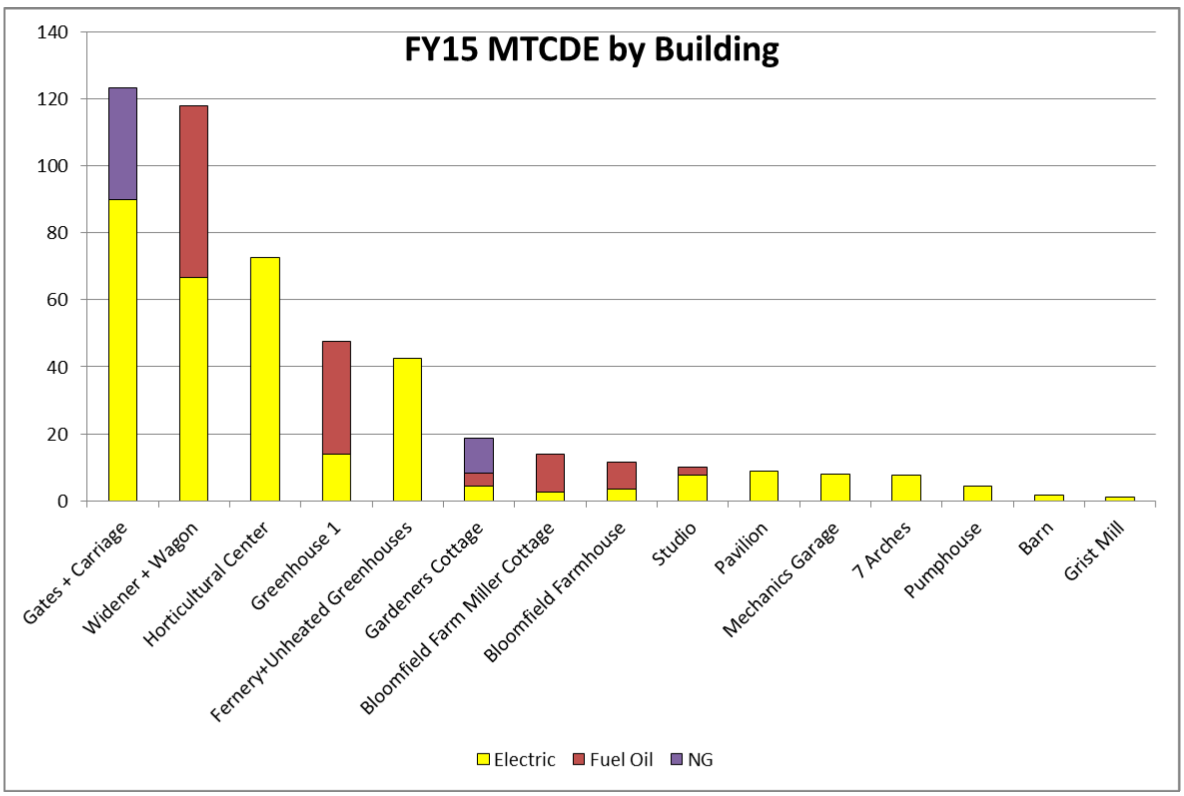

Figure 23- FY 2015 Carbon Emissions by Building, Type (MTCDE)

For the Morris Arboretum, this effect is most evident in the carbon produced by Greenhouse 1, which consumes most of its energy as fuel oil. While it is essentially tied in terms of energy consumption with the Horticultural Center, the carbon produced by Greenhouse 1 is substantially lower since the Horticultural Center only utilizes electricity. As such, energy improvements in the electrical consumption of the Horticultural Center will yield a greater reduction in carbon produced than a similar reduction in the Greenhouse.

As with energy, it is often useful to consider the intensity of the carbon emissions of an organization. The carbon footprint may be normalized by area, using the same square footage of facilities as in the normalization of energy consumption, but another useful metric to consider is the amount of carbon produced per person. While normalization by area can be very effective in determining the efficiency of built structures the carbon footprint includes several factors which are not a part of the operation of the facilities, such as commuting and air travel. Determining the carbon intensity using both factors presents a clearer picture of the carbon production of an organization and provides additional points for comparison and benchmarking.

For the Morris Arboretum in FY15, the annual amount of carbon produced per square foot (considering the areas of all of the facilities) is 12.55 kgCDE/sqft (kilograms of carbon dioxide equivalent per square foot), but this is reduced to 7.10 kgCDE/sqft when carbon sequestration credits are included. By comparison, the University of Pennsylvania main campus has a carbon intensity of 24.37 kgCDE/sqft, which is reduced to 18.45 kgCDE/sqft when the purchased wind energy RECs are included. While it may initially seem to indicate that the main campus is performing very poorly by comparison, it is important to consider the very different nature of the two sites. While the main campus is located in a dense urban location which encourages high utilization of available space due to the cost of expansion, the more rural nature of the Morris Arboretum does not create as much pressure for compact development. Any urban area will be more likely to have a higher carbon intensity normalized by area compared to rural and suburban locations, purely because of economic and logistical pressures, so considered on its own this normalization does not allow for a direct meaningful comparison.

As carbon intensity normalized by area presents an incomplete picture it is useful to consider other normalization factors. One method which is frequently used is to normalize carbon emissions by the number of people utilizing the site. For the purposes of this report faculty, staff, and students, all of whom utilize the space on a daily basis, will be considered but visitors will not. In FY15 the Morris Arboretum produced 16.1 MTCDE/person in gross emissions and 9.1 MTCDE/person when credits for carbon sequestration are included. By comparison, the main campus of the University of Pennsylvania produced 6.7 MTCDE/person in FY15, and this is reduced to 5.1 MTCDE/person when including the wind energy RECs. Once again, this figure is going to be highly dependent on the density of the population utilizing the space. An urban location is far more likely to favor a high density of people, which will allow for the sharing of some energy expenditures such as space heating/cooling and lighting. The difference in density can be seen when comparing the area per person for each institution. Morris Arboretum provides 1,280 sqft/person, while the University of Pennsylvania main campus only provides 275 sqft/person.

4.0 Conclusions and Future Work

The creation of a carbon footprint is an important first step. Its primary use is to monitor emissions and to provide information for emissions reduction programs: "if you don't measure it, you can't manage it." This section summarizes the work that was conducted, reviews the results obtained and provides some analysis of the roadblocks encountered in gathering data. It concludes with suggestions of potential future work toward a carbon action plan.

4.1- Lessons from the 2015 Morris Arboretum Carbon Footprint

The 2015 fiscal year carbon footprint and the historical footprints for fiscal years 2013 and 2014 show a pattern of consumption that is slightly erratic from year to year in terms of energy usage and emissions. The amount of emissions produced by each potential source had some significant differences from the patterns observed in the carbon footprint of the UPenn main campus. As expected, energy use in buildings accounted for the majority of the emissions produced by Morris Arboretum, with fuel oil accounting for 14.5%, natural gas for 6.5%, and electricity for 41% in fiscal year 2015.

While still producing the majority of the emissions in the footprint, 62%, this is significantly less than the 80-85% produced by the built environment in the University City campuses. This difference is mostly accounted for by the increased role of commuting in the carbon footprint for the Morris Arboretum, 18% of emissions, compared to the 3% seen for the University of Pennsylvania main campus carbon footprint. This is due to the more remote location of the Morris Arboretum and the relatively wider distribution of its employees, which encourages commuting by personal vehicle over public transit. Additionally, the consumption of gasoline and diesel for fleet vehicles and equipment represented 10% of the overall footprint. Efforts to mitigate carbon emissions should therefore focus on the built environment, though some reductions could be achieved in the commuting and fleet gasoline and diesel sectors.

The built environment provides the richest potential for reduction of carbon emissions from the Morris Arboretum. To improve the emissions from the built environment, this initial study should be expanded on to examine in greater detail how each structure is utilizing energy, identifying those buildings which exceed national benchmarks for energy consumption, and how specific improvements might impact energy consumption in those buildings. This initial study identified four buildings which may present opportunities for energy reduction based on the magnitude of energy consumed and the energy intensity in terms of kbtu/sqft: 1) Gates/Carriage House; 2) Widener / Wagon House; 3) the Horticultural Center; and 4) Greenhouse 1. In order to determine the best means of achieving these reductions, the individual buildings and their operations would need to be audited and their performance better benchmarked. This approach will allow for the specific recommendations for projects yielding the greatest impact for the lowest cost, narrowing the area of focus when developing a plan of action.

The second area to consider for the reduction of greenhouse gas emissions is employee commuting. Accounting for 18% of the overall carbon footprint, commuting plays a much more prominent role for the Morris Arboretum than it does for the campuses located in University City. Unlike building renovations or changes in operational procedures to reduce emissions, there are fewer options to reduce the emissions from commuting by executive decision. The many of the factors that lead to increased proportional emissions from commuting cannot be directly controlled, such as the availability of convenient public transportation or the geographic distribution of its employees. Employees can be encouraged to alter their commuting habits using educational programs, providing amenities that increase convenience, or providing direct incentives for participation. In order to provide a more specific suggestion, additional studies would need to be conducted to survey employees regarding existing attitudes regarding their current commuting habits and willingness to participate in various potential programs that would reduce emissions.

One final area which may have potential for substantial reductions in emissions is the use of gasoline and diesel for fleet purposes. Currently accounting for 10.3% of the overall carbon footprint at the Morris Arboretum, it is difficult to say at this juncture how much potential for reductions exists in this sector, either through changes to the physical equipment or in policy regarding its operation. Further study regarding the current use of these fuels may identify specific options for reductions

4.2- Limitations of Current Work

A carbon footprint is only the first step to controlling carbon emissions, but these calculations have several limitations. At this stage these are primarily due to the aggregation of data, either the grouping of physical facilities or by using full years as the unit of study. In addition the data for two utility services—electricity for internal loads and cooling—are currently combined. Currently this data cannot be disaggregated as individual units providing cooling are not separately metered. If in the future metering were available to track electrical consumption for cooling then this information would allow for much better analysis of how each facility uses energy and the factors that influence the magnitude of consumption.

An additional limitation is that several facilities share a meter for some utilities, making it difficult to assign the consumption to a specific building. In particular, a single electric account provides the bulk of the electrical energy consumed at Morris Arboretum, and it is split between the largest buildings and some of the smaller ones. This could lead to several complications in the analysis, particularly if there were a significant discrepancy in the performance of buildings. For this report the only means of disaggregating this consumption was proportionally by area. This could hide buildings that are performing poorly, especially if attached to a building that would perform well. Solutions for this could include the installation of additional metering, energy modeling to calculate expected relative energy performance, or statistical modeling based on construction information.

Even greater benefits could be garnered by a temporal disaggregation of the utility consumption data from these individual facilities or for the campus as a whole. By considering finer units of time than a year or month, further insight can be gained into the usage profile of the facilities, allowing better targeting of reduction-oriented programs and/or periods of unusual activity. Coupled with the disaggregation of the consumption by facility, this would provide a powerful set of data in terms of understanding the patterns of utility consumption on this campus. This could be most easily accomplished with the consumption of electricity with a change of meters and data collection software. Monitoring the consumption of fuel oil and natural gas in finer time increments would represent more of a technical challenge, particularly for fuel oil as its consumption is not directly metered but reported from purchase orders. In addition to providing a better snapshot of energy consumption over the course of a year, the more finely calibrated data would also allow for statistical analysis of the patterns of consumption in response to external factors, such as weather, that affect utility usage. Accounting for these factors makes it possible to determine how much change is due to improvements in operations or is attributable to factors beyond the control of facilities managers.

As mentioned in the previous section, the greatest limitation to the disaggregation of utility consumption will be the availability of sub-metering. Sub-metering at the building or section level for steam, chilled water, and electrical usage at shorter time scales is necessary to provide greater in depth of analysis. This data would facilitate the comparison to the other facilities at the Arboretum or compared to the average performance of similar facilities in the region. However, the costs of collecting this data at this level for the Morris Arboretum may exceed the benefits compared to using data at the current levels of aggregation to perform simpler analyses.

4.3- Potential Future Work

There are several areas of research that could follow from this report, in addition to producing annual carbon footprints for the Morris Arboretum. These include: improved analysis of individual facilities on the site; examination of finer periods of time; statistical analysis of utility consumption to evaluate performance in different time periods, to account for external factors that cause changes in emissions; examination of the commuting habits an preferences of Morris Arboretum employees; analysis of consumption of gasoline and diesel fuels for fleet vehicles and equipment; and the creation of scenarios based on statistical data projecting potential improvements in emissions in the built environment.

The further study of buildings as individual facilities will allow for the establishment of targets and the identification of those activities that consume more or less energy than expected. The identification of trouble areas allows funds for energy savings to be better allocated, providing greater energy saving for less money. In addition to identifying facility sections that are more energy intense, tracking individual areas creates a structure by which energy savings may be incentivized through behavioral programs.

The collection of data on individual facility sections also allows for the construction of statistical models to predict energy consumption or identify unusual patterns of energy consumption based on historical behaviors and correlated external variables, such as temperature. These statistical models can detect faults in HVAC systems and other unexpected energy drains allowing for quicker maintenance. Additionally, they can be used to better gauge the impact from programs or renovations designed to reduce energy consumption by accounting for the impact of external variables. The accuracy of the models, however, is dependent on how frequently data is collected and the size of the area captured by the meters. Daily levels of consumption or shorter periods are necessary for statistical relevance and given the size of the facilities at the Morris Arboretum collecting this data at those time intervals may be cost prohibitive for some buildings or utilities.

Another area of future work is the creation of scenarios based on projected changes in greenhouse gas producing activities. By considering historical trends and consulting projections on future emissions factors for electricity, it is possible to project a baseline of expected future carbon footprints that assumes no dramatic changes operations or policy occur. This provides a point for comparison for other projections based on constructed scenarios. These scenarios could cover a range of situations including: a schedule of renovations of existing facilities; anticipated reductions from implementing behavioral programs aimed at reducing consumption or emissions from commuting; or investment in renewable energy sources or other programs that mitigate carbon emissions. These scenarios help formulate a long term plan that can realistically achieve desired carbon reduction goals.