The University of Pennsylvania Health System
Main Campus Carbon Footprint

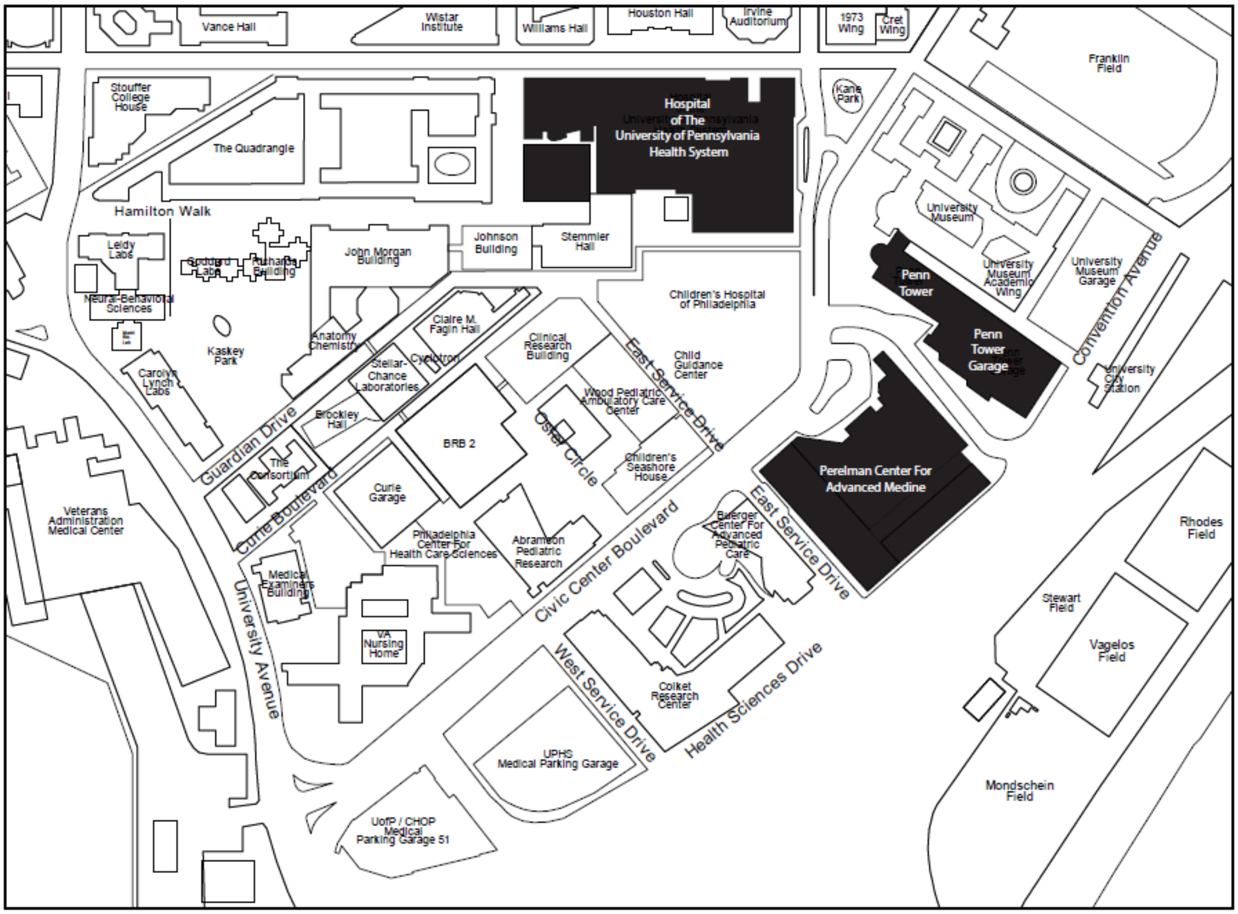

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Table of Contents

Table of Figures

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 University of Pennsylvania Health System campus in University City. The UPHS 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 Morris Arboretum of the University of Pennsylvania 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 UPHS and to calculate the carbon footprint for the current fiscal year, 2015. For historical context, the carbon footprint was also calculated for fiscal years 2012-2014.

The gross emissions during this year were **115,078 MTCDE**, but subtracting the UPHS share of the wind energy RECs purchased by the University, reduces the net emissions to **99,619 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 UPHS campus consisting of HUP, CAM, and the now defunct Penn Tower this is represented by the use of electricity and steam.

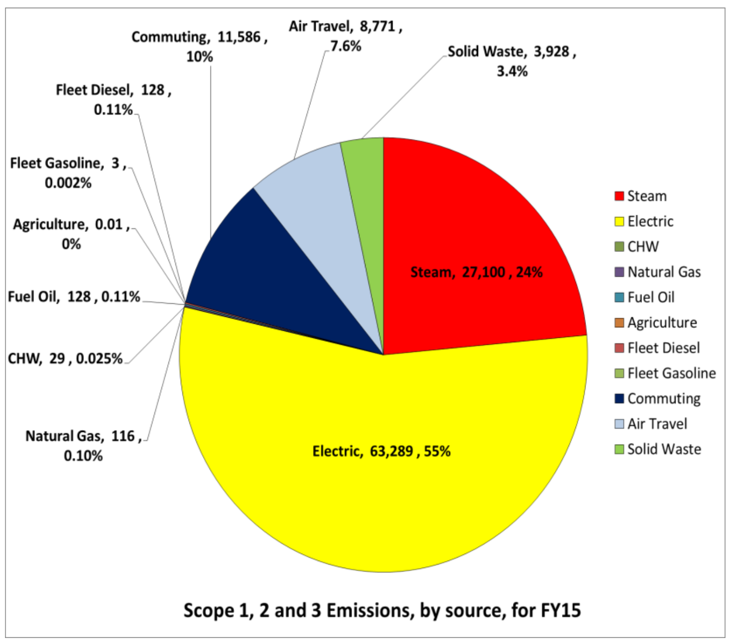

Figure 1- UPHS Carbon Footprint FY15

The UPHS carbon footprint presents a snapshot of the carbon emissions for the UPHS, 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 y ears. 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.

Introduction

This report presents the first greenhouse gas inventory, or carbon footprint, for the main campus of the University of Pennsylvania Health System (UPHS). 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 UPHS office of Real Estate, Design and Construction as part of the President's commitment to extend the Carbon Action Plan too all the units of the University.

1.1 UPHS

The University of Pennsylvania Health System (UPHS) is an organization whose roots stretch back more than two hundred years. Beginning as the Penn School of Medicine, it has steadily expanded its roles as a center for education and research in the medical fields as well as being as one of the premier health systems in the nation, serving the Philadelphia metropolitan region. To facilitate the growth of activities, UPHS has acquired or developed a significant amount of real estate, including major urban hospitals, advanced research facilities, classroom and education buildings, and traditional office space. While the value of the services provided by these facilities cannot be easily quantified, their benefit is obvious.

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 reductions. 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.

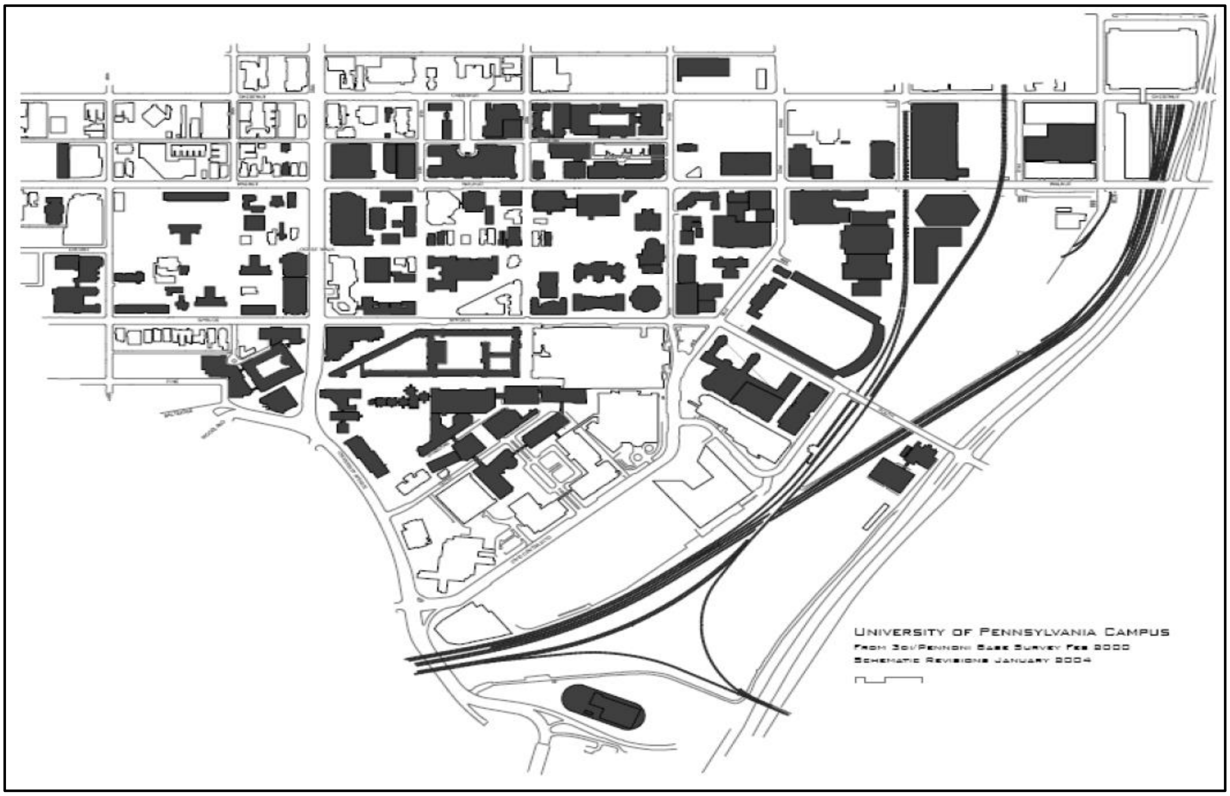

Figure 2- Map of UPenn Carbon Footprint Buildings

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)

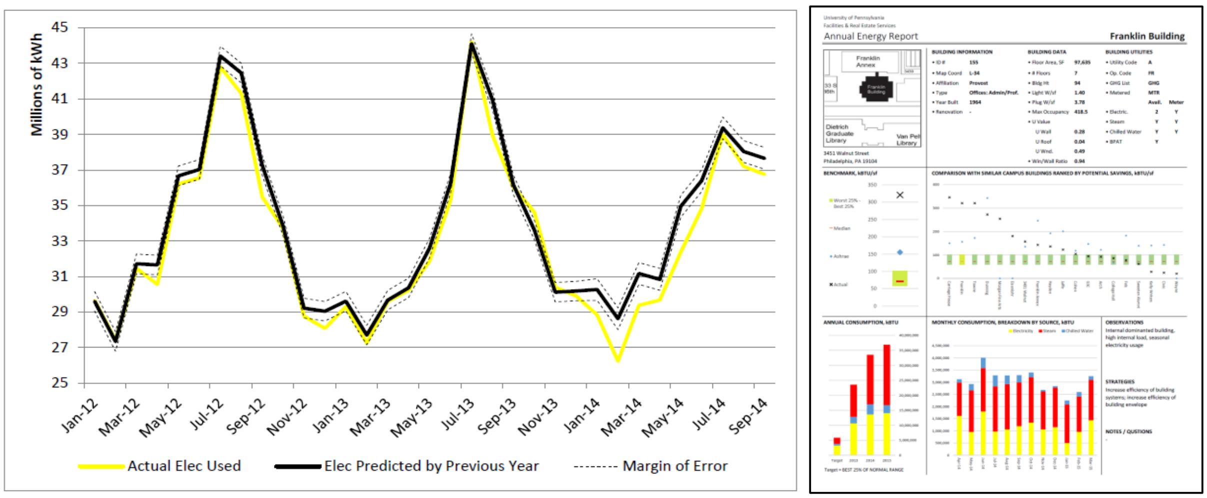

Figure 3- A. Prediction of campus electrical use using historical data, B. Annual Energy Report

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 UPHS 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 UPHS carbon footprint, data gathering focused on the following eight categories, going back to 2012. 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 steam, chilled water, electricity, fuel oil, and natural gas.

2. Transportation through UPHS fleets of cars, vans, buses, and trucks.

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 wind or green electricity credits

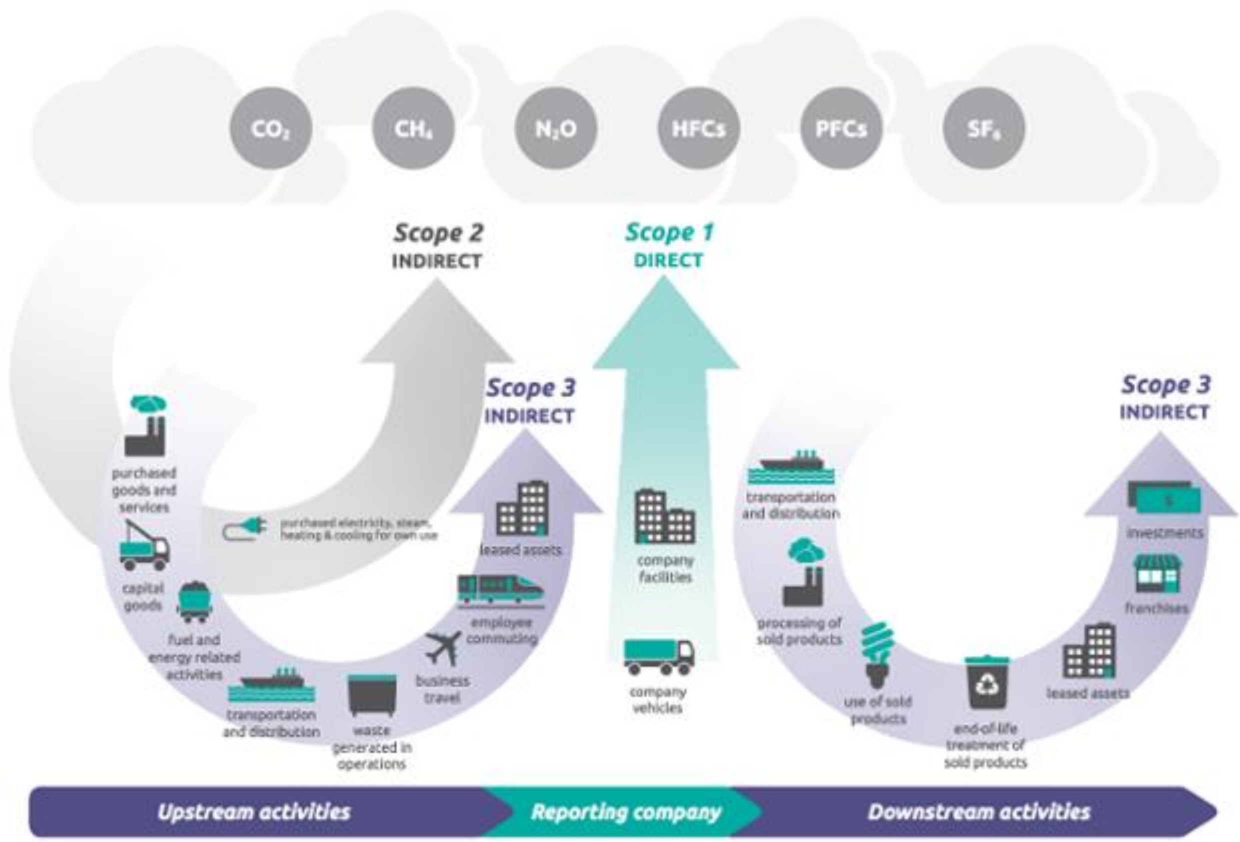

Figure 4- WRI diagram of "scopes" of carbon accounting

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 UPHS 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 2001 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 **Utilities**		MT eCO2/MBTU site energy	kg eCO2/MBTU site energy
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 the actual annual values from Veolia are used. Currently the emissions factor for electricity is derived from the PJM grid supply mix, 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.

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 UPHS Carbon Footprint

This initial UPHS Carbon Footprint includes an examination of the core UPHS campus in University City and only considers consumption at the campus level, rather than that of the individual facilities. Completing a regular carbon footprint for the UPHS will identify the origin of emissions and allow future work to curtail or control emissions.

The core UPHS campus in University City includes the Hospital of the University of Pennsylvania (HUP) complex of buildings, the Center for Advanced Medicine (CAM) Complex, and the Penn Tower and parking garage. Both HUP and CAM are complex facilities comprised of multiple interconnected buildings. CAM includes the Perelman Center for Advanced Medicine, the Smilow Center, and in the future will include the South Pavilion. While Penn Tower is in the midst of decommissioning and will be demolished soon, it is important to catalog the historical production of carbon dioxide from this facility as the activities that produce emissions from that site will be redistributed to other UPHS facilities. The buildings or facilities outside of this core campus are not included, though they can be added using the same protocols.

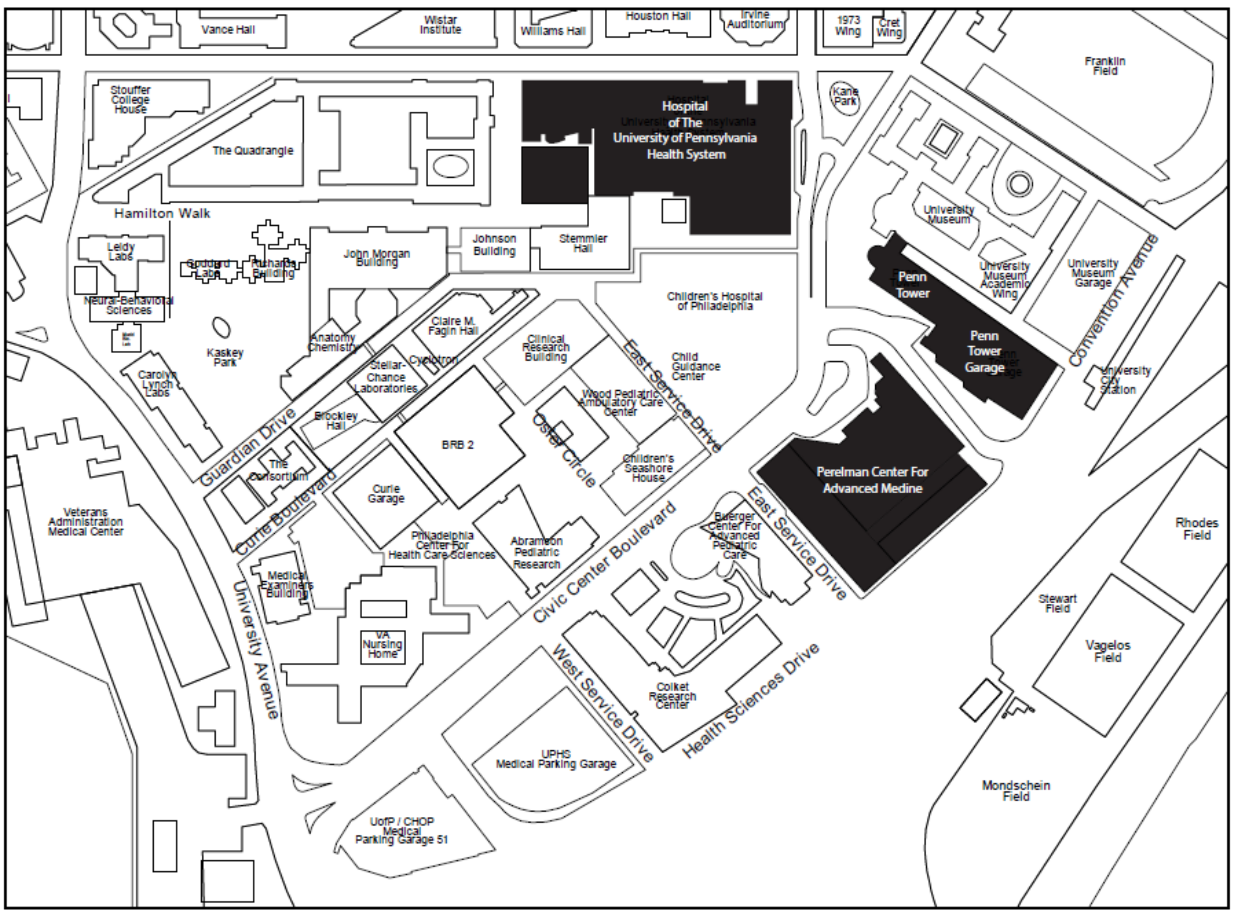

Figure 7- Map of buildings included in FY15 UPHS Carbon Footprint

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 3 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 UPHS system, lighting, equipment, fans, including the majority of the chilled water produced on-site for 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 PJM grid is 0.1384 MTCDE/MMBtu.

Steam- Steam consumption was gathered for all 3 facilities in MLB (thousand pounds of steam). This data was derived from Veolia bills and collected on a monthly basis. Steam is used primarily for heating and other environmental conditioning services. Steam falls within Scope 2, as it is used on campus, but the emissions are produced offsite. The emissions factor for steam 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.

Chilled Water-Most of the chilled water used for cooling is produced on the UPHS campus using electricity provided by PECO, reported in units of kWh, and so is included in the electric utility bills. A small portion of chilled water is drawn from the UPenn campus chilled water loop but is only used by the Smilow Center in the CAM complex on a limited basis to provide additional cooling that is not generated on-site through electricity use. Data for this additional chilled water was derived from UPenn meters monitoring chilled water provided to the CAM building complex. Chilled water falls within Scope 2, as it is used on the campus, but the emissions are produced offsite. Most of the chilled water 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 chilled water in any given year is equal to that for the electricity and is currently 0.1384 MTCDE/MMBtu, about three times as high as for steam.

Natural Gas- A small amount of natural gas is utilized by the HUP facility. 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- Fuel oil is only used in very small amount for the emergency generators and is not considered a significant contributor to greenhouse gas emissions for the UPHS. The emissions factor is 0.0102 MTCDE/gal.

Contact: Peter Zeitz, UPHS Energy Manager; Peter.zeitz@uphs.upenn.edu

2.3- Commuting

Commuting by employees is a significant contributor to the greenhouse gas emissions for the UPHS. Only the emissions arising from employee travel is considered, while the travel by visitors and patients is excluded. The emissions from patients and visitors could be considered in Scope 3 of the UPHS Carbon Footprint, however they are more appropriately considered the Scope 1 and 2 emissions of the patients and visitors. The emissions from commuting to the UPHS University City campus originate from three different sources: car, train, and bus travel. The emissions for each are based on the gasoline, diesel, and electricity used for each. The emissions factor for electricity is the same as described above and varies according the PJM grid electrical generation mix. 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 UPHS. The gallons of gas used for car commuting are not directly tracked by the UPHS and so were estimated from travel data. This is accomplished by using a study which was conducted to determine the commuting habits of UPenn and UPHS employees, students, and visitors to determine the mode, frequency and distance for all employees commuting into the UPHS campus. The values for the number of car commuters, average distance travelled, and average fuel economy are obtained from the report *Campus Circulation: A Study of Multi-modal Access*, 2009, prepared by Orth-Rodgers & Associates and the *University of Pennsylvania Health System: Comprehensive Parking Supply and Demand and Parking Behavioral Study*, 2014, prepared by Tim Haas Engineers & Architects. The average fuel economy of the vehicles being used was obtained from the EPA for the year 2014.

Train Commuting- Smaller numbers of employees commute to work by train. The regional rail system uses a mixture of diesel and electricity to power their trains with a fuel economy of 132.3 miles per gallon of diesel and 6.91 miles per kWh. The number of miles travelled by train commuters each year is estimated in a similar fashion to the data for Car Commuting. The same study contains information on the percentage of employees who commuted in by train. Once the total miles travelled by train commuters for all of UPHS is estimated, the fuel economy for diesel and electricity consumption is used to estimate the gallons of diesel and kWh of electricity used.

Bus Commuting- Smaller numbers of employees commute to work by bus. The SEPTA busses use diesel fuel with a fuel economy of 39.7 miles per gallon of diesel. The number of miles travelled by bus commuters each year is estimated in a similar fashion to the data for Car Commuting. The same study contains information on the percentage of employees who commuted in by bus, the average distance traveled each day, and the number of days travelled each year. Once the total miles travelled by bus commuters for all of UPHS is estimated, the fuel economy for diesel consumption is used to estimate the gallons of diesel.

2.4- Air Travel

Air travel is also a substantial contributor to UPHS 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. Unfortunately, air travel has also proven to be the most difficult component of the UPHS carbon footprint to calculate. World Travel, Inc. handles the travel arrangements for all of UPenn, including travel for the UPHS, and they provided an annual report displaying the total air miles traveled. However, because air travel can be purchased either using a BTA card through the university or paid for on a personal card for which the traveler is then reimbursed, it makes it difficult to determine the proportion of those miles that should be attributed the UPHS air travel versus air travel by the main university. An estimate was reached by comparing the faculty/staff populations of each and dividing the air miles reported by World Travel, Inc. proportionally. Future efforts should continue to refine this method or should encourage the transition to 100% usage of the BTA card for booking travel, as this will allow accurate reporting of air miles travels for both UPHS and the rest of UPenn.

Contact: Mia Teeter, World Travel, Inc.; mteeter@worldtravelinc.com

2.5- Fleet Fuel Usage

The UPHS operates a small fleet of vehicles for shuttle service from the parking lots, material management, and security. The resulting emissions form a small fraction of the overall greenhouse gas footprint for the UPHS. The gallons of gasoline and diesel used by the materials management and security vehicles is tracked and reported annually.

We were unable to make contact with anyone regarding the fuel usage for the shuttles, so this was estimated by examining the type of vehicle (to determine fuel economy), the schedule of shuttle trips (to determine frequency), and the overall length of the shuttle loop (to determine trip length). For the period of time examined, the only shuttle operating serviced the Lot 51 parking area. In mid FY15, additional shuttles began to operate and future footprints will include their fuel consumption. The fuel economy, route length, and frequency are used to estimate annual fuel usage for the shuttles.

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. The fuel consumption for the material management vehicles were reported by Robert Fisher, Director of Materials Management, and Joe Forte, Director of Security.

Contacts: Robert Fisher, Director of Materials Management; Robert.Fisher@uphs.upenn.edu
Joe Forte, Director of Security; Joseph.Forte2@uphs.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 UPHS is currently sent to a landfill without any methane controls, which leads to the highest level of emissions per ton of waste disposed. The UPHS produces two distinct waste streams composed of traditional solid municipal waste as well as regulated medical waste (RMW), however these are both sent to the same type of landfill. Construction waste was considered to be out of scope for this footprint, and should be attributed to the construction companies' footprints instead.

Director of Environmental Services; Steven.Gaynes@uphs.upenn.edu

2.7- Agriculture

The usage of 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. The UPHS uses very little fertilizer at the University City campus and so this category contributes minimally to the overall UPHS carbon footprint and this information is reported by UPHS Environmental Services.

Contact: Steven Gaynes, Director of Environmental Services; Steven.Gaynes@uphs.upenn.edu

2.8- Refrigerants

Though often small in magnitude, refrigerants escaping into the atmosphere can be a significant contributor to the GHG footprint of a facility. Consisting of a number of volatile chemicals, each year some refrigerants are lost and must be replaced. The weights of the refrigerants are multiplied by emissions factors in order to convert the impact of their release into an equivalent amount of CO_2. Direct information regarding the release of the chemicals is not tracked unless it exceeds a specific level; as such it was difficult to estimate these values. This is unlikely to have a significant impact on the carbon footprint as refrigerants are likely to account for less than 1% of the emissions. Future footprints may be able to estimate the amount of refrigerants released by an analysis of purchasing orders over a sufficiently long period of time to determine how much needs to be replaced annually on average.

Contact: Dan Hazley, HVAC Operations Supervisor; Daniel.Hazley@uphs.upenn.edu

2.9- Renewable Energy Credits

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, 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, which may 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 themselves.

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. This bulk purchase of credits is then divided between UPHS and UPenn based on their proportional consumption of electricity. Currently 200,000,000 kWh of wind energy credits are purchased in total, of which 33,502,257 kWh are attributed to the UPHS. As the amount of carbon produced per kWh of electricity varies over time, so too does the value of each kWh of wind energy RECs. Currently the UPHS credits offset 15,459 MTCDE of emissions.

3.0 The UPHS Carbon Footprint

The UPHS 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 renewable energy credits purchased, 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 values utilized to calculate the carbon produced for each activity as well as the combined overall footprint for the UPHS. 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 many of the components accounting 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, therefore they were held constant for previous years. Of the five categories that have significant contributions to the footprint (electricity, steam, commuting, air travel, and solid waste), annual data going back through FY 2012 was obtained for electricity, steam, and air travel. As the commuting data was generated from only two studies, it was impossible to determine how this figure might change from year to year without repeating those surveys, so it was held constant. Solid waste figures for previous years exist and may be used in future reports, but for this footprint were held constant for previous years.

Figure 8, below shows the carbon footprint for the UPHS in FY2015. The gross emissions during this year were **115,078 MTCDE**, but subtracting the UPHS share of the wind energy RECs purchased by the University, reduces the net emissions to **99,619 MTCDE**. The bulk of the emissions, 79%, are created through the provision of utilities to the HUP, CAM, and Penn Tower facilities. Electricity accounts for 55% and district steam accounts for 24% of gross emissions. The remaining 21% is mostly accounted for by commuting, air travel, and solid waste (10%, 7.6%, and 3.4% respectively). Emissions associated with chilled water, natural gas, fuel oil, fertilizer use, and the fleet vehicle were all 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 Penn chilled water, natural gas, etc., 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.

Figure 9 shows the UPHS carbon footprint over time, including FY 2012 through FY 2015. This shows a carbon footprint that has remained largely static. Small deviations from year to year may indicate a trend of carbon intensification from FY12-FY14, with a reversal leading to a significant reduction from FY14 to FY 15, 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.

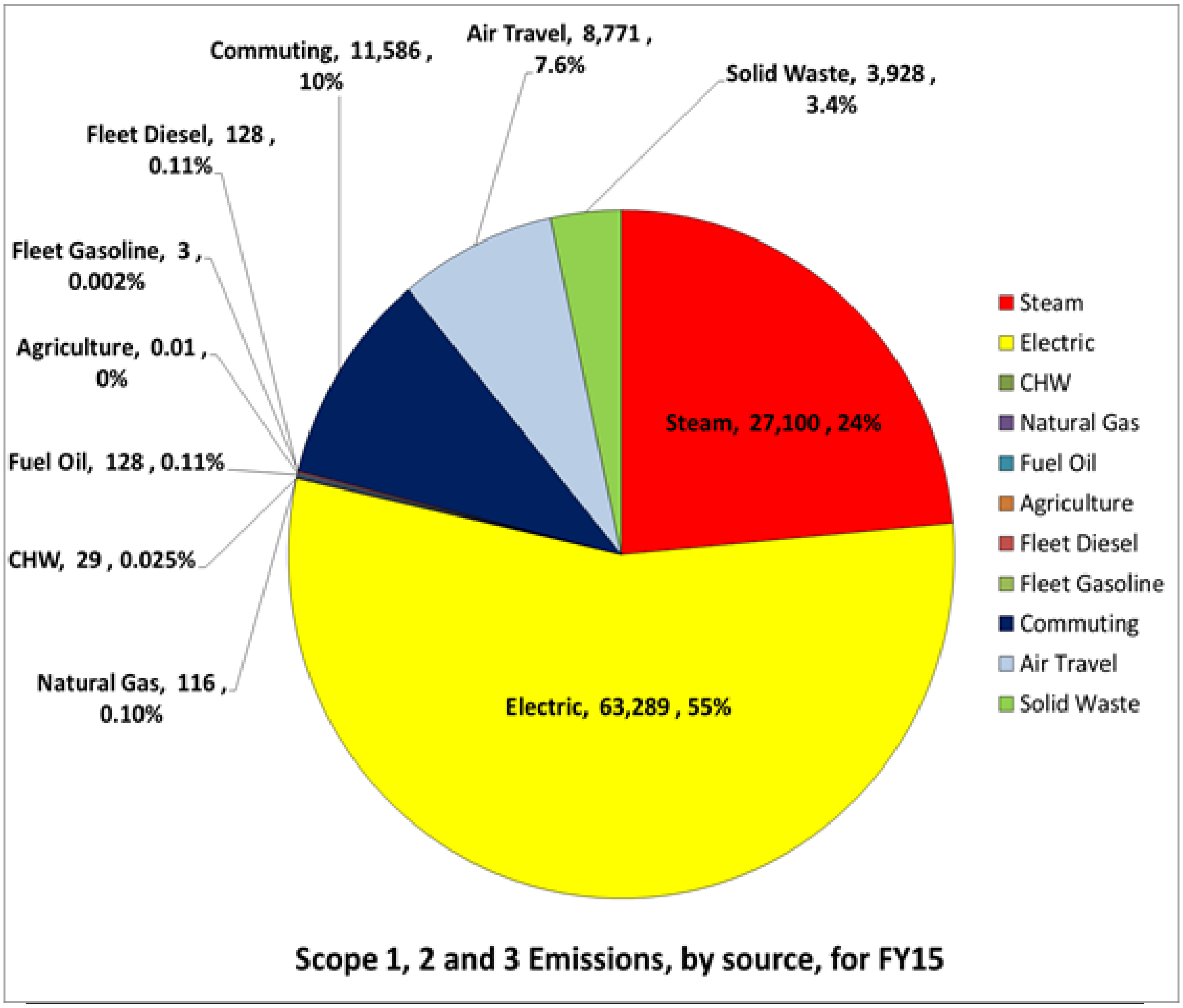

Figure 8- The UPHS 2015 Carbon Footprint, by source of emissions

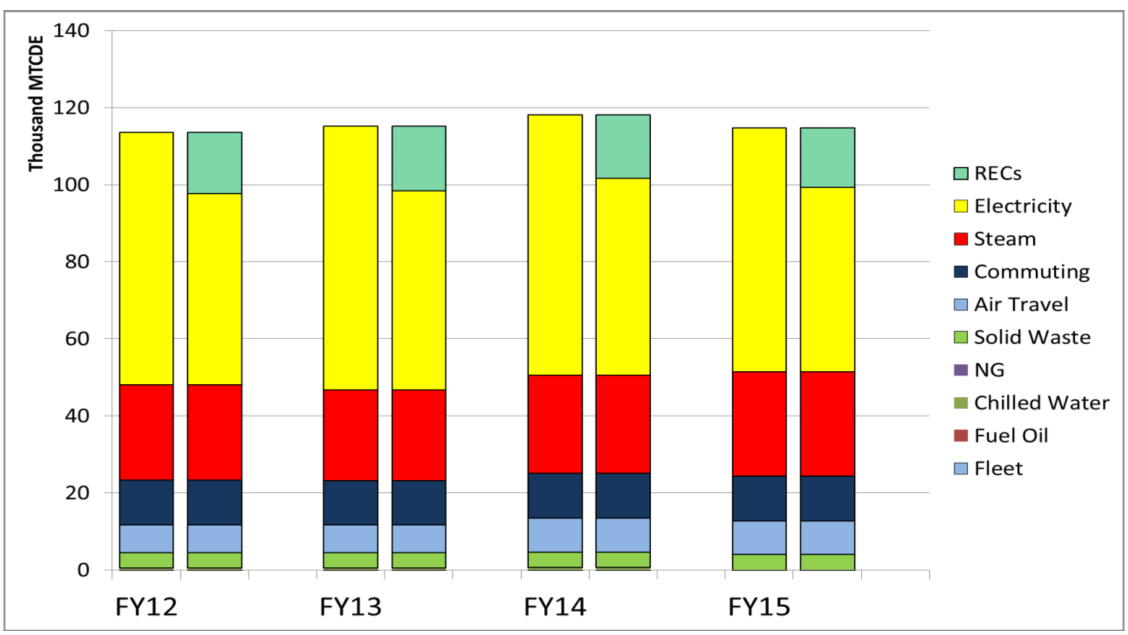

Figure 9- Carbon Footprints for FY 2012-2015, by source of emissions, with and without Renewable Energy Credits (RECS)

1- UTILITIES

MTCDE	Annual		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
63,289	137,238,036	Electricity (kWh)	14,542,986	12,625,475	12,638,200	11,455,256	4,973,441	11,917,307	10,890,071	11,449,751	10,918,959	10,516,626	12,460,735	12,849,229
27,100	449,510	Steam (Mlb)	21,446	22,686	21,490	28,187	44,253	50,910	61,890	59,444	50,519	33,732	32,834	22,119
29	62,348	CHW (kWh)	0	62,348	0	0	0	0	0	0	0	0	0	0
116	20,531	NG (ccf)	1,857	1,618	1,695	1,736	1,565	1,909	1,691	1,664	1,707	1,903	1,513	1,672
128	12,360	Fuel Oil (gal)												

2- Fleet

	Annual		Security	Cargo	Shuttle
3	285	Gasoline (gal)	245	40	
128	12,578	Diesel (gal)		288	12,290

3- Refrigerants

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

4- Commuting

10,720	1,217,935	Gasoline (gal)
464	46,738	Diesel (gal)
402	699,226	Electricity (kWh)

									Electric	Gasoline	Diesel
	7,380	# 5 day/week employees							Electric	Gasoline	Diesel
	820	# 2 day/week employees							kWh/mi	gal/mi	gal/mi
Train	22	% trips	847,880	trip/yr	5.7	mi/trip	4,832,916	mi/yr	0.14468		0.00756
Bus	7	% trips	269,780	trip/yr	1.5	mi/trip	404,670	mi/yr			0.02521
Car	56	% trips	2,158,240	trip/yr	13.6	mi/trip	29,352,064	mi/yr		0.04149	

5- Solid Waste

792	800	Medical Waste (short tons)
3,136	3,168	Solid Waste to Landfill (short tons)

6- Air Travel

8,771	11,290,003	Annual Air Miles

7- RECs

-15,459	33,502,257	Wind Elec (kWh)

200,000,000	Total Penn Wind Credits
72,289,601	HUP Annual Elec
431,550,634	Upenn Annual Elec (campus+HUP)

8- Fertilizer

0	9	lbsN
0	9	lbsP

Figure 10- Tabulated Inputs and MTCDE for UPHS

3.1 Carbon from Utilities

The consumption of utilities was collected as monthly aggregations in the units of consumption. The primary contributors were electricity and steam, which provide the bulk of energy services within the UPHS facilities. Chilled water usage was reported as very low, because it only includes the chilled water fed into the Smilow Center in the CAM complex from the main university loop. The majority of the chilled water used for cooling by UPHS is produced using electricity at local chiller units. The majority of the energy used for cooling is thus incorporated into the totals for electrical consumption. Metering of chilled water usage and electrical consumption for chilled water generation at UPHS is becoming available, so in future years, an effort should be made to determine the amount of electricity being used to provide chilled water for cooling. Natural gas is used in the buildings, but for limited purposes and is wholly overshadowed by the usage of steam and electricity. Finally, the use of fuel oil was recorded only in terms of annual consumption as our initial research indicates it is used on a very limited basis and it is not tracked as rigorously.

Annual		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
137,238,036	Electricity (kWh)	14,542,986	12,625,475	12,638,200	11,455,256	4,973,441	11,917,307	10,890,071	11,449,751	10,918,959	10,516,626	12,460,735	12,849,229
449,510	Steam (Mlb)	21,446	22,686	21,490	28,187	44,253	50,910	61,890	59,444	50,519	33,732	32,834	22,119
62,348	CHW (kWh)	0	62,348	0	0	0	0	0	0	0	0	0	0
20,531	NG (ccf)	1,857	1,618	1,695	1,736	1,565	1,909	1,691	1,664	1,707	1,903	1,513	1,672
12,360	Fuel Oil (gal)												

Figure 11- Utility Inputs

3.2 Carbon from Fleet

The fleet consists of those vehicles operation by the UPHS in normal operations. Three areas contribute to the UPHS fleet including: security, maintenance, and the parking shuttle. Both security and maintenance operate a limited number of vehicles which see low annual mileage, but the shuttle operates continuously, accounting for a large proportion of the fuel consumed in the operation of the fleet (~95%). In addition to directly consuming fuel, the shuttle also supports parking infrastructure that may encourage employees to commute to work by driving rather than by taking public transit, which may indirectly increase emissions from this sector. Using the Lot 51 shuttle schedule it was determined that the shuttle makes 1,719 loops each week, traveling 1.1 miles each time, for a total of 98,327 miles travelled each year. With a fuel economy of 8 miles per gallon the estimated consumption of diesel by the Lot 51 shuttle is 12,290 gal of diesel.

This value was very small and historical information was not available so the data for fiscal year 2015 was used for the historical footprints for fiscal years 2012 through 2014. Carbon footprints in following years should obtain the new consumption data for that year. Additional effort should be made to contact the office running the shuttle regarding fuel consumption, as current levels are estimated based on route and frequency, while fuel consumption for security and maintenance are reported directly by those departments.

Annual		Security	Cargo	Shuttle
285	Gasoline (gal)	245	40	
12,578	Diesel (gal)		288	12290

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 any large organization, and being in a major metropolitan area with a widespread public transit network only increases the difficulty. The methodology to determine these emissions begins with a determination of how many employees are commuting and how many trips they make each year, which can be assumed by whether or not they are full time or part time employees. The trips made by patients and visitors are not considered to be within the scope of this footprint. These trips are then broken down into the modes of travel by determining the percent of commuting that occurs via cars, busses, or trains. The population distribution of the UPHS employees provides an estimate for the average distance traveled via each mode, which when combined with the number of trips per year taken in each provides the total annual miles travelled by bus, car, or train. The average fuel economy of each mode of transportation is known and so the total amount of gasoline, diesel, and electricity used for commuting can be estimated from this information.

Future carbon footprints may be able to provide more accurate information regarding the percentage of employees travelling by each mode and the distances travelled, but this will require additional survey work to directly gather the needed information from a sampling of UPHS employees and staff. Current data is derived from the reports *Campus Circulation: A Study of Multi-modal Access*, 2009, prepared by Orth-Rodgers & Associates and the *University of Pennsylvania Health System: Comprehensive Parking Supply and Demand and Parking Behavioral Study*, 2014, prepared by Tim Haas Engineers & Architects.

1,217,935	Gasoline (gal)
46,738	Diesel (gal)
699,226	Electricity (kWh)

									Electric	Gasoline	Diesel
	7,380	# 5 day/week employees									
	820	# 2 day/week employees							kWh/mi	gal/mi	gal/mi
Train	22	% trips	847,880	trip/yr	5.7	mi/trip	4,832,916	mi/yr	0.14468		0.00756
Bus	7	% trips	269,780	trip/yr	1.5	mi/trip	404,670	mi/yr			0.02521
Car	56	% trips	2,158,240	trip/yr	13.6	mi/trip	29,352,064	mi/yr		0.04149	

Figure 13- Inputs for Commuting

3.5 Carbon from Solid Waste

Solid waste is the largest contributor to greenhouse gasses for the UPHS system 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 significantly higher, about 50 times more impactful. The UPHS 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. A significant amount of waste is also generated by construction activities; however, construction waste is not typically included in the carbon footprint for institutional operations. This comes down to the idea that emissions should be counted in a footprint only if there is operational control over the activity. As such, the emissions from construction waste would be attributed to the construction company as they manage and dispose of the waste without intervention or management by UPHS. As a minor portion of the carbon footprint, the data for fiscal year 2015 was used for historical inputs in fiscal years 2012 through 2014. In future years the actual values will be reported and the data for FY12-FY14 could be updated.

800	Medical Waste (short tons)
3,168	Solid Waste to Landfill (short tons)

Figure 14- Inputs for Solid Waste

3.6 Carbon from Air Travel

Emissions from air travel also required some estimation. While the UPHS books travel through World Travel, Inc., which tabulates air miles travelled and carbon produced, a great deal of travel is booked using personal funds and then reimbursed. It is impossible to disambiguate air miles that were booked in the fashion for UPHS air travel from those that were similarly booked for travel by employees of the UPenn main campus. As a result, the UPHS was assigned a proportional amount of the total air miles traveled as reported by World Travel, Inc. based on the proportional employee numbers of the UPHS and UPenn main campus as reported in the reports *Campus Circulation: A Study of Multi-modal Access* and *University of Pennsylvania Health System: Comprehensive Parking Supply and Demand and Parking Behavioral Study* referenced in section 3.4. The proportion of the total air miles assigned to UPHS = Total Miles * (UPHS Employees / (UPHS + UPenn Employees)), which determined that UPHS was accountable for approximately 36% of the total air miles travelled. Better methods for determining air travel and properly attributing it to departments and organizations should be developed. Until then the data gathered for FY2015 was used for historical production of carbon dioxide emissions in FY12 through FY15 for UPHS.

11,290,003	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. The UPHS uses only a limited amount of fertilizer at the University City campus due to the limited exterior grounds requiring intensive landscaping. Only 10 gallons of fertilizer were utilized in FY2015, which lead to the release of 9lbs each of nitrogen and phosphorous. Due to the small nature of this value historical usage of fertilizer was not explored but was instead assumed to be constant for all years considered. Subsequent carbon footprints should collect new levels of consumption for following years.

9	lbs n
9	lbs ph

Figure 16- Inputs for Fertilizer

3.8 Carbon RECs

The final component of the footprint to be considered are the wind energy renewable energy credits (RECs). The University of Pennsylvania purchases 200,000 MWh. These are divided between the University main campus and the UPHS based on the proportional usage of electricity. This breakdown leads to the UPHS receiving 33,502 MWh of wind energy RECs. While the total number of RECs purchased by UPenn has recently been held constant, the proportion attributable to UPHS remains dependent on the respective use of electricity by the main UPenn campus and the UPHS campus and so should be updated annually.

33,502,257	Wind Elec (kWh)

200,000,000	Total Penn Wind Credits
72,289,601	HUP Annual Elec
431,550,634	Upenn Annual Elec (campus+HUP)

Figure 17- Inputs for RECs

3.9 Energy Consumption by the Built Environment

The consumption of energy in buildings accounts for 79% of the total carbon footprint for the University of Pennsylvania Health system, so this section will more closely examine how and where this energy is being consumed among the health system buildings and facilities. It is useful to consider both the magnitude of the consumption in each facility and the intensity of that consumption. The largest energy users within a group of buildings are a natural place to seek strategies for reductions of emissions.

Magnitude is only one indicator of how effectively energy is being utilized to accomplish the goals of the facility. Hospital A might use more energy than Hospital B, but if they are treating many more patients for that energy use then Hospital B may be the better target for energy reductions. Numerous metrics are typically utilized to evaluate the energy intensity of a facility, the common factor used for normalization is the floor area of the facilities. The energy intensity is reported 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.

For this report, energy is metered at the building level for three facilities: Penn Tower, the Hospital of the University of Pennsylvania, and the Perelman Center for Advanced Medicine. Both HUP and PCAM consist of many interconnected facilities, but since they are metered together they have to be evaluated as a whole. The consumption of steam, electricity, chilled water, and natural gas was considered, however the modest fuel oil consumption could not, at this time, be attributed to specific facilities.

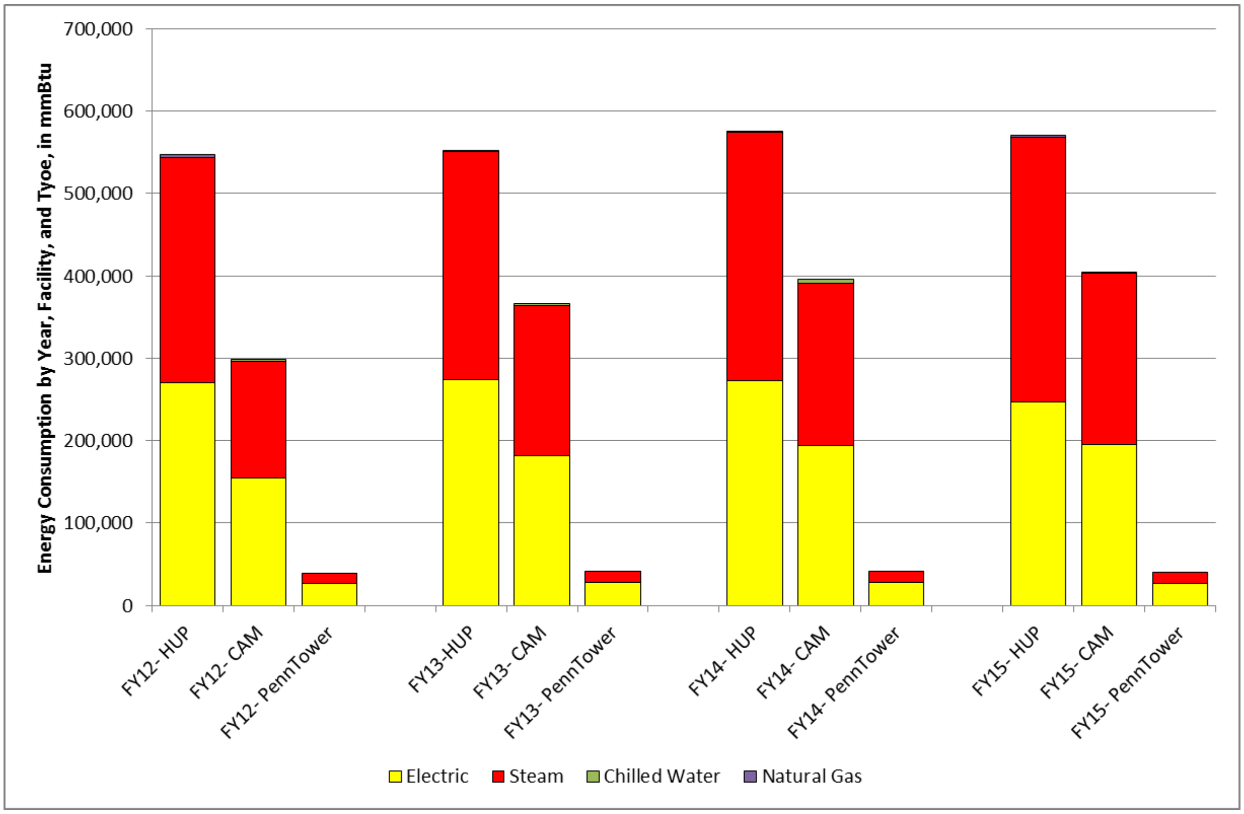

Figure 18- Energy Consumption by Facility, in mmBtu

Figure 18, shows the total energy consumption for each of the three facilities in units of MMBtu, which allows for the direct comparison of the consumption of steam, electricity, and natural gas. The largest of the facilities, HUP, is the greatest consumer of both electricity and steam, totaling 570,331 MMBtu in FY15. While earlier years show a nearly even split in the use of steam and electricity at HUP, by FY15, steam usage has increased to account for 56% of energy use while electricity only accounts for 43%. A small amount of natural gas was also used at HUP but it was small comparatively.

PCAM is a smaller facility than HUP, but uses nearly as much energy. In FY15, PCAM used 403,769 MMBtu of energy, of which 48% is electricity and 51% is steam. Small amounts of chilled water were also obtained from the University loop, but most of the chilling is produced on site so included in the electricity. The energy usage at PCAM shows a steady pattern of increasing energy usage at this facility, a 35% increase between FY12 and FY15. This is likely due to the expanding nature of this facility, construction activities, and the addition of personnel from Penn Tower as it closed. This increase accounts for nearly all the increased emissions from the built sector over the examined period.

Penn Tower utilized a much lower level of energy than either HUP or PCAM, due to its smaller size and different utilization. This consumption remained nearly constant over the time period examined, with energy usage in FY15 of 40,701 MMBtu, 65% in electricity and 35% as steam. As this facility is no longer being used and is currently being demolished, this historical consumption will be the baseline for the facilities that replace its uses.

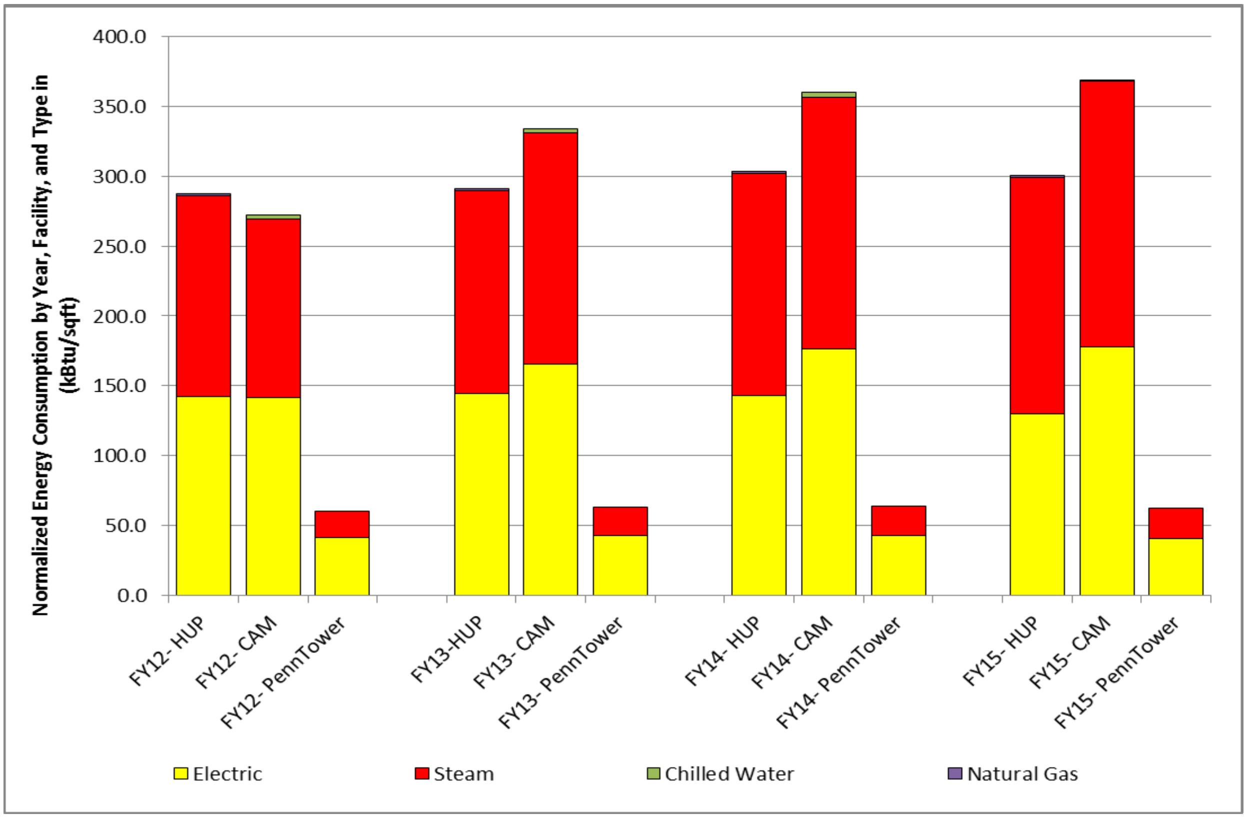

Figure 19- Energy Intensity by Facility, in kBtu/sqft

Figure 19, above, shows the energy consumption data normalized to the area of each building. Energy intensity is a useful means of comparing the relative performance of buildings as it accounts for the size of the facilities. It can also be useful to compare building energy per person, or by other metrics specific to a facility, such hospital beds. Tracking the precise floor area of the UPHS facilities as they undergo construction and demolition was beyond the scope of this study, so these are approximate energy intensities. In general, floor areas that were in use at the end of FY2015 were utilized for the spaces that were operational for the majority of that year. In addition, because of their interconnected nature, some areas excluded from the area calculation may receive energy from meters that serve other sections of the facility.

HUP's floor area was estimated at 1,900,000 sqft; PCAM's area was estimated at 1,100,000 sqft (not including parking garage, South Pavilion, or South Tower); and Penn Tower was estimated at 650,000 sqft. This yielded an energy intensity for HUP in FY15 of 300 kBtu/sqft and for PCAM of 361 kBtu/sqft.

According to the preliminary Energy and Carbon report developed by the energy team for the New Patient Pavilion, the national mean energy intensity for inpatient medical buildings is 227kBtu/sqft, however the report indicates that energy intensities between 300 and 350 kbtu/sqft are typical for comparable Philadelphia hospitals, such as Thomas Jefferson University Hospital, Jefferson Hospital for Neuroscience, and the Children's Hospital of Philadelphia. Penn Tower has a significantly lower energy intensity than either HUP or CAM, which is expected from an office and outpatient activities inserted into a hotel. Penn Tower's energy intensity was calculated at 62.7kbtu/sqft and was relatively constant from FY12-FY15. This level of energy intensity is low compared to other similar facilities.

MMBTU	Electric	Steam	Chilled Water	Natural Gas	Total
FY12- HUP	270,496	273,426	0	2,712	546,634
FY12- CAM	154,853	140,822	3,049	0	298,724
FY12- PennTower	26,867	12,235	0	0	39,102
FY13-HUP	274,493	276,005	0	1,850	552,348
FY13- CAM	181,795	181,536	3,075	0	366,406
FY13- PennTower	27,664	13,356	0	0	41,019
FY14- HUP	272,135	301,452	0	2,256	575,843
FY14- CAM	193,368	197,097	4,675	0	395,139
FY14- PennTower	27,678	13,693	0	0	41,371
FY15- HUP	246,652	321,523	0	2,156	570,331
FY15- CAM	195,290	208,267	213	0	403,769
FY15- PennTower	26,315	14,387	0	0	40,701

KBTU/SQFT	Electric	Steam	Chilled Water	Natural Gas	Total
FY12- HUP	142.4	143.9	0.0	1.4	287.7
FY12- CAM	141.2	128.4	2.8	0.0	272.4
FY12- PennTower	41.4	18.8	0.0	0.0	60.2
FY13-HUP	144.5	145.3	0.0	1.0	290.7
FY13- CAM	165.8	165.5	2.8	0.0	334.1
FY13- PennTower	42.6	20.6	0.0	0.0	63.1
FY14- HUP	143.2	158.7	0.0	1.2	303.1
FY14- CAM	176.3	179.7	4.3	0.0	360.3
FY14- PennTower	42.6	21.1	0.0	0.0	63.7
FY15- HUP	129.8	169.2	0.0	1.1	300.2
FY15- CAM	178.1	189.9	0.2	0.0	368.1
FY15- PennTower	40.5	22.1	0.0	0.0	62.7

Figure 20- Tabulated energy consumption and intensity by facility, year and type

The key finding at this stage of analysis is that the HUP complex is the largest source of energy consumption and carbon emissions and so warrants deeper auditing to identify cost-effective energy reduction strategies. The fact that the data shows PCAM to have a higher energy intensity could be attributed to many causes, including a higher physical density of usage, higher intensity kinds of equipment (Proton therapy), and mixes and areas of use that are not captured in the data.

The more important message of the carbon footprint is revealed in Figure 21, showing the total carbon emissions for each facility. Because the carbon intensity for electricity is about 4 times as great as that for steam or natural gas, the carbon emissions from all the buildings are dominated by electric use. Electricity is used for cooling, air-handling, lighting, and the many kinds of equipment used in a hospital, so initial strategies for carbon reduction should focus on auditing and evaluating the many uses of electricity.

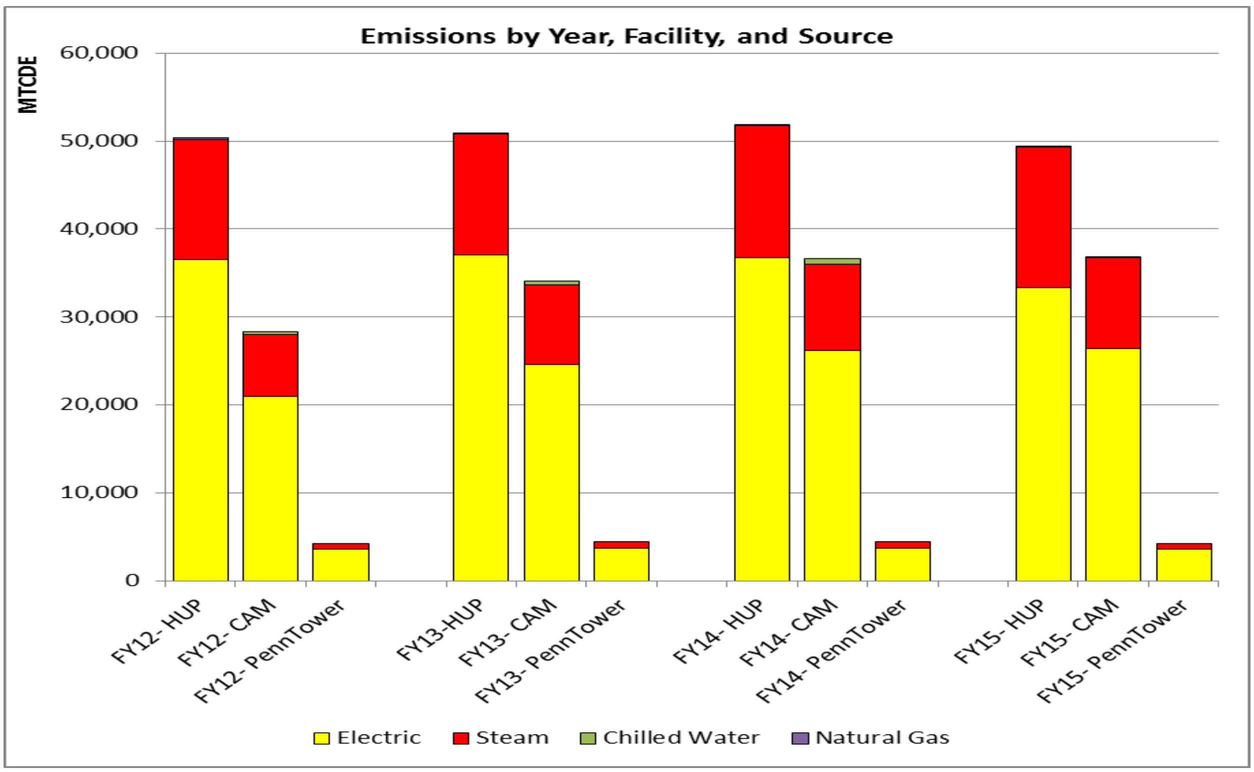

Figure 21-eCarbon emissions by Facility, in MTCDE

4.0 Conclusions and Future Work

The creation of a carbon footprint is an important first step. Its primary use is to to provide information for emissions reduction programs. As the saying goes, “if you don’t measure it, you can’t manage it.” This section summarizes the work that was conducted, reviews the results obtained, and concludes with suggestions of future work toward a carbon action plan.

4.1- Lessons from the 2015 UPHS Carbon Footprint

The 2015 fiscal year carbon footprint and the historical footprints for fiscal years 2012 to 2014 show a pattern of consumption that is relatively stable from year to year in terms of energy usage and emissions, with variations attributable to expansion of the facilities and weather. The distribution of carbon emissions were similar to the carbon footprint of the UPenn main campus. As expected for a service facility, energy use in buildings accounts for the vast majority of the emissions produced by UPHS, with steam accounting for 24% and electricity for 55%. Commuting and air travel account for the next 10% and 7.6% of emissions, with the disposal of solid waste producing the final 3.4%. Other sectors produce carbon or other greenhouse gasses at levels that are insignificant by comparison.

Efforts to mitigate carbon emissions should therefore focus on the built environment, though some reductions could be achieved in the commuting and air travel sectors. One consideration for future work is an improved methodology for collection of data in these areas. While excellent data is available for building utility usage, commuting and air travel both involve some amount of estimation. Air travel in particular is not well tracked and while total miles traveled can be determined for the entire campus, it has been difficult to disaggregate them. For commuting modes and patterns additional surveys may be required to monitor changes.

The built environment provides the richest potential for reduction of carbon emissions from UPHS. In order to determine the best means of achieving these reductions, the individual buildings and their operations will need to be audited and the uses of energy disaggregated to identify opportunities for cost-effective reductions. In addition to this kind of recommissioning, an approach originally developed by Architecture 2030 has also been implemented for the main campus, which is to use the regular cycle of renovation as the opportunity for energy reduction by dramatically increasing the energy standards for future work.

UPHS plans to continue growing, which will only add to total emissions, so the highest standards should be adopted for new construction. The arguments for that approach are well laid out in the UPHS Concept Phase Energy Report (Draft) circulated in November of 2015, which provides an initial list of energy efficiency strategies for the New Patient Pavilion, many of which could be applied to existing buildings as they are renovated or upgraded. These suggestions include:

1. Installation of microturbines for the onsite cogeneration of steam and hot water
2. Enhanced lighting design beyond that required by ASHRAE 90.1-2010 code, including increased use of LED lighting and decreased overall illumination levels
3. Energy recover wheels on return AHUs
4. Heat recovery chiller sized for base hot water loads

5. Konvecta heat recovery systems with efficiency up to 75%
6. Installation of rooftop solar hot water heating systems
7. Limiting window to wall ratios to 27%
8. Installation of rooftop photovoltaic arrays to directly offset electrical consumption
9. Ensuring wall U-values of 0.064 for all construction types

4.2- Limitations of Current Work

A carbon footprint is only the first step to controlling carbon emissions, and 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 and chilled water—are currently combined. While some chilled water usage is monitored when it is drawn from the main campus loop, the majority of the chilled water used by HUP, PCAM, and Penn Tower is produced internally using electric powered chillers, whose usage is not separately metered.

The disaggregation of the UPHS Carbon Footprint by facility and smaller units within facilities would allow for a much improved analysis of the performance of the individual facilities. Currently it is impossible to calculate the energy intensity of the different activities for areas within PCAM or HUP, which would allow more precision in identifying opportunities to improve energy usage. It would be especially useful to be able to separately consider the different segments within each facility as each wing, tower, and expansion is utilized for different and highly specialized purposes, which have different construction and renovation histories. At this stage, however, metered data only exists at the level of the three facilities.

Other benefits can be garnered by a temporal disaggregation of the utility consumption data from these individual facilities or for the UPHS University City campus as a whole. By considering finer units of time than a year, 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.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.

Sub-metering electrical usage at the building or section level (which would disaggregate cooling) would provide the information most useful for reducing carbon emissions. This data would facilitate the comparison to the other campus facilities or compared to the average performance of similar facilities in the region.

The next step for UPHS is to develop carbon reduction goals and an action plan for reaching those goals. The ambitious standards being discussed for the New Patient Pavilion exemplify the kinds of leadership that is required.

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 UPHS and helping to develop an Action Plan. These include: improved analysis of individual facilities on the campus; 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; and the creation of scenarios based on statistical data projecting potential improvements in emissions in the built environment.

The disaggregation of the facilities into smaller components 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 a variety of 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 and composition of the Hospital of the University of Pennsylvania and the Perelman Center for Advanced Medicine, each of which is consists of several wings or sections, it would also be advisable to consider each section separately.

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 and steam, 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 additional renewable energy sources. These scenarios help formulate a long term plan that can realistically achieve desired carbon reduction goals.