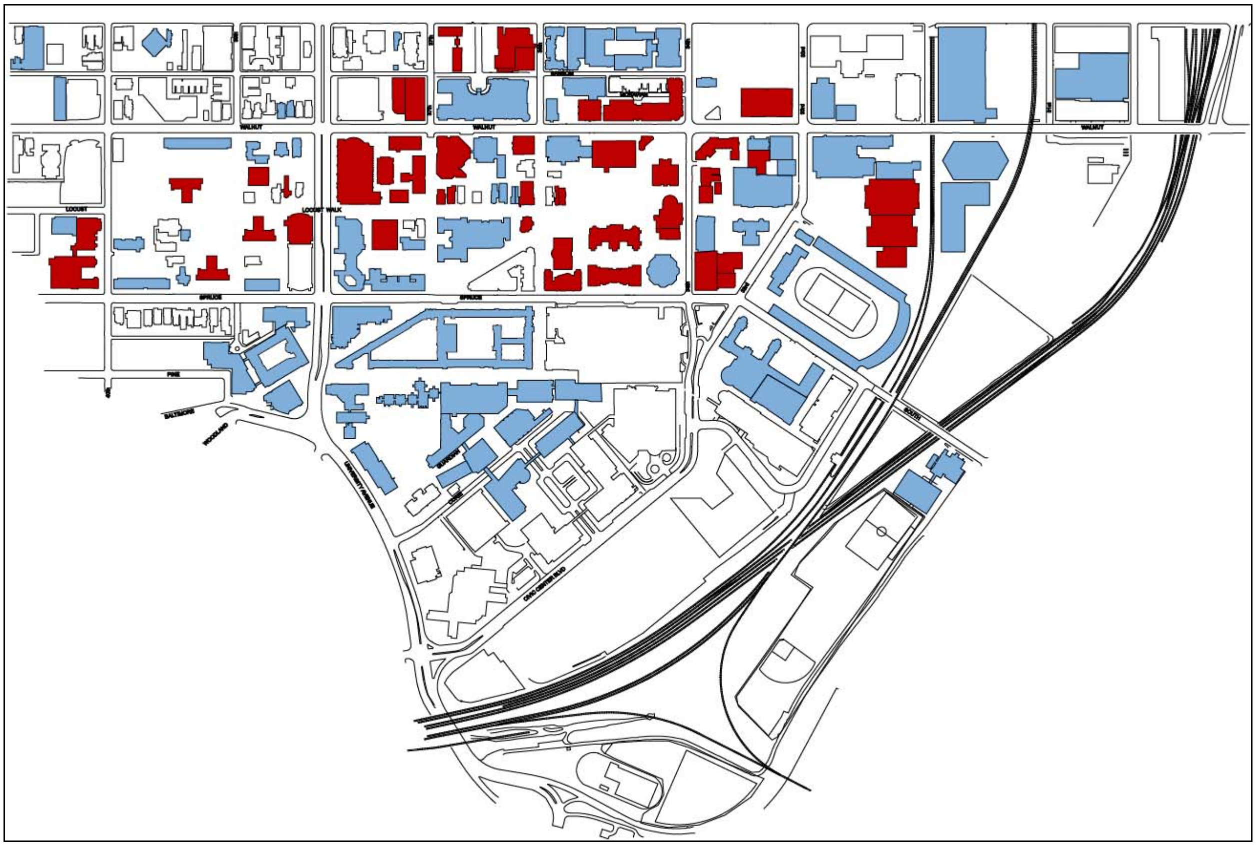
UNIVERSITY OF PENNSYLVANIA SUSTAINABILITY AND AUDIT PLAN

Phase II: A normalized and calibrated algorithm for cost allocation and decision making



Phase II Report

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BuildingSimulationGroup

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I Introduction

The Penn Sustainability Plan began as part of Penn's determination to improve its environmental performance. Much of the initial focus was on energy usages and costs, but the initial study inquired broadly about environmental indicators and effects, from water use to transportation to health. The first phase of the project commenced in the 2005-06 academic year with four broad components:

1. Develop overall campus sustainability goals
2. Develop environmental audit strategies for campus buildings and procedures
3. Conduct a comprehensive energy audit for selected buildings and produce calibrated performance simulation models for these buildings
4. Identify strategies for achieving campus sustainability goals

The work of Phase I provided a preliminary analysis of the University's overall environmental performance, identified major performance indicators, and developed sustainability goals for the campus. The much more demanding task of auditing and evaluating individual campus buildings was subsequently elaborated into two additional phases to be conducted over two years.

Phase II, of which this report is a summary, extended over the 2006-07 academic year and produced energy audits of about a third of the buildings on campus. Since campus buildings are not individually metered for heating and cooling, a new web-based tool was developed and calibrated to estimate the energy consumption of individual buildings– Building Performance Assessment Toolkit Plus (BPAT+). The tool is aimed at facilitating strategic energy planning for the campus and is conceived, in the absence of metering, as a possible replacement for the current cost allocation model.

Phase I concluded with four recommendations, of which the second became the primary task for Phase II and III. The explanation of that recommendation is reproduced here to introduce this report:

> *Perform BPAT audits on all campus buildings to identify performance improvement strategies*
> *Penn does not currently meter individual buildings for heating and cooling, or sub-meter them for electrical usage, allocating utility costs to the schools according to a crude model that does not accurately reflect the energy usage of individual buildings. For the purposes of identifying and evaluating successful performance improvement strategies for the campus for it is imperative that the University develop more precise and useful information about the energy performance characteristics of its campus buildings.*
>
> *Metering existing buildings is expensive, costing $50,000-70,000 per building, and by itself does not indicate which aspects of the building contribute to energy usage. The project team has developed a less expensive technique of assessing building performance that will be applied to all campus buildings over the next two years, enabling the development of precise strategies for improvement. Audit techniques cannot wholly replace the data that would be provided by metering and sub-metering, which is still the only way to actually know how much energy is consumed by an individual building, but they can provide answers to the strategic questions that need to be answered.*
>
> *The Building Performance Assessment Toolkit (BPAT) is decision making tool. It is a technique for auditing and quickly calculating normative, "as-built" energy performance, and it can also be*

used to identify the effect of changing or improving the building. As a normative assessment tool, it can't provide insight into operating or maintenance problems, but it will provide a carefully quantified performance description of every building on campus and allow the first, best understanding of what energy is used for and how it can be used more efficiently.

Deep Audits and Simulation *techniques are more expensive and time-consuming than the BPAT audit, but may be necessary in some cases to assess the effect of more complex or dynamic performance techniques, or to identify operating and maintenance problems.*

BPAT also provides a more reliable method than the current cost allocation model and can be used as a replacement for the current model until metering is introduced. When metering is introduced, which we do recommend, the tool can be easily calibrated with that information and be used to investigate how the energy is consumed within each building to provide better energy planning.

This document provides a report of the second phase of the sustainability plan, specifically the development of the Penn Building Energy Database (PBED), of the BPAT+ audit tool with calibrating procedures, and an initial analysis of BPAT+ results for the buildings studied during this phase.

II Campus Building Audit

The main campus of the University of Pennsylvania comprises about 140 buildings designed, constructed, and repeatedly renovated over many years. It is important to understand the building composition in terms of both the physical systems that are in place and their operation. In order to assemble the data for energy performance audits, both physical surveys and the collection of metered data were carried out. The result is Penn Building Energy Database (PBED), which includes all the relevant information about campus buildings necessary to complete a BPAT+ calculation. PBED is a 'living database' that can be updated regularly as and when buildings are renovated or altered.

2.1 Penn Building Energy Database

Penn Building Energy Database survey data includes information about the building type, size, envelope (building materials), occupation, lighting, plug loads, and HVAC systems. Additionally, electricity consumption data for FY2006 is included for those buildings which have electricity meters. Currently, PBED comprises of data from 50 buildings and is available online via the BPAT+ website. These data were determined based on numerous visits to each building and building documents such as as-built drawings and building specifications.

2.2 Buildings Selected for Phase II Building Audit

Building	Building Type	BPAT+ Results Available?
1920 Commons	Catering	Yes
250 S. 36th St (Castle)	Accommodation	No
3401 Walnut St	Office	Yes
3537 Locust Walk	Office	No
Addams	Office	Yes
Annenberg Center	Assembly	Yes
Bennett	Office	No
Caster	Office	Yes
Chem Labs: 1958 Wing	Penn Labs	Yes
Chem Labs: 1973 Wing	Penn Labs	Yes
Chem Labs: Cret Wing	Penn Labs	Yes
College Hall	Office	Yes
Colonial Penn Center	Office	Yes
Duhring	Office	Yes
Evans Building	Health Care	Yes
Fisher	Office	Yes
Franklin Building	Office	Yes
Gimbel	Sports	Yes
Grad B (Sansom West)	Accommodation	Yes
GSE Building	Office	Yes
Harnwell	Accommodation	Yes
Harrison	Accommodation	Yes
Hill	Accommodation	No
Hillel at Steinhardt Hall	Office	Yes
Houston Hall	Office	Yes

Building	Building Type	BPAT+ Results Available?
Huntsman Hall	Office	Yes
Hutchinson	Sports	Yes
ICA	Assembly	Yes
Jaffe	Office	No
Kelly Writers House	Office	No
Levine	Office	Yes
Locust House	Office	No
Logan Hall	Office	Yes
McNeil Building	Office	Yes
Meyerson	Office	Yes
Morgan	Office	Yes
Music	Office	Yes
Music Annex	Office	Yes
Nichols (Sansom East)	Accommodation	Yes
Palestra	Sports	Yes
Pottruck	Sports	Yes
Rodin	Accommodation	Yes
Schattner Center	Health Care	Yes
Solomon	Office	No
Squash	Sports	No
Stiteler	Office	Yes
Sweeten Alumni Center	Office	No
The Arch	Office	No
Van Pelt Library	Office	Yes
Williams	Office	Yes

Table 1 50 Buildings Selected for Audit in Phase II

Fifty campus buildings were selected for audit during this phase. Data sets were collected for all 50 buildings. The buildings selected included 30 office-classroom buildings, 7 dormitories and residences, 5 athletics facilities, 3 laboratories, 2 health care facilities, 2 assembly halls, and 1 dining hall. This approximates the overall allocation of space on the campus, though laboratories constitute a larger proportion of the campus than of this initial group. The 50 buildings and their types are indicated in Table 1.

Of the 50 buildings audited this year, 11 buildings lacked the information for complete BPAT+ results at the time of this report. 8 buildings are not metered for electricity while 3 buildings had metered data which was inconsistent with the surveyed lighting and plug loads. Data for those 11 buildings will be clarified and concluded in Phase 3.

Of the 39 buildings for which complete BPAT+ results are available, there are 22 office-classroom buildings, 5 dormitories and residences, 4 athletic facilities, 3 laboratories, 2 health care facilities, 2 assembly halls, and 1 dining hall.

2.3 Building Audit: Surveyed Data

The following sections describe the information collected or calculated for each building, and then entered into the database.

2.3.1 General Building Information

Building types: Each building is assigned one of ten building types based on its primary function. Types include accommodation, assembly, catering, educational (K-12), clinical health care, non-clinical health care, office, Penn labs, retail, and sports. Buildings with large areas of different distinct functions may be subdivided into multiple sectors, each with a unique type.

Building size (floor areas & height): The gross and net areas of all thermal enclosures (building skins) and the building height were calculated using as-built drawings of the building.

Occupation: The building occupancy was calculated using the Philadelphia Building Code[1]. For spaces with fixed seating (such as an auditorium), the occupant load was determined by the total number of fixed seats[2]. For all other spaces, occupant load was calculated based on function and floor area[3]. The values given by the Building Code are the maximum allowable occupation for a particular building. The typical occupation number, as utilized by BPAT+, was determined as 50% of the maximum occupation.

2.3.2 Building Envelope

U-Values: The coefficient of heat transmission (known as the “u-value”) is a measure which describes a material or building envelope’s heat conduction capability. The u-value was determined for each different thermal enclosure type for each building (for example, the roof, windows, and exterior walls will all have different u-values). This value is calculated using the thermal resistance (“r-value”) for each material used in the building envelope. The r-values for each material type were determined based on information in the as-built drawings of the building and the building specifications. Where these values were not available, they were estimated based on standard material types.

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[1] March 1999 edition, Section B-1008.0: Occupant Load
[2] B-1008.1.6: Fixed Seats
[3] Table B-1008.1.2: Maximum Floor Area Allowances per Occupant

Solar Heat Gain Coefficient (SHGC): The solar heat gain coefficient is a fractional value (from 0 to 1) representing the percentage of solar heat that can pass through a specific material. This value was determined for each window material type in each building using information from the as-built drawings and building specifications. Where this value was not available, it was estimated based on standard glass types.

2.3.3 Lighting and Plug Loads Power

Lighting Survey: The total installed lighting wattage was determined for each building based on individual building audits. Members of the team visited each room or space within the building, noting the type, wattage, and number of bulbs in each light fixture. Wattages were determined by actual bulb inspection where possible. Where inspection was not possible (for example where lighting was concealed in ceiling fixtures), wattage was estimated based on standard bulb types. The result of the lighting survey is a list of all lighting fixtures in each of the 50 buildings surveyed during this phase, a determination of the total installed wattage due to lighting in each building, and a calculation of the installed lighting wattage per net square foot for each building. See Appendix A.2 for the lighting survey table.

Plug Loads Survey: The total installed plug load wattage was also determined for each building. As with lighting, individual audits were required to determine this value. Members of the team recorded the number and type of each plug load in each room or space within the building. Plug loads include all electrically powered devices except for lights and mechanical equipment, such as computers, printers, clocks, personal heating and cooling devices (for example, space heaters and window A/C units), and so on. Wattages were determined by inspecting the device where possible. Where inspection was not possible, the wattage was approximated based on standard values. The result of the plug loads survey is a list of all plug loads in each of the 50 buildings surveyed during this phase, a determination of the total installed wattage due to plug loads in each building, and a calculation of the installed plug load wattage per net square foot for each building. See Appendix A.2 for the plug load survey table.

2.3.4 Fan and Pump Power

Fan Power: The total installed horse-power for fans was determined for each building. This value was determined based on both as-built drawings and individual building audits. During building audits, members of the team were accompanied by FRES engineers, who determined the HP for each accessible fan. When fans were not accessible (for example, if located in a ceiling), values were estimated. In certain cases, as-built drawings did not indicate any fan information and all fans were located in inaccessible areas of the building. In these cases, the total HP was estimated based on the building type and total floor area.

Pump Power: Although BPAT+ does not require the pump power, these values were determined during building audits for many of the buildings.

2.3.5 HVAC Systems

HVAC Systems: With the help of FRES personnel, six categories of HVAC system types were developed and each of the buildings surveyed was assigned an HVAC category type. Many of the buildings on campus have similar systems, receiving heating from steam and cooling from chilled water. Of these, campus buildings may differ in terms of ventilation types (natural, forced, or combination) and controls (thermostats available). Additionally, certain campus buildings are not on the steam or chilled water loops and must generate their own heating and cooling. The established HVAC types included all cases of systems types found in the 50 buildings surveyed during this phase.

2.4 Building Audit: Metered Data

Many of the buildings on campus are metered for electricity. Metered data is useful as it reflects the actual energy consumption at the building level. Penn buildings are not metered for steam or chilled water. Steam and chilled water consumption may not bear any discernible relationship to the electricity consumption, so metered electricity data alone cannot predict total building performance. However, this data is useful in that it supplements BPAT+ calculations. The combination of calculated and actual (metered) consumption provides to provide a more accurate assessment of total performance than calculated data alone.

III Campus Energy Performance Assessment

3.1 Necessity for a New Tool

Energy performance simulation has reached a very high level in the last decade, and a variety of simulation tools have been developed to facilitate the accurate prediction of building energy performance, including detailed dynamic behaviors, system interactions, air movement, and so forth. While these software packages can provide accurate results, the quality of the output depends on the precision of the data that is provided to the software. This process can be very time consuming for even a modestly complex building, and requires experience, judgment, and consistency to make the results meaningful. These types of performance simulations can be expensive to prepare and typically provide more detailed and sophisticated information than is necessary for strategic decision making. What Penn required was a tool which could provide a simple assessment of building energy performance and provide a good normative output. The tool developed to meet this goal is the Building Performance Assessment Toolkit Plus (BPAT+). BPAT+ is based on readily available information, is sufficiently accurate to rank campus buildings, can be used to identify useful strategies for action, and has the potential to be used as an alterative for the current cost allocation model. It provides a kind of "triage" technique for evaluating campus buildings, allowing both inefficiencies and opportunities for the greatest gain to be readily identified.

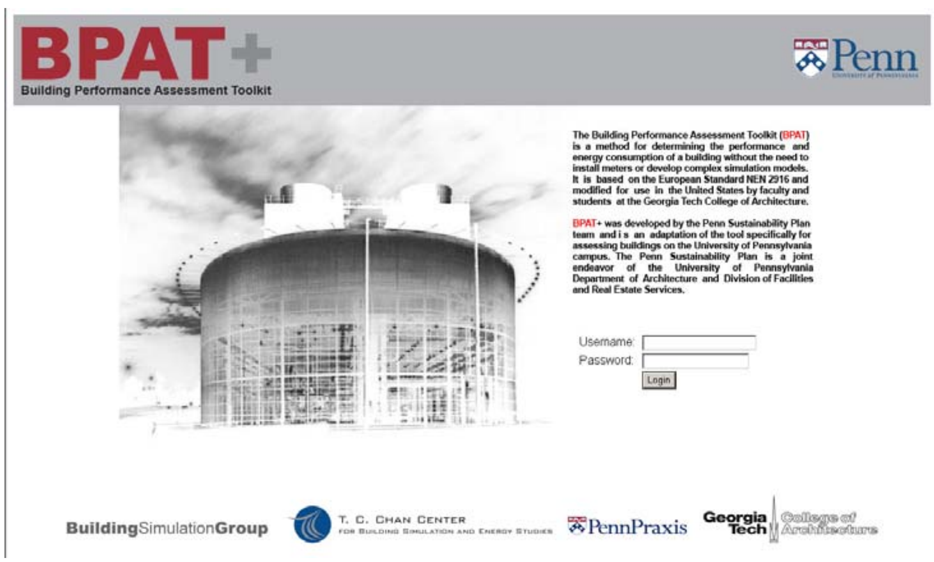

Figure 1 Web-based BPAT+ (https://domus.design.upenn.edu/BPAT+)

BPAT+ was developed during Phase II as a robust, online tool. The tool necessitates input data as described in Section 2 and uses this data to perform quick calculations of a building's annual energy consumption. The equations used in BPAT+ are based on European Standard NEN 2916. The development of BPAT+ from the original standard is described in Section 4.

It is important to note that BPAT+ is not a dynamic simulation, but instead uses a normative, steady-state approach. BPAT+ can only predict performance within a broad range, and is primarily intended for comparative analysis. However, the survey data assembled in the Building Energy Database can be used for many kinds of analysis, simulation, or projection, and constitutes a useful resource for strategic planning.

IV Building Performance Assessment Toolkit Plus (BPAT+)

4.1 NEN 2916

BPAT+ provides normative measures of building energy consumption based on European Standard "NEN 2916: Energy Performance of Non-Residential Buildings, Determination Method." NEN 2916 includes steady-state algorithms based on empirical data and dynamic simulations of European buildings. These algorithms were calibrated on a set of existing buildings for which dynamic simulations were also conducted for calibration purposes. NEN 2916 has subsequently been expanded to become the European norm (ISO TC163) on which progressive new building energy codes have been based. Appendix A1 discusses the structure of NEN 2916 in greater detail.

4.2 BPAT+ Development

BPAT+ was developed from an American adaptation and automation of NEN 2916 prepared for the General Service Administration (GSA) by a team from the Georgia Tech College of Architecture. This tool was called the GSA Toolkit. The GSA Toolkit was developed specifically for the GSA and only incorporated those aspects of NEN 2916 which were required for the GSA. For use on Penn's campus, the BPAT+ was developed by both increasing the functionality of the GSA Toolkit to include all aspects of NEN 2916 and by modifying certain components to refer specifically to Penn (Figure 2).

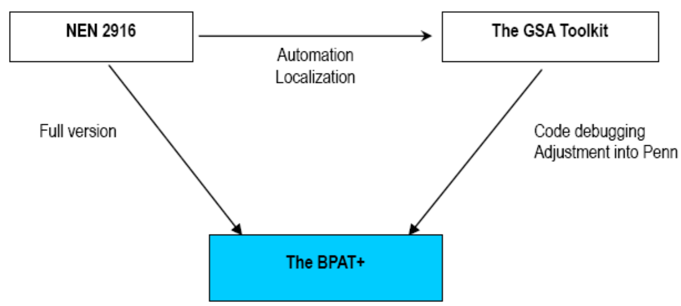

Figure 2 Relationship between provisions for the determination of the energy consumption for heating and comfort cooling (From NEN 2916)

BPAT+ development occurred in two phases – the original GSA toolkit code was modified to BPAT (which featured full NEN 2916 functionality) and the BPAT was then converted to BPAT+ (taking into consideration the local climate data and specific information pertaining to Penn campus). Figure 3 compares the frameworks of the original GSA Toolkit with that of BPAT+.

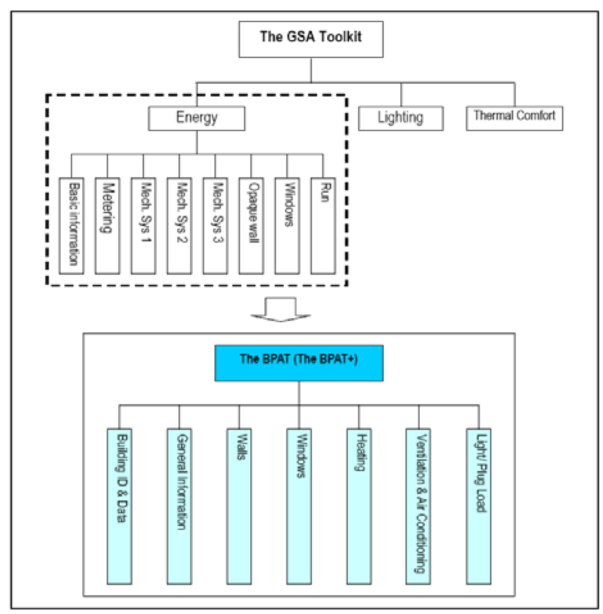

Figure 3 Comparing Frameworks of System between GSA Toolkit and BPAT+

4.2.1 Conversion from GSA Toolkit to BPAT

The "GSA Toolkit" is a program that a team from Georgia Tech's College of Architecture had previously created using "NEN 2916:1998." This program automated major portions of NEN 2916. The existing code was used as the basic framework for the BPAT+, and this code was debugged and adjusted so that the full version of NEN 2916 was included according to former NEN analysis.

The GSA Toolkit included preliminary tools to evaluate lighting and thermal comfort in addition to calculating energy consumption. These were not necessary for BPAT and BPAT+, as these tools deal strictly with energy consumption.

4.2.1.1 Debugging

The first stage in the development of BPAT from the GSA Toolkit included debugging. The debugged items include the following:

Domestic Hot Water

The original Toolkit code gave an NaN (division by zero) error for domestic hot water energy consumption value when "Steam" was chosen for domestic hot water production (Mech. Sys. 2 tab on the GSA Toolkit). The original code contained a typo which sets the generation efficiency of the domestic hot water to 0. The code was changed to set the generation efficiency of the domestic hot water (ngen;dhw) to a value of 0.45 when steam is chosen (ngen;dhw ,Table 34, 12.6.2 in NEN 2916).

Ventilation

The original Toolkit code gave an NaN (division by zero) error for Heating, Cooling, and Fans energy consumption values when "Only Natural Ventilation" was chosen for Ventilation System (Mech. Sys. 2 tab on the GSA Toolkit). The original code specified a value of 0 for factor a constant depending on the indoor climate system of energy sector (csys, 7.3.2.2 in NEN 2916), which is later used as a denominator in the equation for the computation value of the effective power in energy sector (Peff, 7.3.3.1 in NEN 2916). The code was changed to specify a value of 0 for the computation value of the effective power in energy sector (Peff) when "Only Natural Ventilation" is chosen.

Humidification

The original Toolkit code gave a 0 value for Humidification energy consumption values when "Natural Supply and Mechanical Exhaust" or "Mechanical Supply and Exhaust without Mechanical Cooling" were chosen for Ventilation System (Mech. Sys. 2 tab on the GSA Toolkit). The original code did not specify any value for the specific air flow of direct entering fresh outside air to be heated, due to mechanical ventilation during operation time (uvme) factor to present in the Humidification energy consumption equation (11.4 in NEN 2916). The code was changed to specify this value according to Section 6.5.3.3 in NEN 2916.

Heat Gain

The original Toolkit code gave an NaN (division by zero) error for heat gain (Qgain) values during the summer months when "Only Natural Ventilation" (Mech Sys 2 tab on the GSA Toolkit) was selected for Ventilation System. The original code specified that transmission heat loss (Qtr) is 0 when the outside temperature is greater than the inside temperature (for example, during summer months). When "Only Natural Ventilation" is chosen, the ventilation heat loss (Qvent) is 0. The denominator would equal 0 during summer months when "Only Natural Ventilation" was chosen because the denominator for the gain-loss ratio (6.6.5.2 in NEN 2916) is the sum of heat loss (Qtr + Qvent). This led to errors in the utilization factor for heat gain (nb;heat) and heat gain (Qgain) calculations. Code was modified so that the utilization factor for heat gain (nb;heat) and heat gain (Qgain) values were set to 0 during that particular set of circumstances.

4.2.2.2 Modifications

Besides debugging the original code, the “GSA Toolkit” was modified such that the full version of NEN 2916 was included and so that the interface would be more comprehensive and user-friendly. BPAT fully reflects and automates all aspects of NEN 2916, with the exception of certain systems options which are not relevant to Penn’s campus buildings.

The major modifications and enhancements of BPAT include the following:

Energy Sectors

The GSA Toolkit assumed that a building consisted on only one energy sector and did not allow for data from multiple energy sectors to be input. Code has been modified so that a building can have 1, 2, or 3 energy sectors with unique input values. While most calculations allowed for simple summation of consumption by energy sector in order to obtain the consumption for the whole building, modifications were necessary in the ventilation/fans calculations (the computational value of the effective power in the energy sector (Peff) and related factors, Section 7.3.3.1 in NEN 2916).

Building Types

The original Toolkit code did not specify factors for building types other than “Office”, with the exception of the specific energy consumption for light (eli in Table 21 in Section 8.2.3) values. If the user were to choose a building type other than “Office”, the specific energy consumption for light (eli) value would have been correct for that building type while the other factors would have been set for those of “Office” type. Correct factors for the various building types were added for equations regarding ventilation (6.5.2.1 in NEN 2916), heat gain (6.6.5.2 in NEN 2916), utilization for cold (10.6.1 in NEN 2916), humidifying (11.2 in NEN 2916), and domestic hot water usage (12.3.2 in NEN 2916). In addition, the building type “Penitentiary” was eliminated from the list of choices as this building type is not relevant to Penn’s campus.

Window u-values

The Toolkit interface only allowed for a single u-value to be used for all windows. It also only allowed for 12 windows total. Code and interface were changed so that up to 20 windows could be specified, each with unique orientation, SHGC, shading devices, and u-values.

Opaque Wall Types

The Toolkit only allowed for a single type of opaque wall to be specified for all walls entered (Type A: Open to air, Type B: Below grade, Type C: Connected to adjoining heated space). This meant that below-grade walls or spaces connected to other buildings could not be treated separately. Original interface allowed for 12 opaque walls total, including roof. Code and interface were changed so that up to 20 opaque wall sections could be specified, each with unique orientation, u-value, and type.

Units

Original Toolkit used metric units for input and output (for example, area in m2, u-values in W/m2-K, energy consumption in MJ). Code and interface were modified to all for SI units as input and output (for example, area in SF, u-values in BTU/hr-sf-°F, energy consumption in kBtu).

Security

Original Toolkit interface used an individual password for each building. To modify or look at results for any building, the user was required to use the individual password for the desired building. Code and interface were modified so that two usernames exist, one for “Guest” and one for “Admin”, where the Guest account only allows the user to view the results pages for all buildings that have been input. The Admin account allows the user to modify input and run results for all buildings. Also, the current program has a secured https:// address.

Building Selection and ID

Original Toolkit automatically assigned a number to each building and required use of that number to select the building for input editing or to run the results. Code and interface have been modified so that the user can specify a specific number for each building. The user can now select the building from a pull-down menu based on building name or number.

Auto-Save

Original program required the user to save the input values on each page. In addition, the building’s ID number and password needed to be entered each time a save was desired. Code and interface was modified so that the input values are saved automatically and the building only needs to be selected once, at the beginning of each editing session.

Format and Interface

General formatting was changed for all pages to include appropriate logos, etc. The naming and organization of tabs was changed so to clarify the data input for each page. Additionally, many input fields were relocated so that similar data input is grouped appropriately. In BPAT, general data such as area, building type, occupancy, etc is grouped in the first page. Information about materials follows (separated into two groups: “Walls” for opaque materials and “Windows” for transparent materials. Systems information, previously divided into groups simply called “Mech 1, 2, and 3” have been reorganized by function (“Heating”, “Ventilation and A/C”, and “Lighting and Plug Loads”). Results can be seen by clicking on the final tab. Finally, all data input fields which are not relevant to Penn campus buildings have been deactivated (for example, fields for information about photovoltaics). The deactivated fields can be reactivated in the event that they become relevant to any new or renovated campus buildings.

4.2.2 Conversion from BPAT to BPAT+

BPAT+ is a modified version of BPAT which has been further adapted towards Penn’s campus buildings. Many values used in the NEN 2916 equations are specified by building type. However, in certain cases, FRES and the Penn Sustainability team have been able to collect more precise data. Some of this data is specific to the campus (for example, set point temperatures) and some is specific to individual buildings (for example, installed lighting wattages). BPAT+ uses these values instead of the NEN standard values. Additionally, metered electricity consumption data is used in conjunction with the BPAT+ calculated consumption data.

The modified components or procedures in BPAT+ include the following:

4.2.2.1 New Building Type “Penn Labs”

A new building type was added for Penn lab buildings as this category is not present in the NEN 2916 standard. The new building type uses the same factors as the “Office” type with the exception of fvent, fraction of the time that ventilation is operational, which was set to be the same as the “Health Care – Clinical” building type (fvent = 0.80). These choices were made because Penn Labs often operate on the same schedule as an office/classroom but use increased ventilation.

4.2.2.2 Set Point Temperature

The current Toolkit code specifies a temperature of 21.1°C. NEN 2916 specifies various set point temperatures based on building type. The BPAT+ code was modified so that the user can elect to input a set point temperature specific to the building or default to the typical set point temperature of Penn campus buildings. The input allows for the temperature to be entered in °F. The default set point temperatures in BPAT+ have been set to be 68°F for winter and 78°F for summer, the standard set points for Penn campus buildings.

4.2.2.3 Lighting and Plug Load Power Densities

The NEN and original Toolkit code used a standard or average density for lighting power and for plug load power based on building type. The BPAT+ code was modified so that an actual lighting or plug load power density, calculated through building surveys, could be used as input into the NEN equations.

4.2.2.4 Lighting and Plug Load Schedules

The NEN and original Toolkit code used a standard or average schedule for lighting and plug loads based on building type. The schedules represents the hours per year that the lights and plug loads are used. The BPAT+ code was modified so that an actual schedule for lighting or plug loads could be used as into the NEN calculations.

4.2.2.6 Metered Electricity Consumption

While many buildings are metered for electricity, sub-metering is currently not available. Data is therefore only available for electricity usage at the whole building level. BPAT+ calculates the energy consumption for various functions separately, including lights, plug loads, fans, and pumps. Using BPAT+ in conjunction with the available metered data allows for an estimate of the breakdown of various functions of electricity consumption without the need for sub-meters.

The procedure used to calculate this data occurs in two steps. First, BPAT+ results are calculated for the building using the specific lighting and plug load densities as input values. For this step, the standard schedules (in hours per year) are used. The results of this step include calculated electricity consumptions for lights, plug loads, fans, and pumps. The next step involves the determination of a lighting and plug load schedule based on the actual metered data. To determine this schedule, the BPAT+ calculated consumption values for fans and pumps are subtracted from the actual metered electricity consumption. The remaining value represents the electricity used for lights and plug loads. This value is divided by the total installed wattage for the fans and pumps, and the resultant value indicates the total number of hours per year that the installed lights and plug loads would have to be in use to consume the metered electricity value. BPAT+ is then run again using this calculated schedule for the lights and plug loads. The results of this second BPAT+ calculation once again indicate the estimated consumption for lights, plug loads, fans, and pumps separately. The sum of the consumption values of these individual functions will equal the actual metered electricity data.

V Preliminary BPAT+ Results for Phase II Buildings

5.1 Overview

This section will examine the results of the BPAT+ audits for the first set of buildings studied. The first question concerns the accuracy, and consistency of BPAT+. In general terms, BPAT+ provides a sturdy first-order analysis of overall building energy performance, suitable for strategic analysis. A more detailed review of its validation is discussed in the next section, but it is important to always recall the simplicity of the analysis as we proceed to evaluate the results. BPAT+ is the starting point, not the conclusion of the performance assessment of both individual buildings and the entire campus.

The next question, of course, is how to interpret this array of performance data. In general terms, the purpose of this work is to rank campus buildings in terms of their energy performance, so that inefficiencies can be identified and strategies for improvement can be implemented. These inefficiencies can occur in different systems or different aspects of the building's performance, heating versus cooling versus lighting, for example. There are also important differences in scale, and so buildings and their inefficiencies have to be evaluated according to a variety of criteria. Principle among these is the type of use supported by the building. Research laboratories in particular simply use more energy as a class, and so will warrant particular study, but each class of buildings has to be evaluated on its own terms.

It is important to note that, while the number of buildings studied in this phase is large enough to make some preliminary conclusions about overall campus energy consumption, one cannot accurately determine the relative performance of any individual building until the next phase, when all campus buildings will have been studied. The rankings presented in sections 5 and 6 should be considered preliminary, and useful only in their general indications.

This section reports information about the total amount of energy used, breakdowns of energy consumption by major use--heating, cooling, and electricity--and further breakdowns of electricity consumption by major use – lighting, plug loads, and mechanical equipment – for each of the building studied during Phase II. These data are reported as both a total consumption (MBtu or kBtu per building per year) and as a normalized intensity (MBtu or kBtu per gross square foot per year), which facilitates comparisons among buildings. In current usage, kBtu-per-square-foot (kBtu/Sf) has become the building energy performance equivalent of miles-per-gallon for automobiles, and is widely reported in surveys and studies. For example, the national average intensity for office buildings is about 90 kBtu/Sf, while the average intensity for the campus buildings is 161 kBtu/Sf. This section will also evaluate total and normalized peak electric loads, as determined by the building surveys, which are commonly reported in kWh-per-square-foot (kWh/Sf). The information is presented in graphical format in this section and in tabular form in Appendix A.2.

The BPAT+ result for each building indicates the estimated annual energy consumption used by that particular building, commonly called "site energy." The "site energy" is different from the "source energy," which is the energy consumed at the power plant or central system to supply the energy to the building. The difference in these two values is due to the many other inefficiencies of combustion or conversion at those plants, as well as to the line losses which occur as the energy moves from plant to building. The "site energy" does include energy conversion losses that occur within the building due to inefficiencies in HVAC systems such as the conversion of steam to hot water in Penn buildings.

The consumption of both heating and cooling is calculated by the BPAT+ program. The consumption of electricity is adjusted within the BPAT+ program to match the electricity metered consumption for FY 2006 as indicated in Section 4.2.2.6. This was done to accurately account for electric consumption in the analysis, but also to account for the effect that electricity has on heating and cooling loads, an effect that can be substantial. Since sub-meters are not currently available, the breakdown of electricity consumption within each building is estimated by BPAT+ based on building-by-building surveys. These breakdowns are still estimates, and some uncertainty remains about the different schedules for electric usage.

The BPAT+ results can be evaluated in a variety of ways; normalized intensities can be compared against each other, against campus buildings of a specific type, against the general campus average, or against national norms and standards such as the EPA's EnergyStar. Each of these will be investigated in the following sections.

5.2 BPAT+ Validation

The Phase I report described the procedure used to calibrate and validate BPAT. The report illustrated the use of the dynamic simulation engine "EnergyPlus" as a comparison to BPAT. The conclusions from that work illustrated that the EnergyPlus simulations and BPAT calculations were on average within 4% of each other and showed similar trends in annual energy consumption for the buildings simulated. To provide more confidence in the results of BPAT+, the overall campus averages for steam and chilled water consumption were used as measures for the validation. Since individual buildings are not metered, this is the only other objective measure available for validation. These are compared to the BPAT+ results in the Figures 4-7, suggesting the areas of uncertainty with the assessments and areas for further investigation.

The total annual energy intensities of the Phase II of buildings, as calculated by BPAT+, are plotted individually in Figure 4, along with lines indicating their average value and the overall campus average. The total energy intensity is calculated as the sum of the energy used for heating, cooling, and electricity. The average intensity value for the phase II buildings is 133.5 kBtu/Sf, while the campus average is 161.2 kBtu/Sf. The difference between these values is 27.7 kBtu/Sf, or 17.2%. There are many possible reasons for this difference, including differences between the study group and overall campus, and uncertainties about different aspects of the building performance or systems.

The annual heating intensities are indicated in Figure 5. The average normalized heating intensity for the selected group of buildings is 58.9 kBtu/Sf and the campus heating average is 76.0 kBtu/Sf. The campus heating average was determined as the total campus heating consumption for FY2006 divided by the sum of the gross areas of the 98 buildings on the campus steam loop. Heating accounts for 62% of the total difference between the total BPAT+ calculated energy intensity and the campus average. This difference is likely caused by the fact that the average heating (steam) intensity for the campus includes the Hospital of the University of Pennsylvania (HUP), which, as a medical facility uses a different amount of heating than the general campus. At this point, it is still physically impossible to separate HUP's consumption, so the overall average consumption remains an approximate point of reference. There is also considerable uncertainty about the conversion efficiency of steam to hot water within the buildings, estimated at 80%, but certainly different among buildings of different ages and sizes. It is notable that the Phase II buildings include fewer labs proportionally than the campus average, and labs typically use more heating to condition the replacement air required by the fume-hood ventilation systems. The first two questions will be investigated more thoroughly in Phase III, while the third will no longer be an issue once the full survey is completed.

The annual cooling intensities are indicated in Figure 6. The average normalized cooling intensity for the selected group of buildings is 15.0 kBtu/Sf and the campus cooling average is 23.5 kBtu/Sf. The campus cooling average was determined as the total electricity consumption used by the campus chillers in FY2006, divided by the sum of the gross areas of the 71 buildings on the campus chilled water loop. Cooling accounts for 31% of the total difference between the total BPAT+ calculated energy intensity and the campus average. This difference could be caused by a number of factors, the first being line and

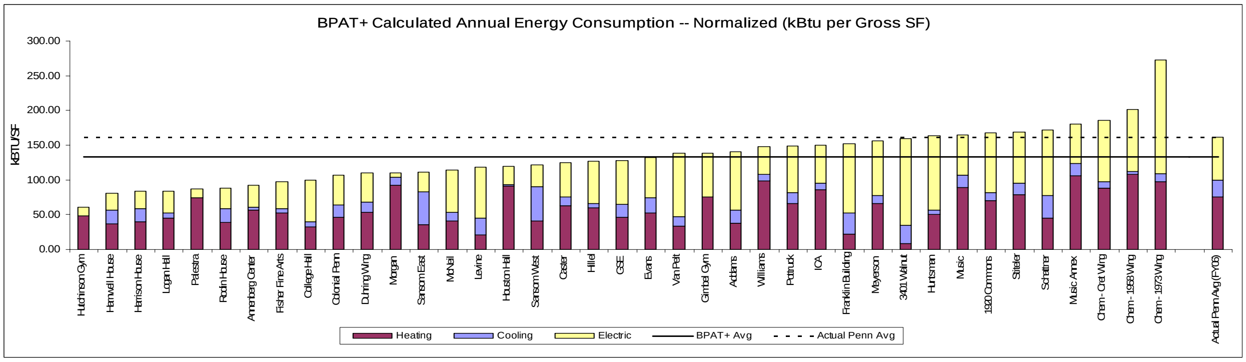

Figure 4 Comparison of BPAT+ Calculated Total Energy Intensities and Campus Average

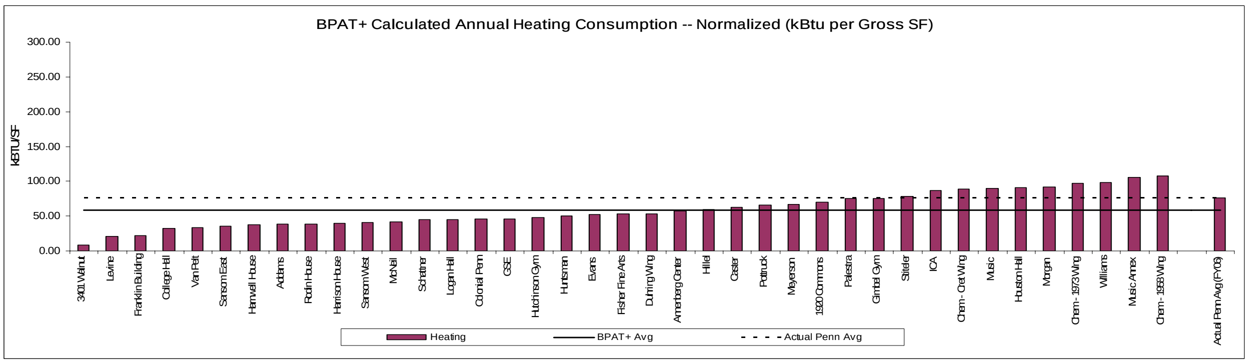

Figure 5 Comparison of BPAT+ Calculated Heating Intensities and Campus Average

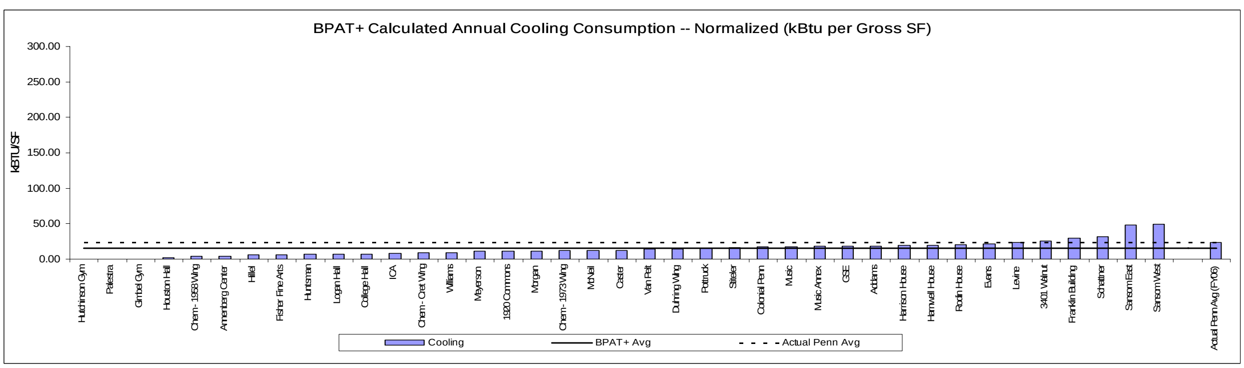

Figure 6 Comparison of BPAT+ Calculated Cooling Intensities and Campus Average

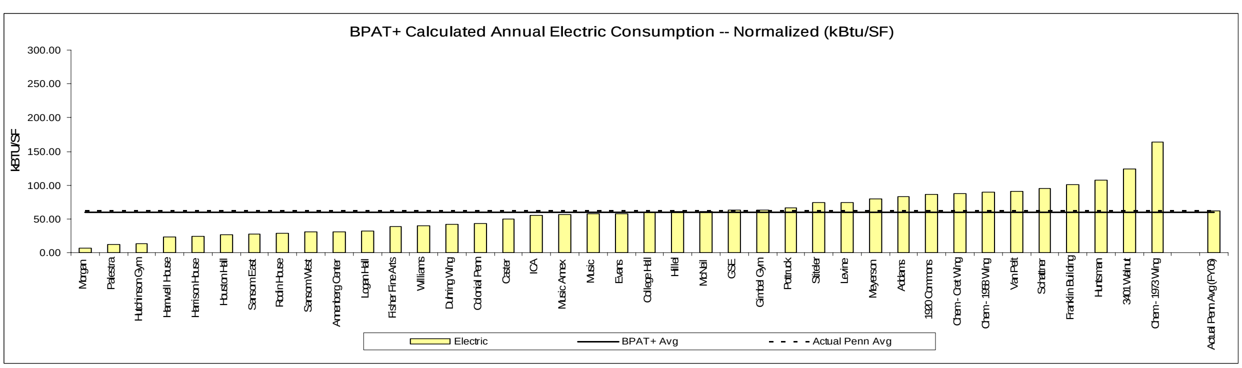

Figure 7 Comparison of BPAT+ Calculated Electricity Intensities and Campus Averages

conversion losses within the campus cooling network, for which there is no current estimate. It may also reflect the composition of the Phase II study group, which included three buildings--Hutchinson Gym, Gimbel Gym, and the Palestra--that have no cooling systems. Additionally, the selected group of buildings does not include many cooling-intensive buildings such as laboratories or dining halls. And finally it may reflect inconsistencies in the BPAT+ system descriptions for cooling, which were not as explicit or important in the European study.

The annual electricity intensities are indicated in Figure 7. Because most of the buildings on Penn's campus have electricity meters, accurate values of each building's electricity consumption were available for this study. BPAT+ input data was modified so that the results would reflect the metered data, as described in Section 1. The average normalized electricity intensity for the selected group of buildings is 59.6 kBtu/Sf and the average metered value is 61.7 kBtu/Sf. The average metered value was determined as the average of the metered electricity intensities for the selected group of buildings only. Electricity accounts for 7% of the total difference between the total BPAT+ calculated energy intensity and the campus average. The small difference is likely caused by the rounding of small values during the BPAT+ calculation process.

Our conclusion to date is that BPAT+ is reasonably accurate for such a straightforward assessment tool, and provides an appropriate level of data for the kind of analysis we plan to do in the next Phase of work. As more buildings are added to the study, these comparisons will be revisited.

5.3 Energy Use Distribution

The Phase II data provide a tantalizing view of the energy performance of campus buildings. While the different aspects of this data are evaluated and ranked in subsequent sections, it is also useful to examine the aggregate breakdown of energy consumption by end use. This data can help confirm and further identify the larger priorities for subsequent retrofit/renovation scenarios. Based on the Phase II buildings, heating and non-cooling electricity are each 45% of the total energy intensity, with cooling making up the remaining (Figure 8). This breakdown is broadly consistent with the macro-level data analyzed and reported in Phase I (Figure 9), with some tradeoff between cooling and end-use electricity, as discussed above. It confirms the importance of finding new efficiencies in heating and end-use electricity.

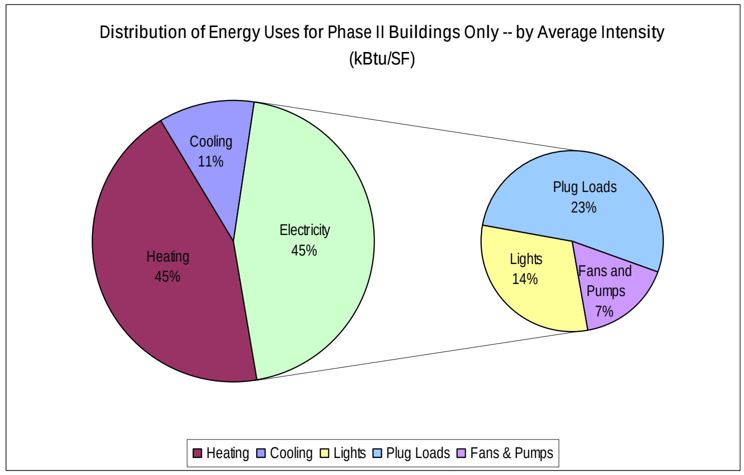

Figure 8 Phase II Buildings Only - Energy Distribution by Use

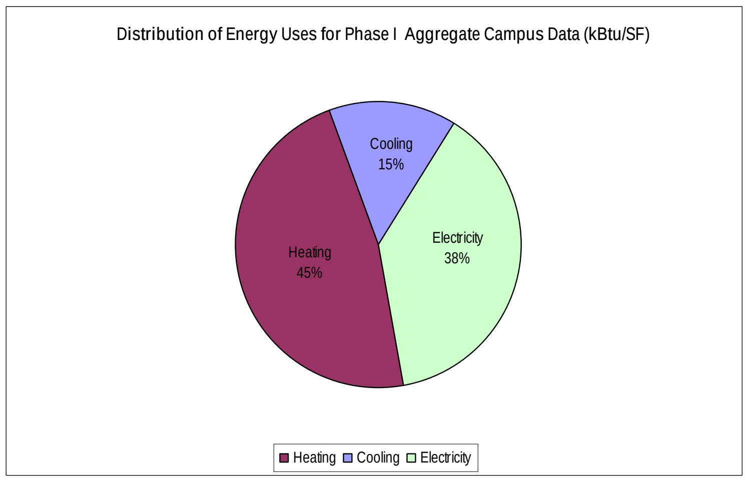

Figure 9 Aggregate Campus Data (FY2006) -- Energy Distribution by Use

Using the BPAT+ audit data, the non-cooling electricity use can be further broken down into sub-categories (Lighting, Plug Loads and Pumps & Fans). This breakdown illustrates the additional information that BPAT+ audits can provide to both isolate issues in an individual building and identify campus-wide energy conservation opportunities. As seen in Figure 8, Plug loads are nearly 25% of the Phase II energy intensity, lighting is 14% and pumps & fans are 7%. An initial conclusion from this preliminary data would be to look more closely at plug loads on campus, especially as this appears to be a category that has grown steadily over the years. An investigation into the kind of equipment being operated in campus buildings, along with the timing and schedule of use, would suggest a variety of possible strategies to reduce this significant cost.

5.4 Total Energy Consumption

The total annual energy consumption for the Phase II buildings is indicated in Figure 10, while the normalized energy intensities for the buildings studied are indicated in Figure 11. The difference in the two rankings is illustrated by the different positions of the Music Annex, which uses the least overall energy of any building in the group, but has among the highest energy intensities. Big buildings use more energy than small ones, so energy intensity is a better indicator of comparative performance. It is not surprising to see that the 3 buildings with the largest intensities are laboratories. It is more unexpected to see Huntsman Hall so high on the list. The recently completed Huntsman is ranked just next to the 40 year old Meyerson, a building with similar uses and schedules, but much less efficient building skin and systems.

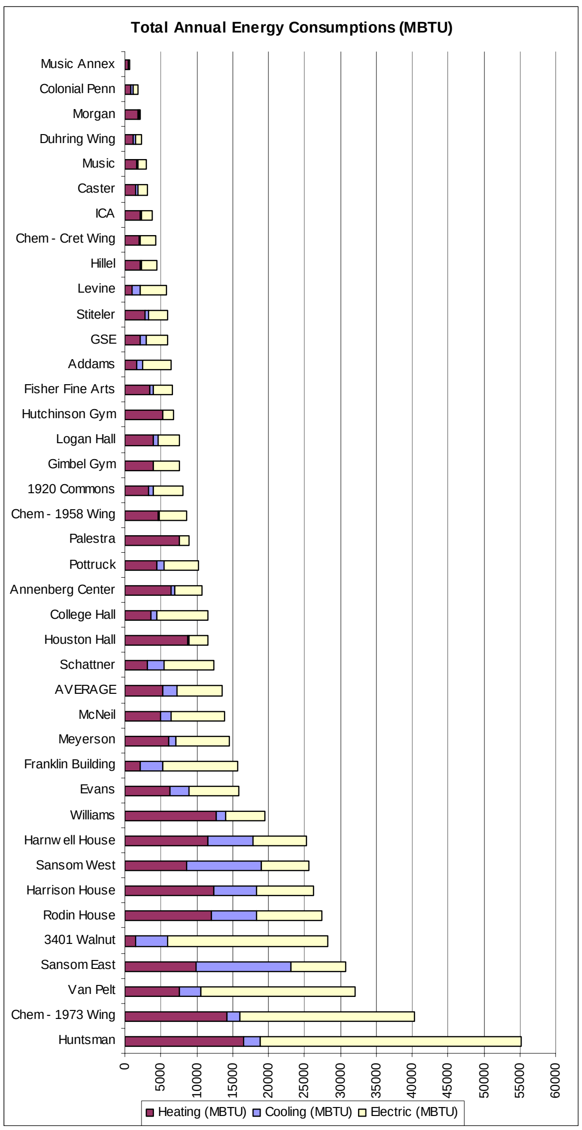

Figure 10 Total Annual Energy Consumption (MBtu)

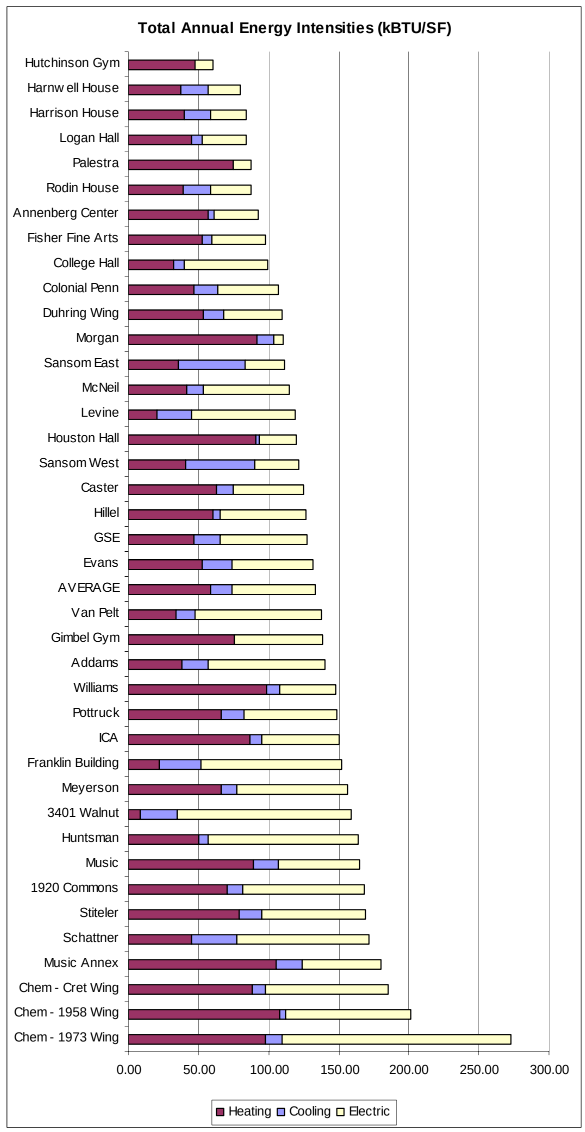

Figure 11 Total Annual Energy Intensities (kBtu/Sf)

5.5 Heating Consumption

The estimated annual energy consumption used for heating and hot water for the buildings studied is indicated in Figure 12, while the normalized annual heating intensities for the buildings studied are indicated in Figure 13. As with the overall consumption, it is the intensities that provide real performance insight, and by charting specific intensities, they suggest causes and potential solutions. The high heating loads of the lab buildings are likely due to the large amounts of replacement air required by the fume-hood systems. The high heating loads of the other buildings like Morgan, Houston Hall, and Williams suggest inefficiencies in their enclosures, which will be investigated during Phase III.

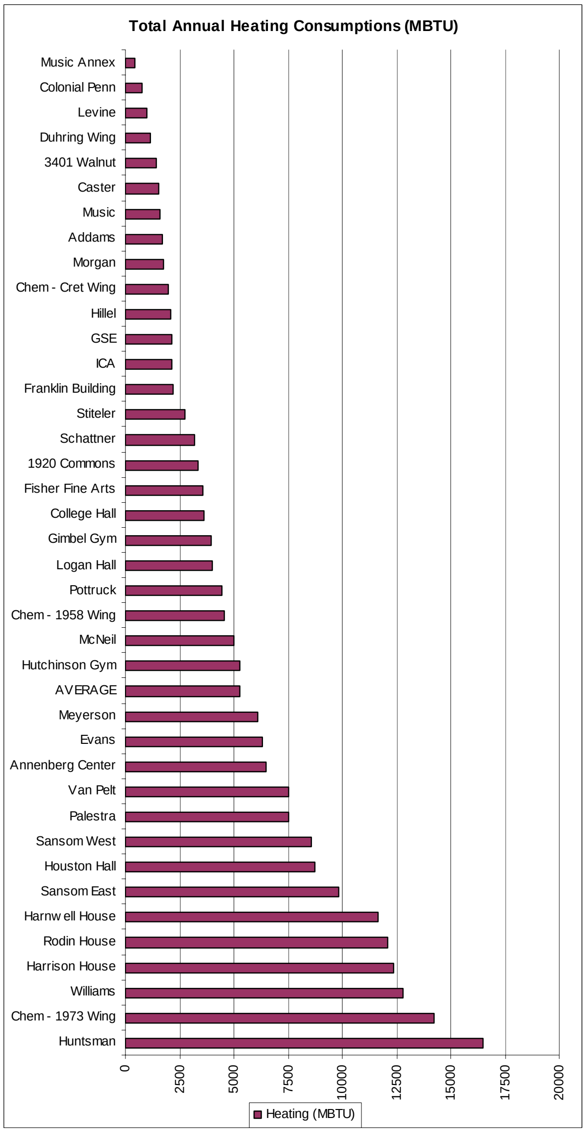

Figure 13 Total Annual Heating Consumption (MBtu)

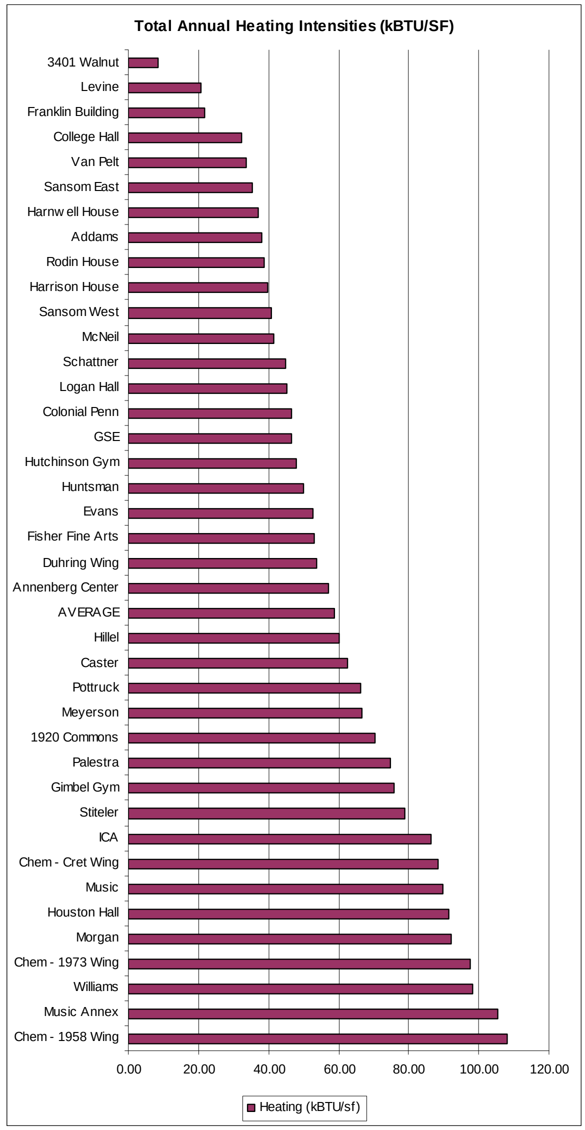

Figure 12 Total Annual Heating Intensities (kBtu/Sf)

5.6 Cooling Consumption

The estimated annual energy used for cooling in the buildings studied is indicated in Figure 14. Three of the selected buildings, Hutchinson Gym, Gimbel Gym, and the Palestra, have no cooling systems; therefore, the estimated cooling consumption for these buildings was zero. The normalized annual cooling intensities for the buildings studied are indicated in Figure 15. The three high-rise towers (Harnwell, Harrison, and Rodin) use more total cooling because they are such large buildings, while the Sansom East and West both have higher cooling intensities indicating inefficiencies and opportunities for savings. Cooling is somewhat more complicated than heating, because every source of heat from people to lights, equipment, and sunlight increases cooling. The other buildings with higher cooling intensities suggest either inefficiencies in their windows, large sources of internal heat gain, or inefficiencies in their cooling systems.

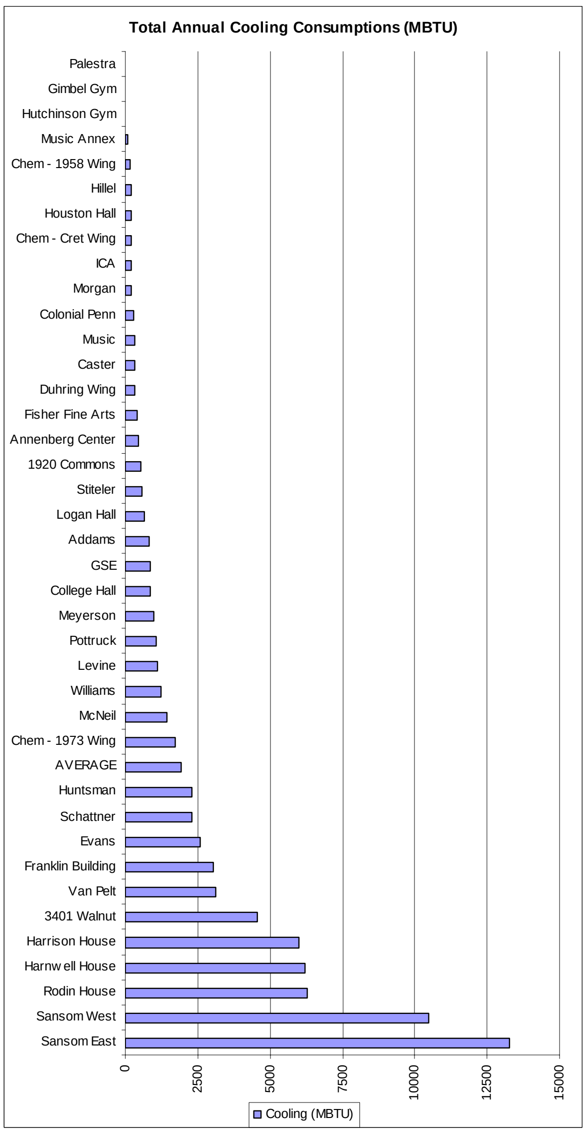

Figure 14 Annual Cooling Consumptions (Mbtu)

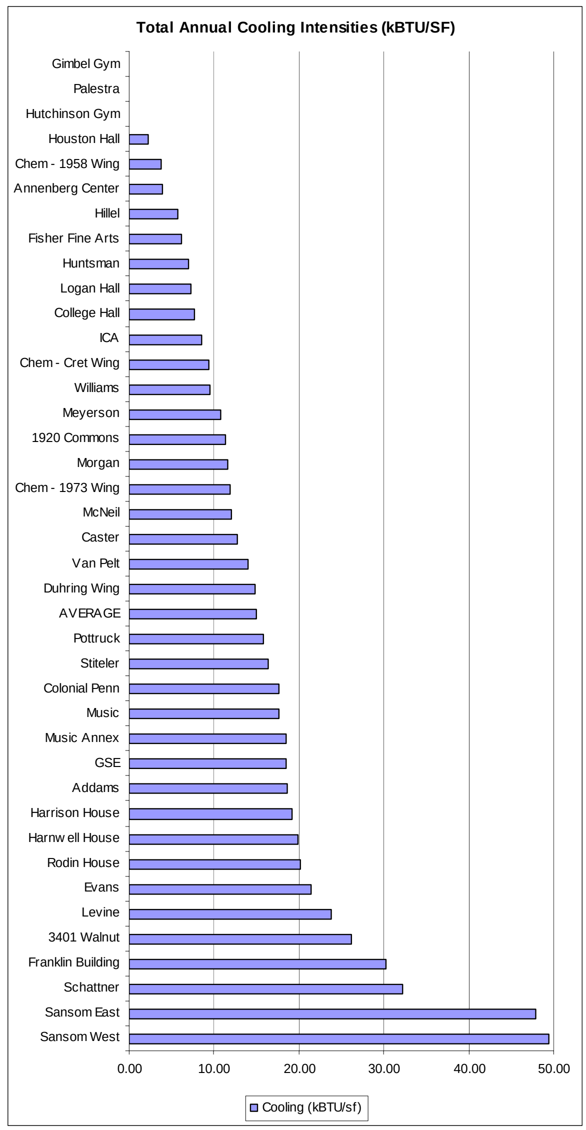

Figure 15 Annual Cooling Intensities (kBtu/Sf)

5.7 Electricity Consumption

In addition to matching the metered electricity data, BPAT+ can be used to estimate the total amount of electricity used for different purposes, such as lighting, plug loads, and fans and pumps. The annual electricity consumption in the buildings studied, including a breakdown of usage into sub-categories, is indicated in Figure 16. The normalized annual electricity intensities for the buildings studied is indicated in Figure 17. The buildings with the highest normalized electricity intensities are the 1973 Wing of the Chemistry Labs Building, 3401 Walnut St., Huntsman Hall, the Franklin Building, and the Schattner Center. The average electricity intensity of the selected buildings is 61.7 kBtu/Sf.

It was expected that laboratory buildings would rank among the larger consumers because across the entire campus, laboratory buildings account for over 50% of electric consumption. But it is striking the buildings with higher intensities are of such different types, suggesting quite different causes and strategies for improvement.

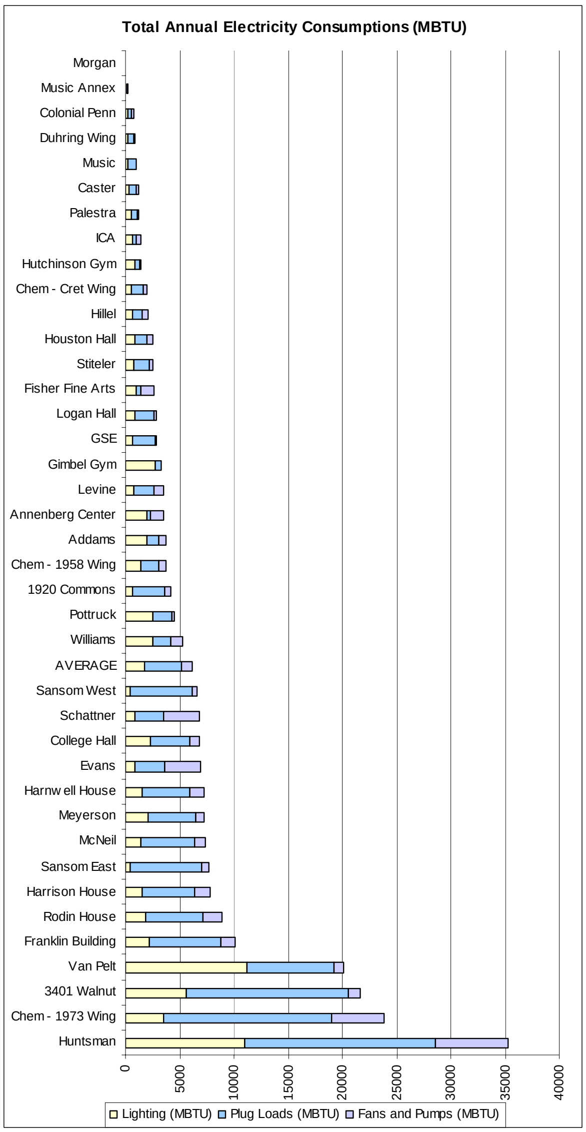

Figure 15 Total Annual Electricity Consumptions (MBtu)

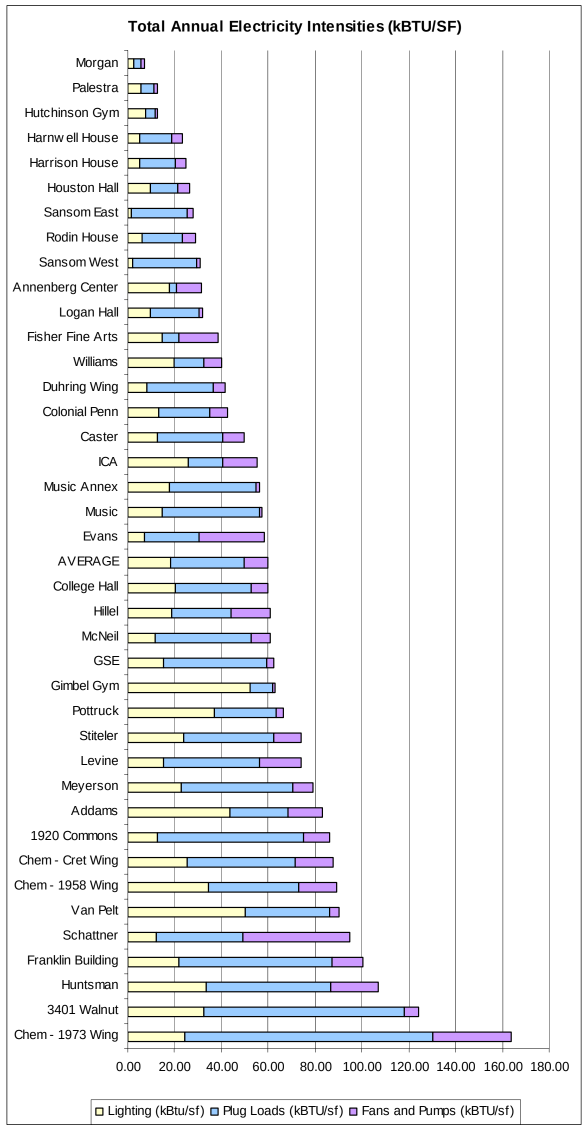

Figure 16 Total Annual Electricity Intensities (kBtu/Sf)

5.7.1 Electricity Consumption for Lighting

The estimated annual electricity consumption used for lighting in the buildings studied is indicated in Figure 18. All five of the largest lighting consumers are large buildings with either intensive uses or longer operating schedules. The estimated normalized annual lighting intensities for the buildings studied are indicated in Figure 19. The fact that the lowest intensities are largely in residential buildings is to be expected. Of the higher intensities, the fact that Gimbel and Pottruck are also on the high consumer list suggests them as prime candidates for improvement, though the lighting demands and schedules of gymnasiums present special challenges. Van Pelt has similarly specific needs, but Addams may simply be using inefficient lighting.

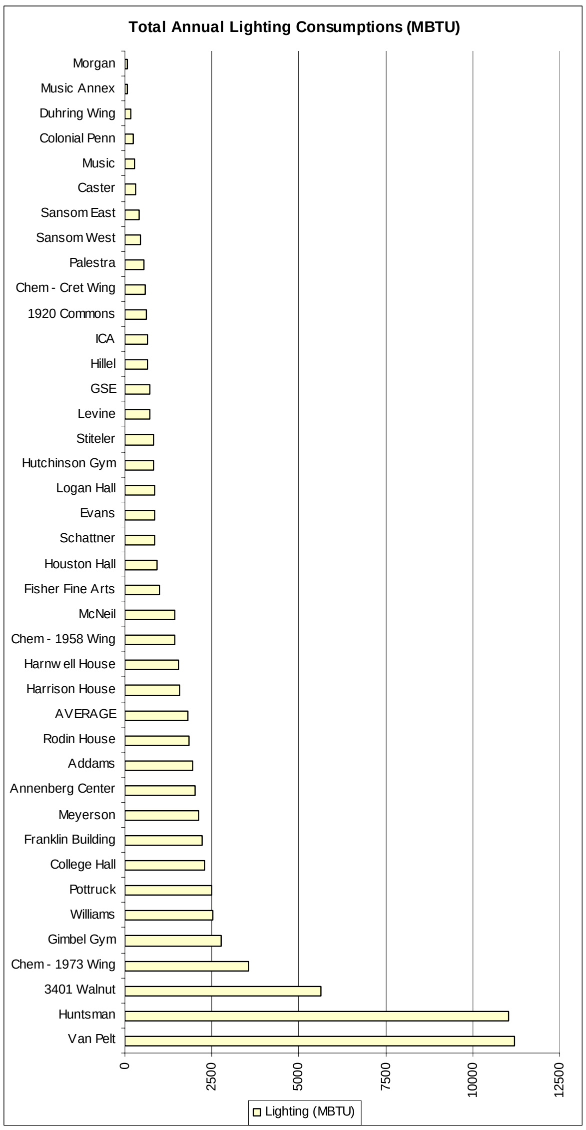

Figure 17 Annual Lighting Consumption (Mbtu)

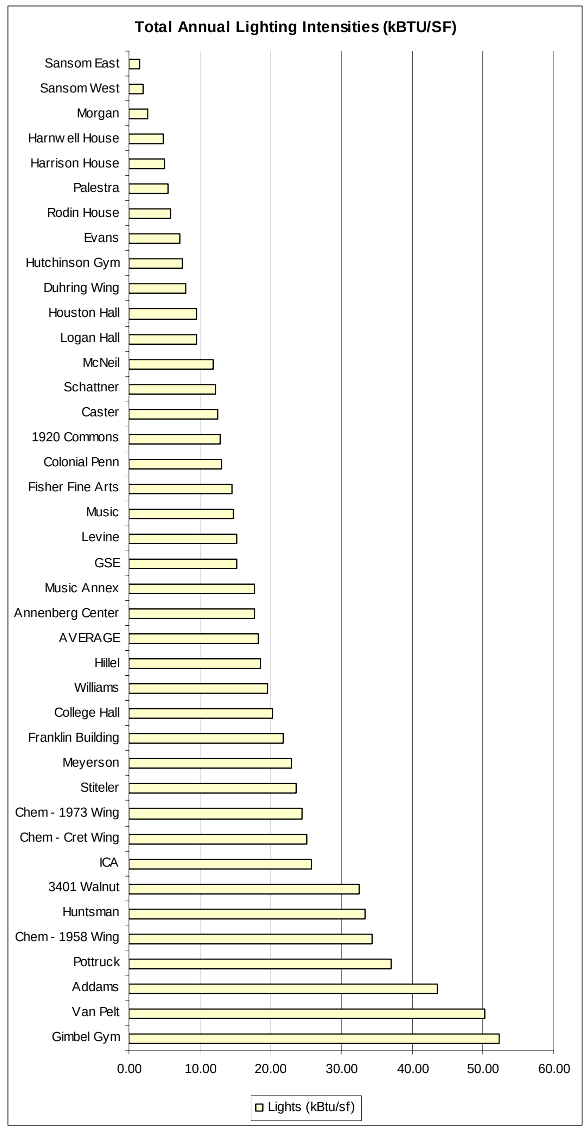

Figure 18 Annual Lighting Intensities (kBtu/Sf)

5.7.2 Electricity Consumption for Plug Loads

The estimated annual electricity consumption used for plug loads in the buildings studied is indicated in Figure 20. The estimated normalized annual plug load intensities for the buildings studied is indicated in Figure 21. In most cases, the highest intensities are equipment intensive uses, though further study will be required to precisely identify opportunities for savings.

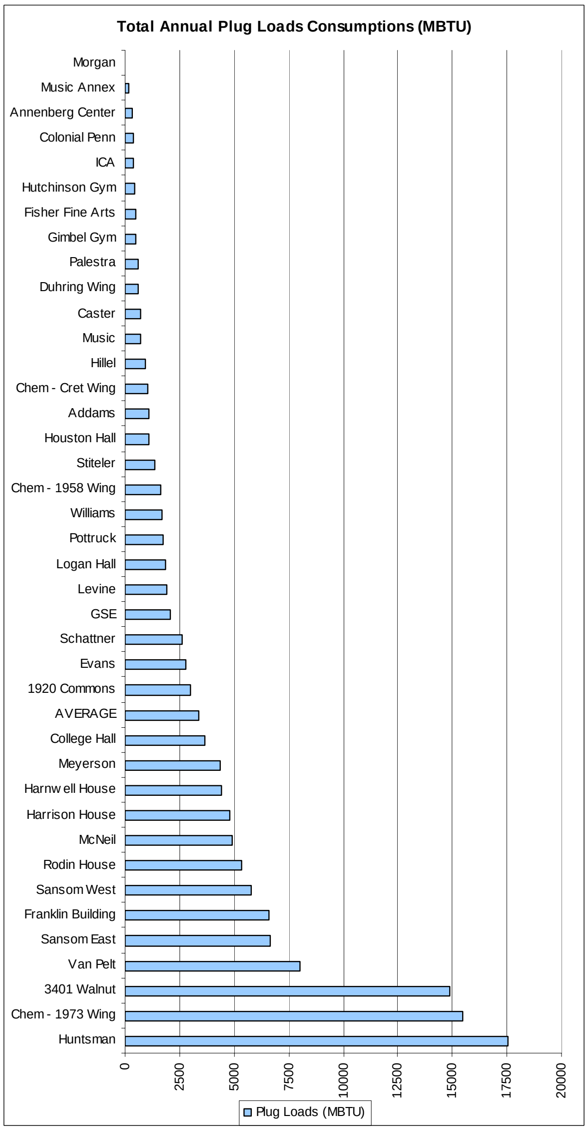

Figure 19 Annual Plug Load Consumptions (MBtu)

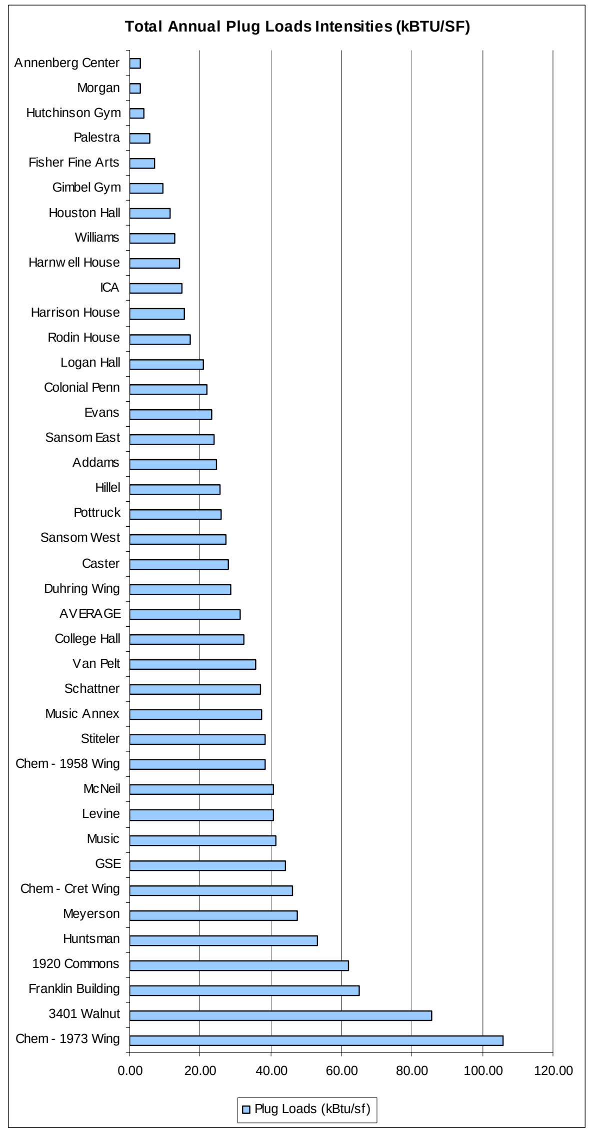

Figure 21 Annual Plug Load Intensities (kBtu/Sf)

5.7.3 Electricity Consumption for Fans and Pumps

The estimated annual electricity consumption used for fans and pumps in the buildings studied is indicated in Figure 22. The estimated normalized annual fan and pump intensities for the buildings studied is indicated in Figure 23. This is an aspect of the audits with even larger uncertainties because of the difficulty of correctly identifying their actual operating schedules. In the case of Schattner, the fans may be serving an adjacent building as well.

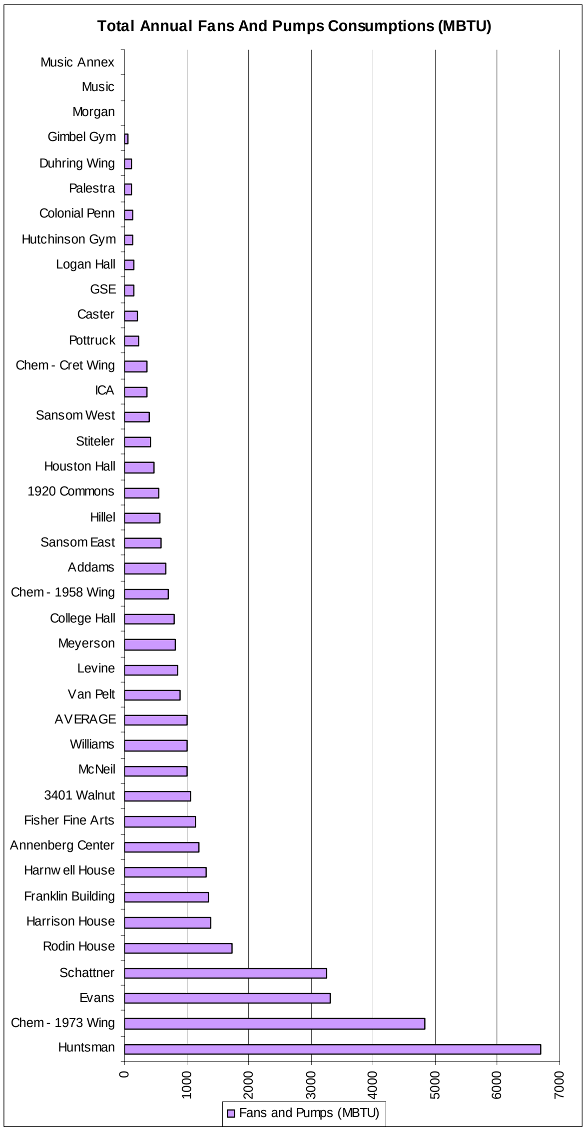

Figure 21 Annual Fans and Pumps Consumption (Mbtu)

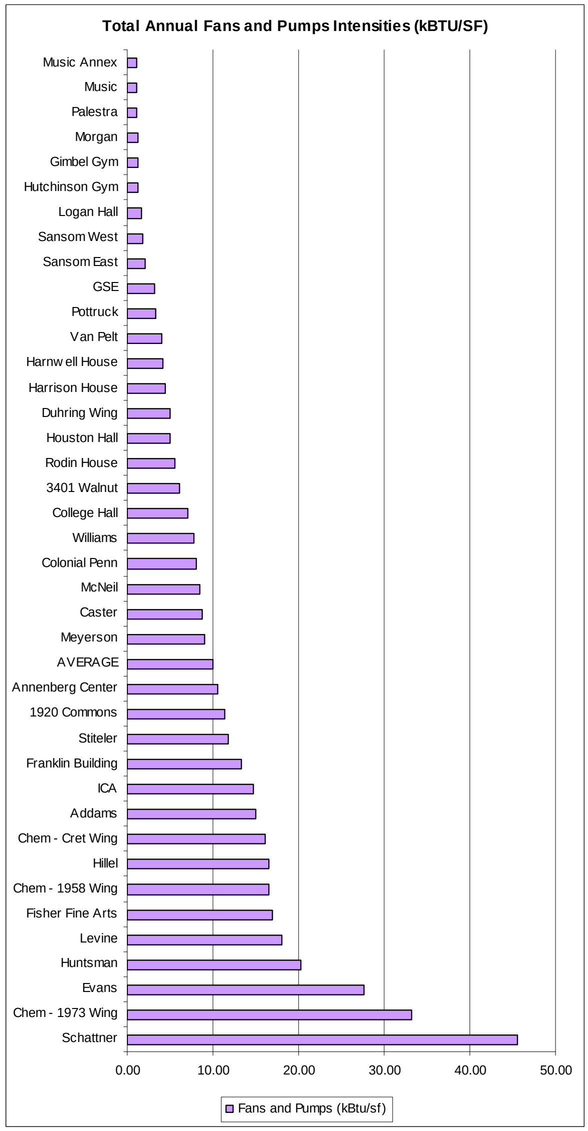

Figure 20 Annual Fans and Pumps Intensities (kBtu/Sf)

5.7.4 Peak Loads due to Lights and Plug Loads

In addition to the metered electricity data and the usage breakdowns calculated by BPAT+, we can also examine the peak loads due to lighting and equipment as surveyed in each building. The survey procedure is described in Section 1. The peak load indicates the total installed wattage each building contains in the form of lights and plug loads such as computers and other equipment. Figure 24 indicates the total potential peak loads of the surveyed buildings.

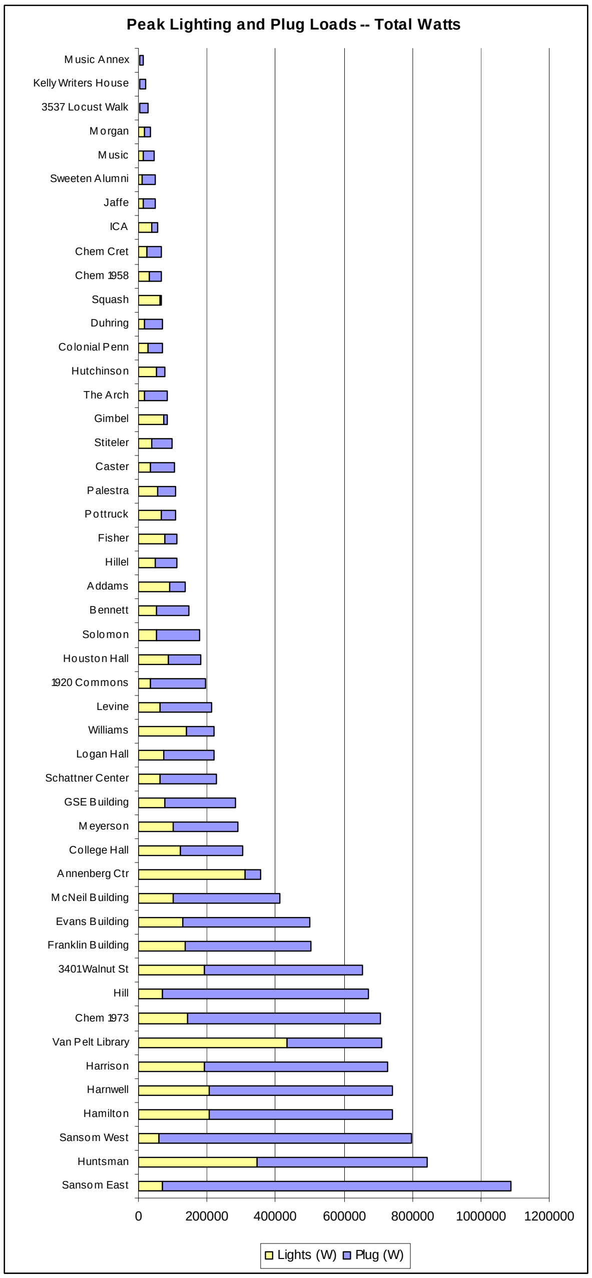

Figure 22 Total Peak Load from Lights and Plug Loads (Watts)

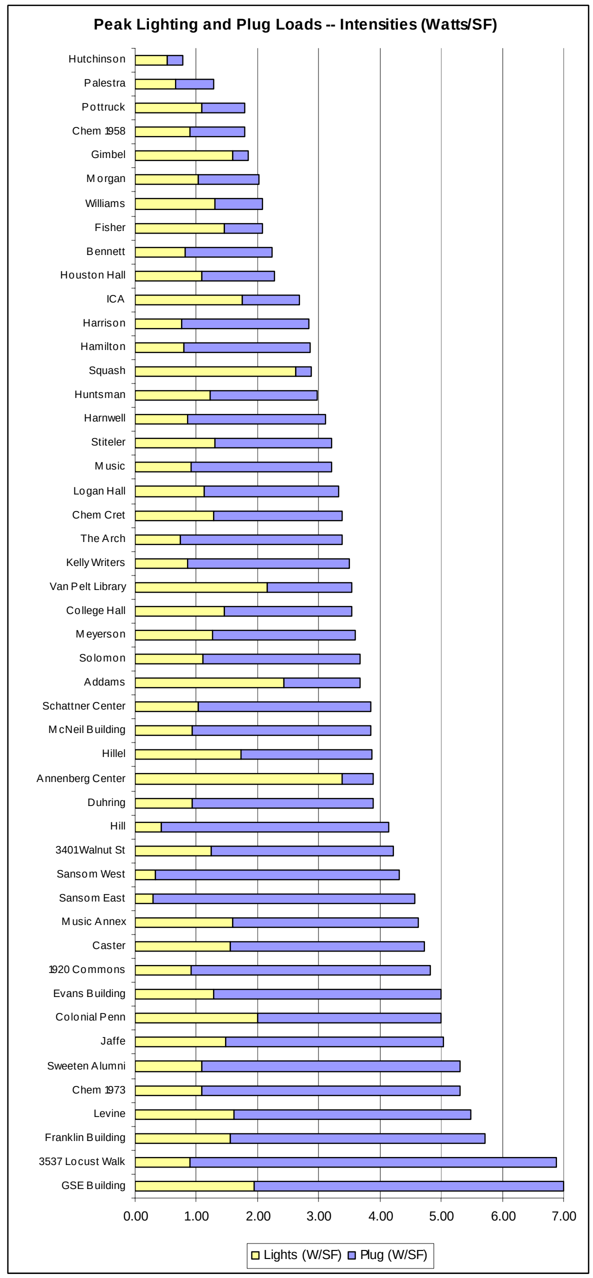

Figure 23 Peak Load Intensities from Lights and Plug Loads (Watts/Sf)

Though peak loads do not translate directly to consumption, depending on both schedules and other patterns of usage, these can be an important index since the lighting and equipment standards in energy codes are often specified in these terms. The current standard in ASHRAE 90.1 (2004) for lighting loads in office buildings is 1.3 W/Sf, substantially lower than most of the loads surveyed. These are also an important measure, since they represent the installed capacity of electric equipment and the maximum potential electric demand.

Figure 25 indicates the normalized peak load intensities (Watts/Sf) of the surveyed buildings. As a performance complex, the Annenberg Center would be expected to have a high lighting intensity, the other four high intensity buildings raise serious questions and suggest immediate strategies for improvement. On the other hand, the buildings with higher plug loads are quite various and may only represent standby equipment, but do warrant further investigation.

VI Preliminary Evaluation and Performance Ranking for Phase II Buildings

6.1 Overview

As the previous section has shown, campus buildings can be ranked relative to one another in a variety of ways according to the basic array of building performance categories—heating, cooling, lighting, plug loads, and pumps and fans. In addition to comparative evaluations among campus buildings, the BPAT+ results can be compared with national building performance standards or targets. It was observed in the Phase I report that while the campus appears to perform about as well as other campuses of its age and size, it still falls well short of average national performance among commercial buildings, much less of ambitious high-performance goals. So to provide a broader point of reference for the BPAT+ results and to further prepare for a ranked action plan, the following sections examine the performance of the first study group relative to the two national ranking programs, EnergyStar and Labs21.

6.2 EnergyStar Performance Standards

The EnergyStar performance standard was developed by the Environmental Protection Agency (EPA).[4]. This program establishes target annual energy intensities in kBtu/Sf for individual buildings based on type, square footage, number of occupants, and other information specific to the type. The Targets themselves are derived from statistical analyses of data from the Commercial Buildings Energy Consumption Survey (CBECS) conducted by the Department of Energy (DOE) every four years. The Energy Star building rankings effectively describe the percentile performance of a building within its class, for example EnergyStar 50 means that a building performs as well as 50% of other buildings of that type. The minimum ranking to achieve an EnergyStar rating is 75, and this has been used as a datum of comparison to evaluate Penn buildings. At this stage we selected the minimum EnergyStar 75 target, rather than EnergyStar 90 or 95, or even more ambitious performance goals, because EnergyStar 75 represents an achievable target with contemporary techniques. EnergyStar is also the basis of the energy credits awarded in LEED's Existing Building (LEED-EB) program.

The EnergyStar "rankings" used in the following sections were determined by taking the ratio of the BPAT+ energy intensity with the EnergyStar 75 target intensity obtained from the EnergyStar Target Finder for each building. A ratio of 1.0 indicates that the building meets the EnergyStar 75 target; a higher ratio indicates that the building uses more energy than the target value. These ratios can then be compared against each other to form rankings. Unfortunately the EnergyStar Target Finder data is only available for certain very common types of buildings. Of the buildings surveyed in phase II, only offices and residence halls were eligible for comparison. For the purposes of this report, we will compare the normalized annual energy consumption estimated by BPAT+ for each building with the EnergyStar 75 target for site energy.

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[4] http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder. The current version of Target Finder (2007) uses 2003 CBECS data.

6.2.1 EnergyStar Target Rankings for Offices

Among the phase II campus buildings, 22 have similar uses to an office building and can be reasonably compared to the performance targets for offices. For most of the office-classroom buildings, this is a fairly accurate standard, though buildings like Van Pelt or Stiteler have somewhat different uses and schedules. The input data necessary to generate a target consumption for offices are gross square footage, the total number of occupants, the number of PCs, and the operating hours per week. Of these, the first three inputs were already available from the database developed for BPAT+. The operating hours per week was estimated to be 56 hrs/week (8 hrs/day, 7 days/week). Although there is variation in operation hours in the buildings on campus, it was found that a 25% increase in hours per week only changed the target consumption by 4%, so the effect is small.

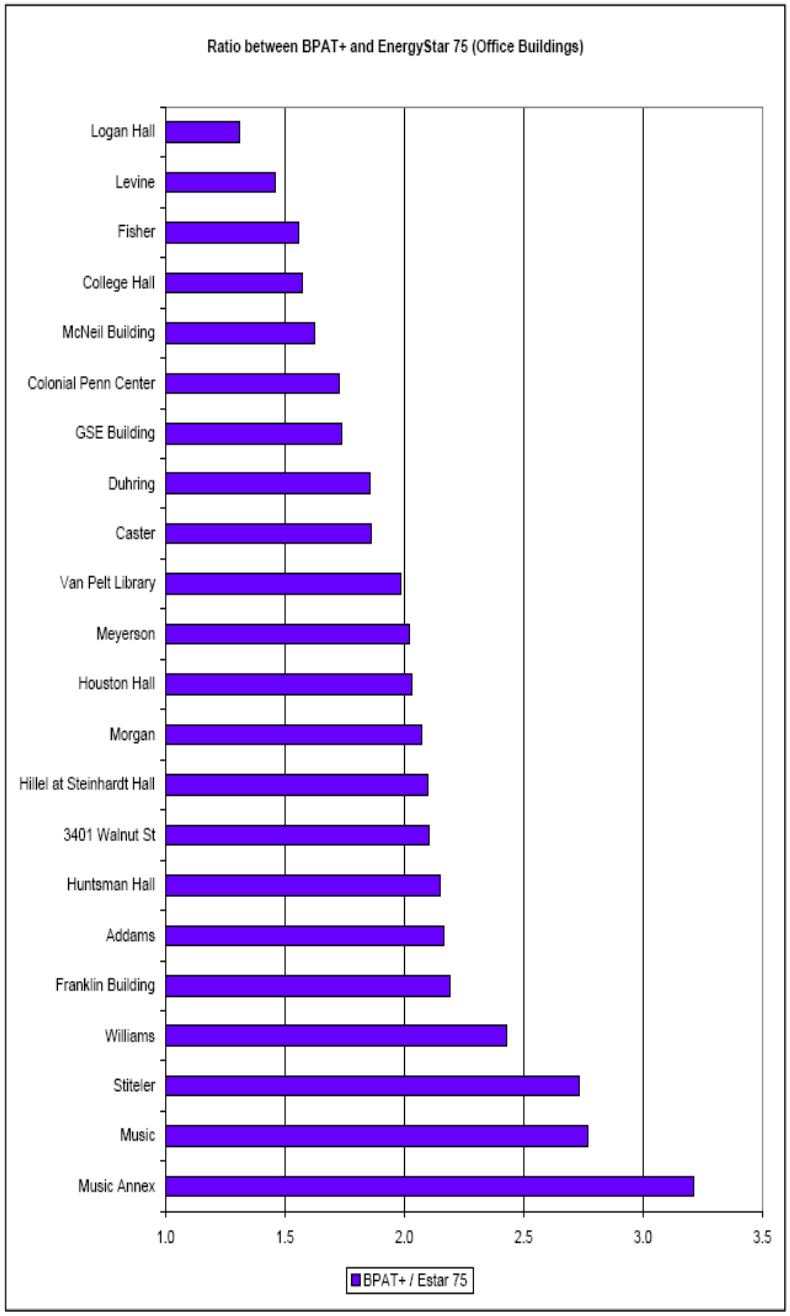

Figure 24 BPAT+ Estimated Normalized Energy Consumption and EnergyStar 75% Target Consumption – Offices

Figure 26 indicates the ratio of the BPAT+ results and the EnergyStar 75 target for each "office" building. It is important to note that none of the 22 buildings meet the target consumption, and more than half exceed it by a factor of 2. Logan Hall is the closest to the EnergyStar 75 rating, with a current estimated annual consumption that is 1.3 times higher than the EnergyStar 75 target. The Music Annex is the furthest from the EnergyStar 75 rating, with an intensity that is 3.2 times higher than the EnergyStar 75 target. This comparison indicates that all of the office-classroom buildings could perform substantially better with contemporary building practices.

Admittedly improving existing buildings in this way could only be applied according to the regular cycle of renovation on campus, and it may be too difficult to impose some high-performance building techniques on existing buildings and equipment. Nonetheless, the EnergyStar 75 target does describe an achievable level of improvement and potential savings for these buildings. The energy and cost savings that could be realized by improving each of these buildings to this standard have been estimated in Table 2. The difference between the BPAT+ estimates and EnergyStar has been multiplied by $.20/KBtu, the price Penn has been paying for steam and electricity in recent years. These savings depend on the estimates and will increase and decrease with energy costs.

		BPAT+ (Site)		Estar 75 (Site)		Savings = BPAT+ - Estar 75	
Building	square footage	kBtu/SF	$/Yr*	kBtu/SF	$/Yr*	$/yr	%
Logan Hall	88,315	84.39	$149,058	64.5	$113,926	$35,132	24%
Levine	47,304	118.82	$112,409	81.5	$77,106	$35,303	31%
Fisher	67,108	97.81	$131,276	62.7	$84,153	$47,123	36%
College Hall	113,555	99.50	$225,968	63.2	$143,534	$82,435	36%
McNeil Building	120,371	114.48	$275,602	70.5	$169,723	$105,879	38%
Colonial Penn Center	17,049	106.97	$36,475	61.9	$21,107	$15,369	42%
GSE Building	46,368	127.63	$118,358	73.4	$68,068	$50,290	42%
Duhring	21,227	109.98	$46,692	59.2	$25,133	$21,560	46%
Caster	24,636	124.61	$61,400	67	$33,012	$28,388	46%
Van Pelt Library	222,918	137.97	$615,134	69.5	$309,856	$305,278	50%
Meyerson	91,816	156.70	$287,743	77.4	$142,131	$145,612	51%
Houston Hall	95,741	119.64	$229,084	58.8	$112,591	$116,493	51%
Morgan	19,352	110.61	$42,809	53.3	$20,629	$22,180	52%
Hillel at Steinhardt Hall	35,070	126.54	$88,752	60.3	$42,294	$46,458	52%
3401 Walnut St	173,600	158.95	$551,879	75.5	$262,136	$289,743	53%
Huntsman Hall	329,883	163.87	$1,081,127	76.2	$502,742	$578,386	53%
Addams	44,369	140.05	$124,279	64.7	$57,413	$66,866	54%
Franklin Building	100,990	152.46	$307,938	69.5	$140,376	$167,562	54%
Williams	130,089	148.03	$385,154	60.9	$158,448	$226,706	59%
Stiteler	34,689	169.18	$117,373	61.9	$42,945	$74,428	63%
Music	17,635	164.67	$58,081	59.5	$20,986	$37,095	64%
Music Annex	3,961	179.94	$14,255	56	$4,436	$9,819	69%
						$2,508,102	

Table 2 Potential Office-Classroom Savings. BPAT+ Results - EStar 75

6.2.2 EnergyStar Target Rankings for Residence Halls

Of the surveyed campus buildings five can be considered residence halls and compared with the EnergyStar Targets for the Residence Hall/Dormitory type. The input data necessary for residence halls are the gross square footage, the number of rooms, the percentage of rooms which are air-conditioned, and the percentage of rooms which are heated. It was assumed for all residences that 100% of all rooms are both cooled and heated.

One challenge with the EnergyStar Target Finder program for the residence halls is that targets are only available for residences with 50-800 rooms total. Four of the five buildings considered have over 800 rooms (the three undergraduate towers have around 1000 rooms each, while Sansom East has about 830 rooms). Therefore, in order to use the Target Finder for these buildings, it was necessary to use the maximum value of 800 rooms instead of the actual number of rooms in each building. As the EnergyStar target finder indicates increasing target consumption values with increasing number of rooms, one can assume that the actual target consumption for buildings with over 800 rooms would in fact be slightly higher than the given values for 800 rooms only.

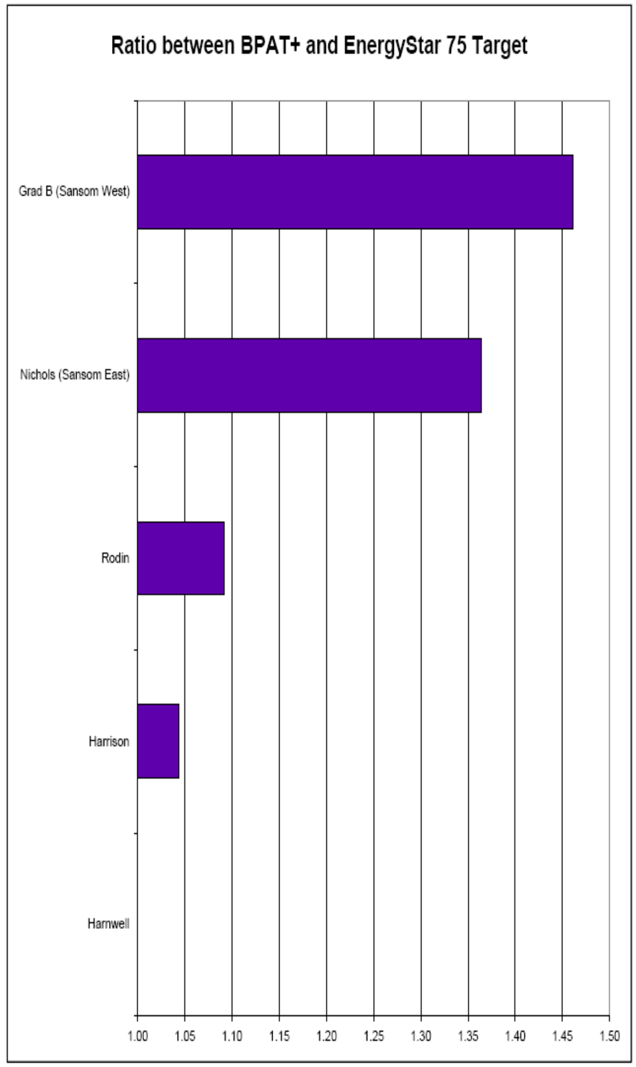

Figure 25 Ratio between BPAT+ and EnergyStar 75 Target

Figure 27 indicates the ratio between the BPAT+ results and the EnergyStar 75 target for each residential building. Figure 21 indicates the normalized annual energy consumption for each building as estimated by BPAT+ and the EnergyStar 75 target consumption for each building, in order of increasing difference. Note that the estimated normalized annual energy consumption for Harnwell House meets the EnergyStar 75 rating, as it is slightly lower than the Energy Star target. Additionally, Hamilton and Rodin Houses have estimated annual energy consumptions which are only 1.04 and 1.09 times above their targets, respectively. Because each of these three buildings has about 200 more rooms than what was input into the Target Finder, it is very likely that truer 75 targets would have been higher than the current consumption targets and that all three buildings would meet the EnergyStar 75 criteria. Sansom Place West is the furthest from the EnergyStar target, which an estimated normalized consumption which is 1.46 higher than the EnergyStar target, largely because of cooling. On average, the residences considered are far closer to their EnergyStar targets than the office buildings.

6.3 Rankings for Laboratories

Perhaps the most challenging group of buildings on the campus are laboratories. These highly-specialized, energy and ventilation-intensive buildings are typically the largest energy consumers on a campus. In the Phase I report it was already noted that while campus lab buildings account for about 30% of the gross area, they consume nearly 55% of the campus electricity. Laboratories themselves also come in a variety of types with important distinctions: dry versus wet, with and without fume hoods.

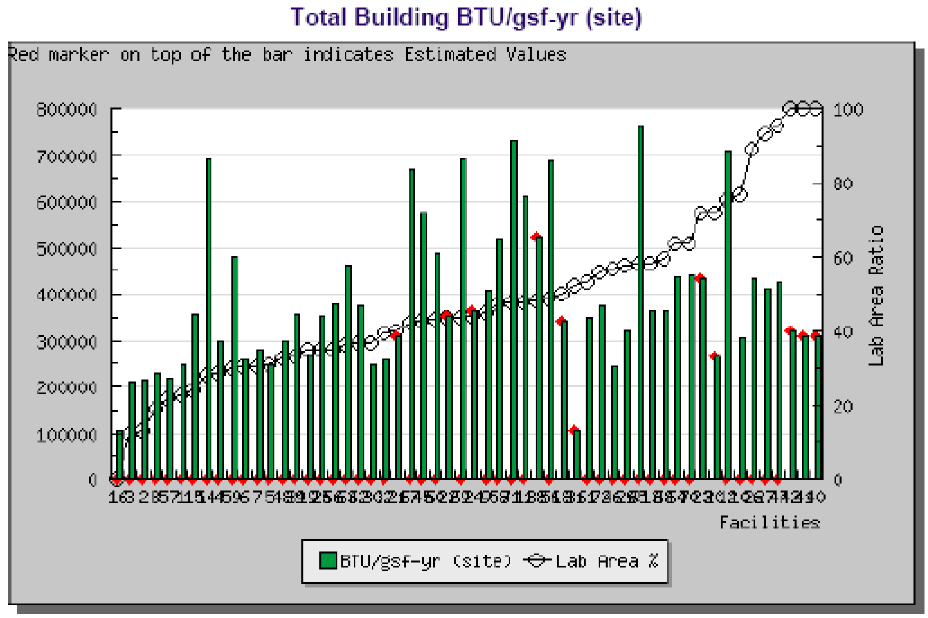

Figure 26 Laboratory Energy Intensity from EPA LABS21 database

Unlike offices and residences there is little consistent national data available for laboratories. The EPA and DOE have an EnergyStar type program called Labs21, which has developed a modest database of performance data that shows intensities ranging from 200 to 400 kBtu/Sf and above.5 These average intensities are for buildings with different percentages of labs, and further indicate the complexity of the situation (Figure 28). This data also suggests that Penn's labs may well be within normal operating parameters for contemporary labs. So while the lab buildings rank high on many of the lists, they are likely representative of the special challenges of this whole class.

5 www.labs21century.gov

VII Summary

In Phase II, a database of information for a third of the campus buildings was developed, including performance parameters for the buildings, their systems, and their uses. The Building Performance Assessment Toolkit (BPAT+) was then successfully adapted from its European source for use on the buildings of the University. Validation studies confirm that it now provides a sturdy, first-order analysis of overall building energy performance, suitable for strategic analysis. The tool is designed as a decision making system for energy planning and retrofit. It can also be used as a replacement for the existing cost-allocation energy model. In the case that the university buildings become metered (which we do highly recommend) the system can be calibrated with this information and can used to reveal the sub-behavior of the elements and systems that contribute to the energy consumption of the buildings.

In Phase III, the information assembled in the database will be used to further evaluate and validate the BPAT+ results.

Even at this early stage, with data gathered for only a third of the campus buildings, a number of preliminary conclusions can be advanced.

1. Laboratories constitute a special, high-energy building type and specific strategies should be developed for addressing their improvement. This might involve a working group of lab managers, more detailed analysis, or both, and it can draw on the best-practices developed by the LABS21 program.
2. While there are many more office-classroom buildings to be assessed, it is already clear that as a class, these buildings fall short of even modest performance goals. This building type constitutes over 40% of the campus and so warrants specific strategies for improvement.

7.1 Phase III

In Phase III, which will be completed by the summer of 2008, performance data will be gathered for the remaining buildings on the main campus, and BPAT+ analyses of these buildings will be performed. The specific buildings included in the Phase II & III studies are illustrated in the map below (Figure 29) and are listed in Appendix A.4. This includes all main campus buildings that are fully conditioned and directly occupied by University operations.

Once the performance results are complete, a descriptive ranking and action plan will be prepared, outlining strategies for improving the energy performance of the campus buildings.

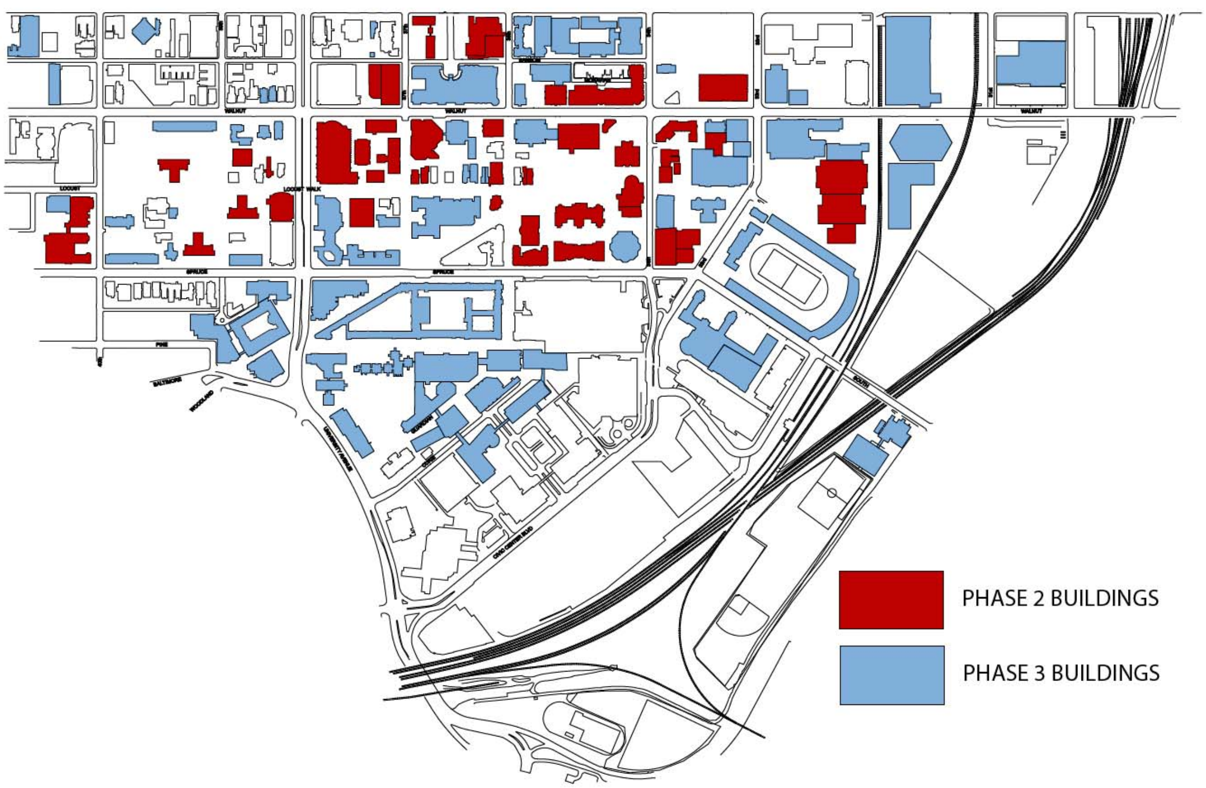

Figure 27 Campus Map with Phase II and Phase III Buildings

VII APPENDIX:

A.1 Understanding NEN 2916

NEN 2916 includes normative calculation algorithms based on empirical data of European buildings and calibrated against the results of dynamic simulations. In order to use such algorithms to evaluate American buildings, a detailed study of NEN 2916 is necessary to determine any modifications required to adapt the algorithms to the American standards and specifically to Penn's campus environment.

Several data related to Penn's energy performance as well as normative values introduced in NEN 2916 are necessary to calculate the energy consumption of a building. This section will provide information regarding the environmental factors that affect the energy performance of a building. Additionally, this section will explain situations where the NEN 2196 normalized coefficient values were modified or removed for the new BPAT+ tool.

To understand NEN 2916 precisely and make accurate modifications and adjustments, a simple framework was developed in Excel spreadsheets. This step was followed by modifications through code adjustments and debugging of the "GSA Toolkit." The preliminary tool produced was referred to as BPAT (Building Performance Assessment Toolkit). BPAT was further adapted to the BPAT+ with the addition of Penn-specific modifications.

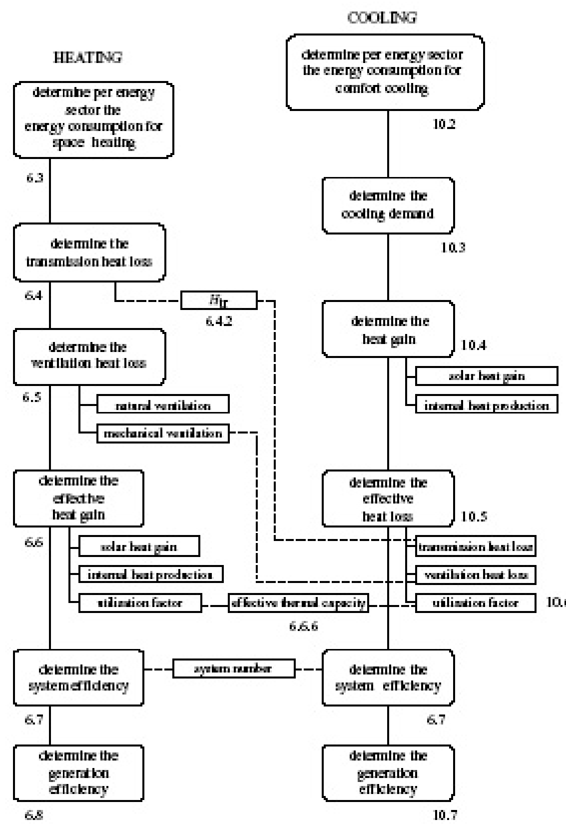

Figure 28 Relationship between provision for the determination of the energy consumption for heating and comfort cooling

The algorithms provided by NEN 2916 and used by BPAT+ use input data about a specific building to calculate its characteristic annual energy consumption. The characteristic annual energy consumption of a building is calculated as the sum of the energy consumptions of the various functions. These functions include heating, cooling, fans, humidifying, lighting, hot water and pumps. Each function has a characteristic series of calculation steps. In every step, data is either determined or calculated. To obtain these data, it is necessary to determine conditions such building types, system types and so on. Energy consumption is determined as the quotient of energy demand and the energy generation and distribution efficiency. Additionally, the calculation procedures for some of the functions are coupled, such as heating and cooling. The calculation structure for heating and cooling is indicated in Figure 28. Additionally, the energy consumption for heating and cooling is interrelated with other functions such as lighting, ventilation, and equipment.

The data required by NEN 2916 can be categorized into three types. These include a normative value that can be adapted directly, an Americanization value that should be modified according to a condition specific to American standards or practices, and a coloring value that can be adjusted to Penn campus buildings.

A.1.2 Energy Consumption for Heating

A large portion of a building's total energy consumption is used for heating and cooling. Energy consumption used for heating is determined as the quotient of the heat demand and heat generation efficiency increased by the primary energy consumption for auxiliary energy of the heat generation appliances. The heat demand consists of the sum of the transmission heat loss and the ventilation heat loss minus the utilized heat gain. This is divided by a factor that indicates the energy efficiency of distribution and temperature control.

To understand this procedure, NEN 2916 was exploded thoroughly into a tree-like excel sheet (Table 3). This diagram aids in our understanding of the relationship of input and output data and in the determination of which data should be obtained to calculate energy consumption of Penn buildings.

A.1.2.1 Heating Demand

The heat demand of a building can be obtained by subtracting the building's total heat gain from the building's total heat loss by transmission and ventilation. Most heat loss occurs from transmission through the building exterior and from ventilation by window or mechanical systems. Most heat gain is caused by the heat production of lighting, occupants, office appliances, or mechanical systems. Therefore, these values are calculated individually in NEN 2916 and dealt with by summation or subtraction.

A.1.2.1.1 Transmission Heat Loss

To calculate transmission heat loss, the interior and exterior temperatures should be determined and the transmission heat loss coefficient should be calculated. For these calculations to be applicable to Penn campus buildings, the exterior temperatures should be determined based on monthly local (Philadelphia) climate data and the interior temperature should be determined based on the winter and summer set point temperatures of Penn campus buildings. To obtain the transmission heat loss coefficient, the thermal transmittances of individual building, area of projections, and characteristics of the space should be surveyed. Essentially, both the thermal transmittance and the square footage of all walls, windows, and roofs in a building must be calculated or obtained.

A.1.2.1.2 Ventilation Heat Loss

To calculate the ventilation heat loss, it is necessary to determine the interior and exterior temperatures, usable floor area, and ventilation heat loss coefficient. The temperatures again depend on the local climate data for Philadelphia and the Penn campus building set point temperatures. The useable floor area is dependent on the specific building. The ventilation heat loss coefficient is based on a variety of factors such as building height, building type, heat recovery system and ventilation type.

In order to apply these calculations to Penn buildings, each campus building should be categorized using NEN building types. NEN building types which are not applicable to Penn buildings, such as penitentiaries, were removed from BPAT. Additionally, NEN provides a variety of "standard" system types for heat recovery and ventilation. A number of these were also removed following an investigation of Penn systems. NEN provides six types of heat recovery systems, but only three are applicable to Penn buildings and the remaining types were removed. Similarly, NEN provides four types of ventilation, but only two types are applicable to Penn buildings and the remaining types were removed.

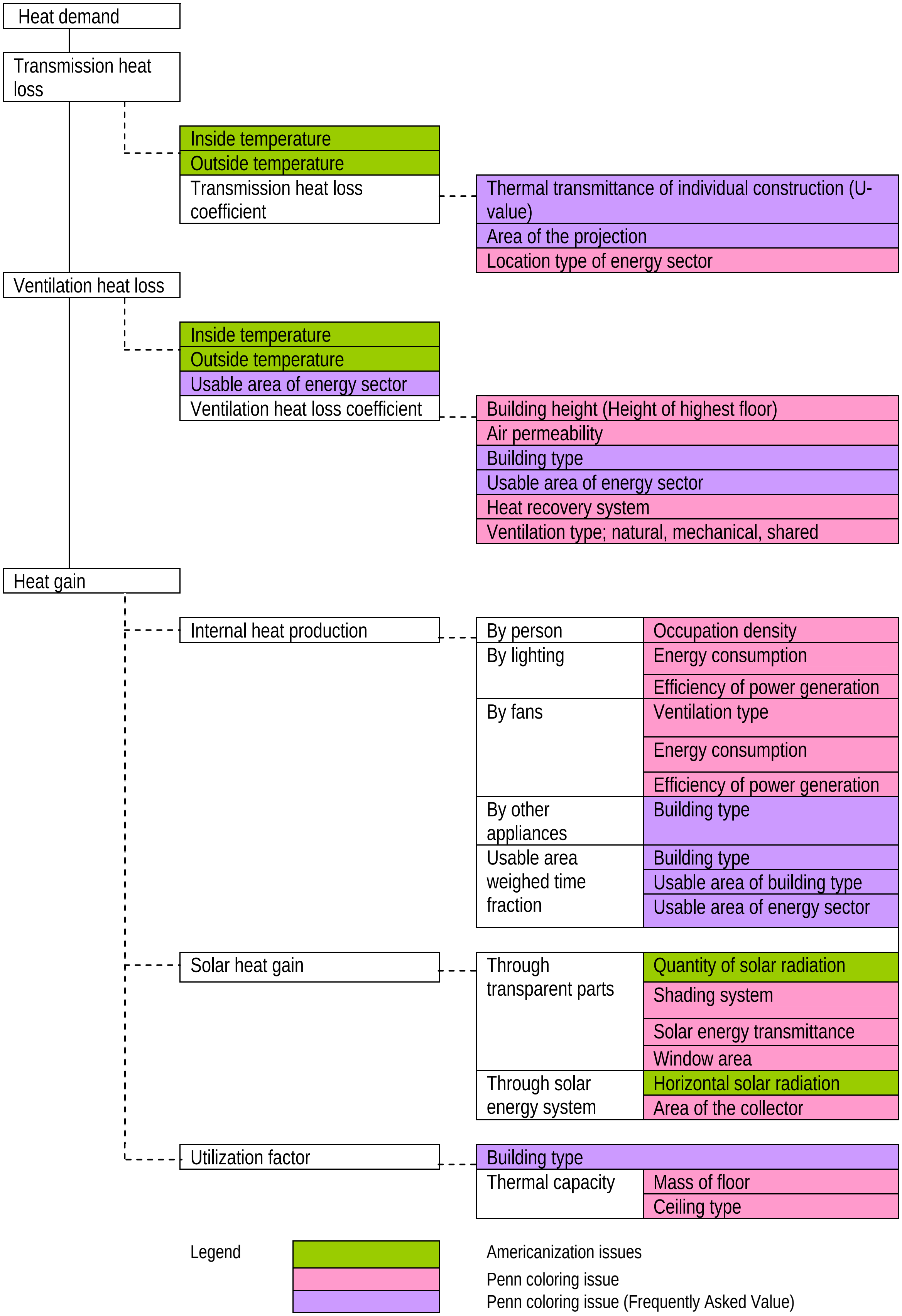

Table 3 Calculation Procedure of Heating Demand

A.1.2.1.3 Utilized Heat Gain

After calculating heat loss, the heat gain must be calculated. The main sources of heat gain are internal heat production by people, ventilation, lighting, fans and other appliances and solar heat gain through transparent parts.

Internal Heat Gain

Internal heat gain is produced by occupants, lighting, plug loads, fans, and other equipment. Data used to calculate the heat gain from fans and ventilation equipment is the same as that which will determine total energy consumption used for ventilation. These data will be discussed in the ventilation section. Additionally, data regarding heat gain from occupants, lighting, and plug loads must be calculated or obtained. NEN 2916 provides normative values for much of these inputs; however, American buildings are often very different from European buildings in regards to these conditions. For applicability to Penn buildings, it will be necessary instead to collect data regarding the occupants, lighting, and plug loads directly from each building, instead of using the normative values provided by NEN 2916.

Solar Heat Gain

To determine the solar heat gain, it is necessary to determine the quantity of solar radiation to reach each vertical and horizontal surface on the building. The given values in NEN 2916 should be modified to reflect local (Philadelphia) climate conditions. Additionally, specific information about each building such as the size and orientation of each window and its shading system (if applicable) is necessary.

Utilization Factor for Heat Gain

The utilization factor for heat gain is necessary to determine the final value of total heat gain. The utilization factor is a function of various data such as of heat gain and loss, building type, thermal transmittance, ventilation type and thermal capacity.

A.1.2.2 Heat Distribution System Efficiency

If the actual efficiency of a building's heat distribution system is known, this value should be used. For buildings on the Penn Steam loop, which transfer the energy to hot water in heat exchangers within each building, a conservative, general efficiency of 80% has been used. To calculate the heat distribution efficiency, the distribution type and distribution medium (water or air) should be determined. Additionally, the heat distribution efficiency calculation requires values for the heating and cooling demand. Table 4 indicates the structure of the full calculation.

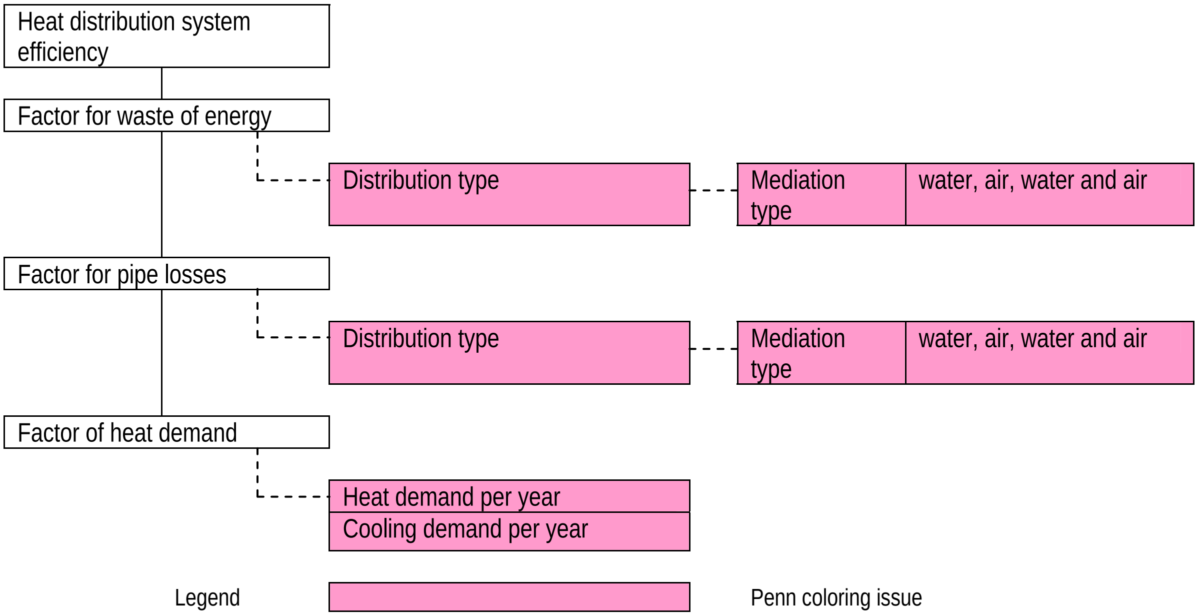

Table 4 Calculation Procedure of Heat Distribution Efficiency

A.1.2.3 Heat Generation Efficiency

Heat generation efficiency depends on the performance of the heat generator. As with the heat distribution efficiency, either an actual or calculated value may be used. Table 5 indicates the structure of the full calculation. Because Penn uses steam to heat its campus buildings, heat is not actually generated in its buildings. Therefore, the heat generation efficiency was set to a default of 100%.

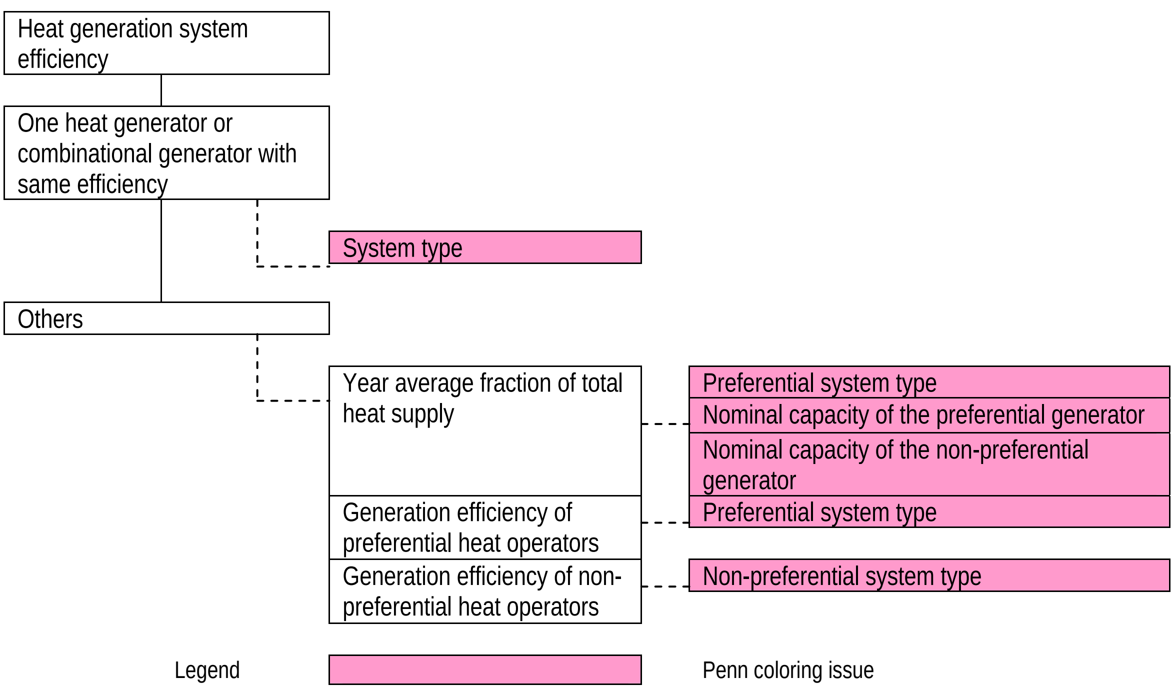

Table 5 Calculation Procedure of Heat Generation System Efficiency

A.1.3 Energy Consumption for Cooling

The procedure to calculate cooling is similar to that of heating. Energy consumption used for cooling is calculated as the quotient of cooling demand and cold generation efficiency. Cooling demand is the quotient of cooling demand at room level and cold distribution efficiency. As with heating, numerous input data are necessary to complete the calculations. The full procedure is indicated in Table 6.

A.1.3.1 Cooling Demand

The cooling demand is determined based on solar heat gain and internal heat production reduced by the utilized heat losses through ventilation and transmission, the distribution system efficiency and a fixed factor for latent cooling load. The calculation of internal heat production and solar heat gain through transparent parts is the same as that of heating demand.

A.1.3.1.1 Heat Gain

The calculations for heat gain used in the procedure for determining cooling consumption include those already calculated during the procedure for determining heating consumption. Additionally, the cooling consumption procedure includes a calculation for solar heat gain through opaque materials. This calculation will be further explained in this section.

Solar Heat Gain

The solar heat gain comes from solar energy which strikes the building's exterior surfaces. The solar heat gain through transparent materials is the same as that explained in the procedure for determining heating consumption. For determining the cooling consumption, it is also necessary to calculate the solar heat gain through opaque materials. To determine this value, it is necessary to calculate the quantity of solar radiation to strike each part, the thermal transmittance of each material, and the projected area of each part.

A.1.3.1.2 Heat Loss

Heat loss is caused by transmission and ventilation. To determine the total heat loss, it is necessary to calculate the transmission and ventilation. The sum of these values is then multiplied by a dimensionless utilization factor, described below.

Transmission Heat Loss

The transmission heat loss is determined by multiplying the transmission coefficient and the temperature difference between the interior of the building and the exterior. The transmission coefficient depends on the thermal transmittance of the building's construction materials and the surface area of the building. As indicated previously, the interior and exterior temperatures should be specific to Philadelphia and to Penn buildings.

Ventilation Heat Loss

To calculate the ventilation heat loss, the temperature difference between the interior of a building and its supply air is multiplied by the ventilation heat loss coefficient. Necessary data for to determine the ventilation heat loss coefficient include the building type, natural ventilation facility, airflow, and usable floor area. These values will all be specific to an individual building.

Utilization factor for cold

The utilization factor depends on the ratio of heat loss to heat gain, as described below.

Cooling demand

Heat gain	Internal heat production	By person	Occupation density	Penn coloring issue
		By lighting	Energy consumption	Penn coloring issue
			Efficiency of power generation	Penn coloring issue
		By fans	Ventilation type	Penn coloring issue
			Energy consumption	Penn coloring issue
			Efficiency of power generation	Penn coloring issue
		By other appliances	Building type	Penn coloring issue
		Usable area weighed time fraction	Building type	Penn coloring issue (Frequently Asked Value)
			Usable area of building type	Penn coloring issue (Frequently Asked Value)
			Usable area of energy sector	Penn coloring issue (Frequently Asked Value)
	Solar heat gain	Through transparent parts	Quantity of solar radiation	Americanization issues
			Shading system	Penn coloring issue
			Solar energy transmittance	Penn coloring issue
			Window area	Penn coloring issue
		Through opaque parts	Horizontal solar radiation	Americanization issues
			Thermal transmittance	Penn coloring issue
			Area of the collector	Penn coloring issue
Heat loss	Heat loss through transmission	Transmittance heat loss coefficient	Thermal transmittances of the individual constructions	Penn coloring issue (Frequently Asked Value)
			Area of the projectors	Penn coloring issue (Frequently Asked Value)
			Location type of energy sectors	Penn coloring issue (Frequently Asked Value)
		Inside temperature		Americanization issues
		Outside temperature		Americanization issues
	Heat loss through ventilation	Ventilation heat loss coefficient	Building type	Penn coloring issue (Frequently Asked Value)
			Natural ventilation facility	Penn coloring issue
			Required min. & max. air flow	Penn coloring issue
			Usable area of building type	Penn coloring issue (Frequently Asked Value)
			Usable area of the energy sector	Penn coloring issue (Frequently Asked Value)
		Inside temperature		Americanization issues
		Temperature of the supply air		Penn coloring issue
	Utilization factor for cold	Loss-gain ratio		
		Building type		Penn coloring issue (Frequently Asked Value)
		Effective thermal mass capacity	Mass of floor	Penn coloring issue
			Ceiling type	Penn coloring issue
Loss-gain ratio	Heat loss from transmission and ventilation			
	Heat gain from internal and solar heat load			

Legend:
- (green) Americanization issues
- (pink) Penn coloring issue
- (purple) Penn coloring issue (Frequently Asked Value)

Table 6 Calculation Procedure of Cooling Demand

A.1.3.1.3 Loss-Gain Ratio

The heat loss-gain ratio is the ratio of heat loss to heat gain. This value will depend on factors such as building type, transmission coefficient, ventilation coefficient, and effective thermal capacity.

A.1.3.2 Cold Distribution System Efficiency

The determination of the efficiency of cold distribution is similar to the calculation used to determine the efficiency of heat distribution. Table 7 indicates the full calculation procedure. In addition to those values calculated for heat distribution efficiency, it is necessary to determine the cooling demand factor. This value may be calculated using the heating demand factor as determined in the heating section. Additionally, it is necessary to determine the specific system type and medium (water or air) used by an individual building.

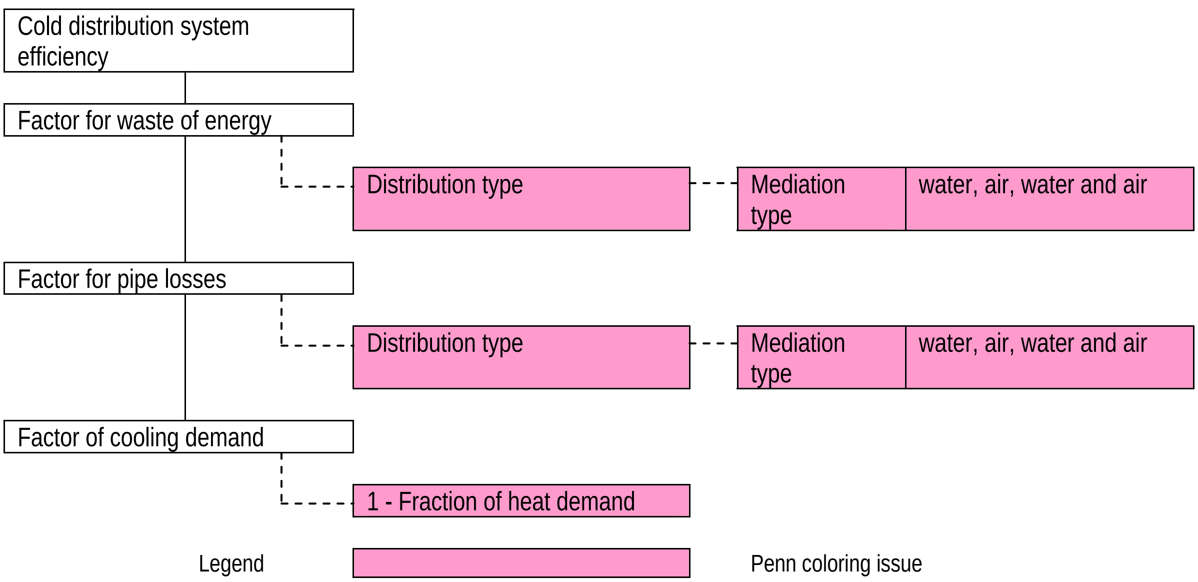

Table 7 Calculation Procedure of Cold Distribution System Efficiency

A.1.3.3 Cold Generation System Efficiency

The cold generation system efficiency depends on the efficiency of the chiller. Table 8 indicates the factors which affect this value. However, Penn's campus buildings use water which has already been chilled (by the campus chiller plants) and so they do not actually generate their own cooling. Therefore, the value of cold generation efficiency for buildings which are provided cooling by the chiller plants is set to 100%.

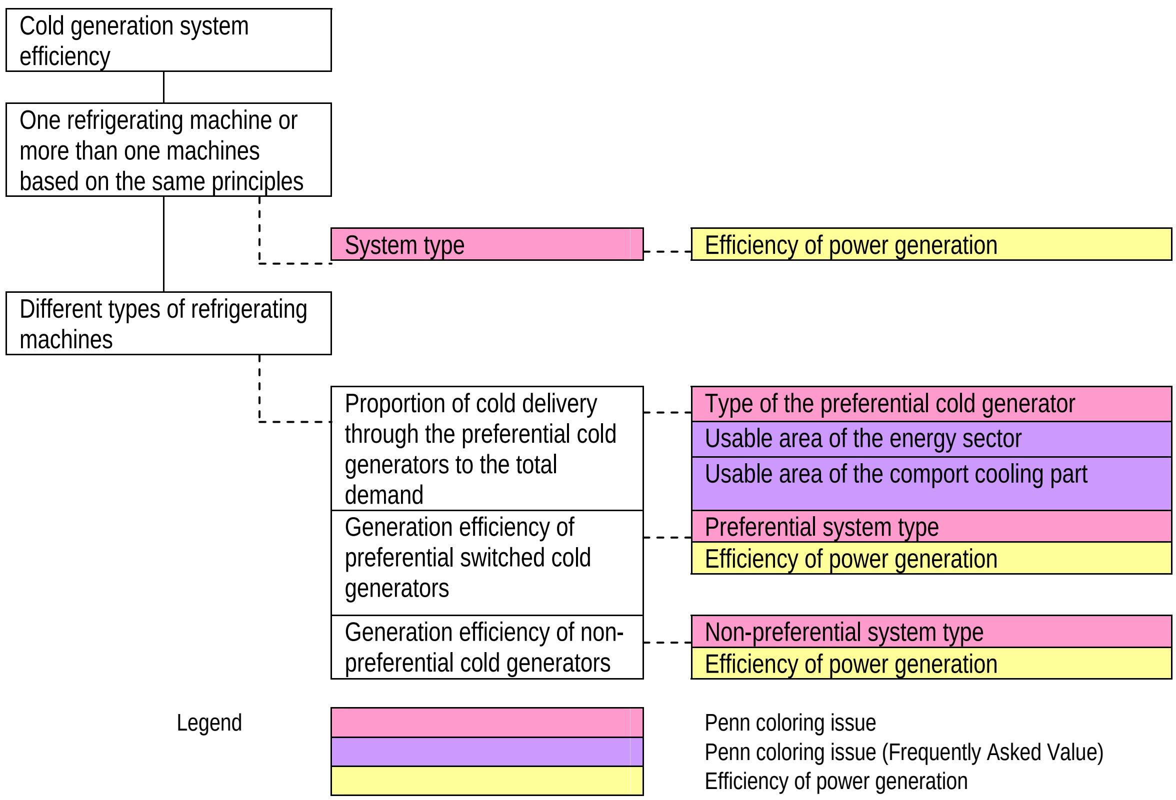

Table 8 Calculation Procedure of Cold Generation System Efficiency

A.1.4 Energy Consumption for Lighting

The energy consumption for lighting should be determined for each energy sector based on the connected power of the installed lamps, the lighting hours and lighting control appliances. There are two calculation methods in NEN 2916. These procedures are indicated in Table 9. The first calculation uses an agreed value of the specific electricity consumption per year per unit of usable area in the building. This calculation procedure uses normalized factors for lighting control systems.

The other lighting calculation method is based on real connected load. For this calculation, daylight, artificial lighting during the day, and artificial lighting during the evening are considered separately. This calculation also calls for individual window sizes, areas which are day lit, areas which are lit artificially, etc. In the original NEN 2916, this calculation also uses an assumed number of burning hours per year and an average value of connected power based on the building type. As these values have been normalized based on European buildings, they are not applicable to American buildings. To use this calculation in Penn buildings, it is necessary to survey each building individually to determine its actual connected power. Additionally, it is necessary to determine the total annual burning hours specific to each individual building.

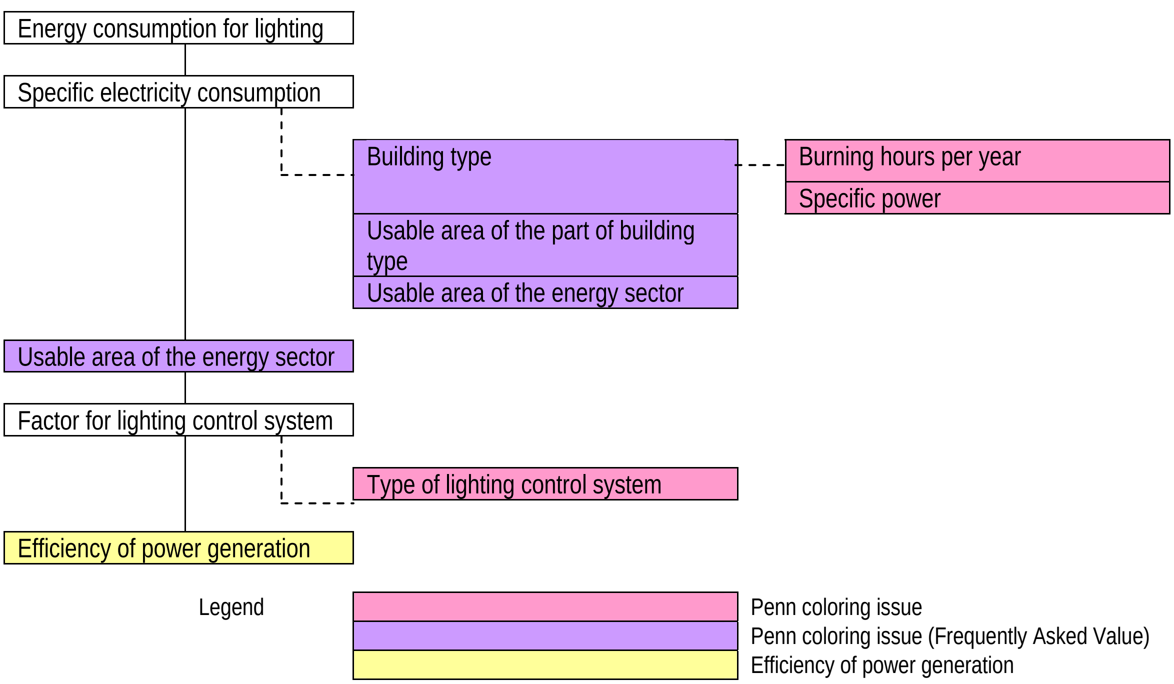

Table 9 Calculation Procedure of Energy Consumption for Lighting

A.1.5 Energy consumption of fans for ventilation and air circulation

The energy consumption used for ventilation and air circulation in the building is determined as the product of the operation time (in hours per year) and the effective electric power of the fans and ventilation equipment. This procedure is indicated in Table 10.

The total effective power is based on the airflow due to mechanical ventilation. The data necessary to determine this value include shaft capacity and power, electric voltage and current, required maximum and minimum airflow, the type of electromotor and ventilation, various area and effective power of fans etc. For Penn buildings, a real value of effective power is determined based on building audits and examination of the ventilation equipment.

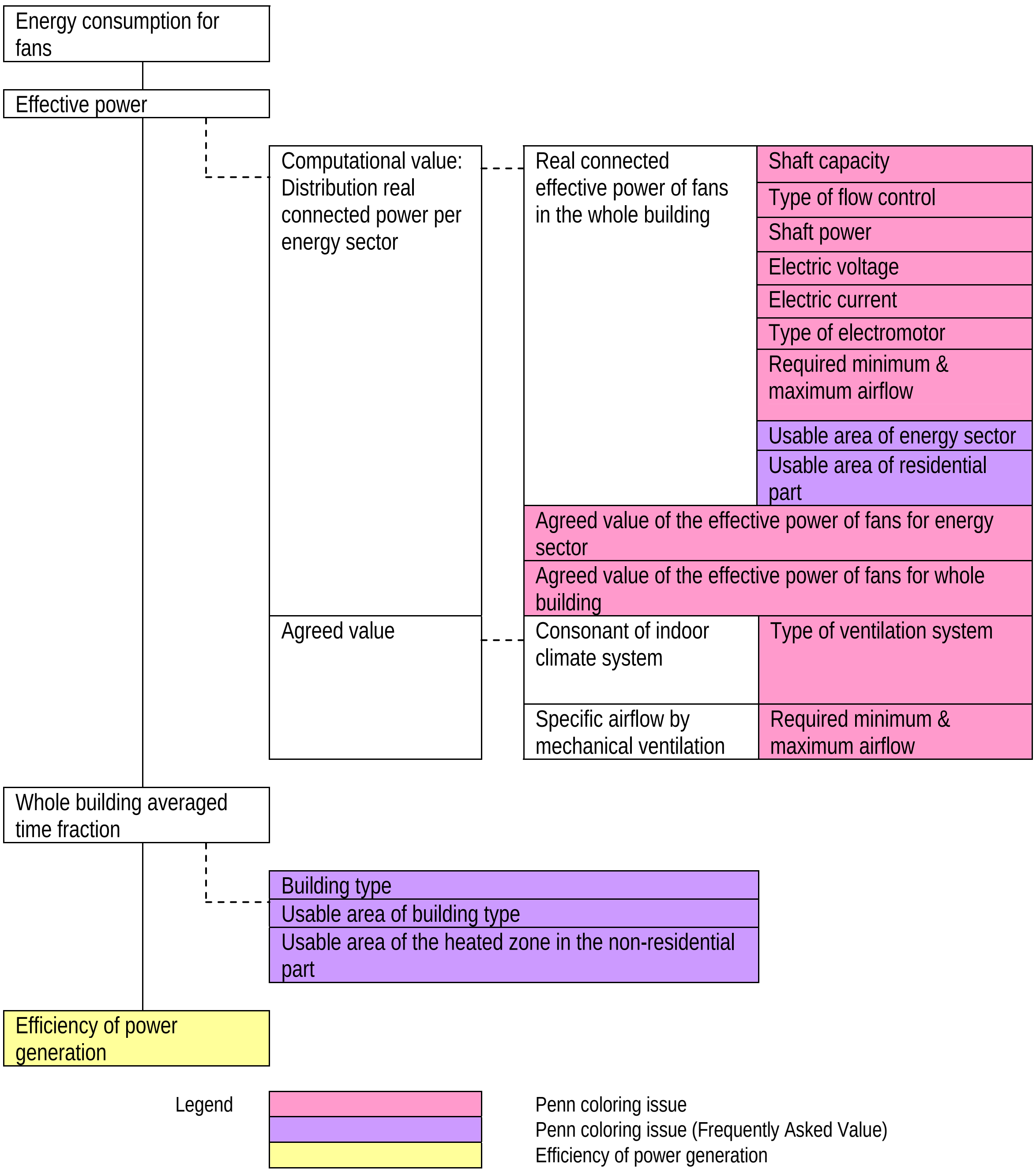

Table 10 Calculation Procedure of Energy Consumption for Fans

A.1.6 Energy consumption of pumps

The energy consumption used for pumps is determined by agreed values for the energy consumption per square meter. There also exists a correction factor to account for energy saving pump controls, if applicable. To calculate the primary energy consumption used by the pumps, the usable area of the heated and cooled zones of each building should be calculated and the flow control system types should be surveyed. The weighting factors for the type of flow control are given as normative values in NEN 2916. The procedure is indicated in Table 11.

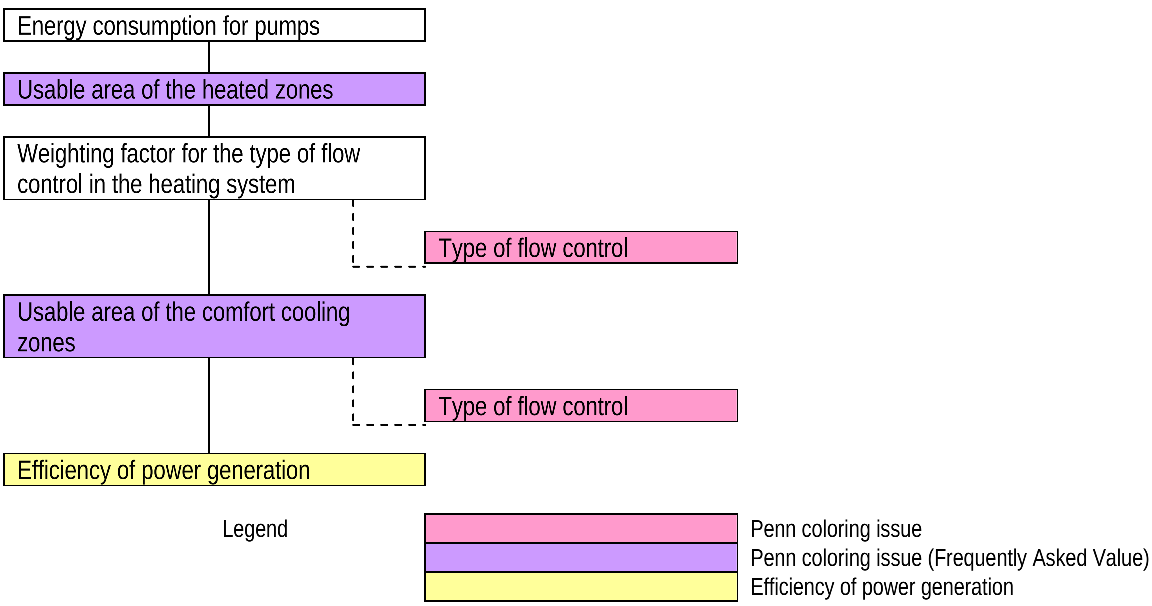

Table 11 Calculation Procedure of Energy Consumption for Pumps

A.1.7 Energy consumption of humidification

If the building contains a facility for humidifying, the energy consumption for humidifying needs to be determined by the amount of air to be humidified. Possible recovery of moisture from the return air and the way in which the necessary latent heat of vaporization is produced are both considered. The procedure for this calculation is indicated in Table 12. However, as Penn buildings do not currently offer humidification, this value does not need to be calculated.

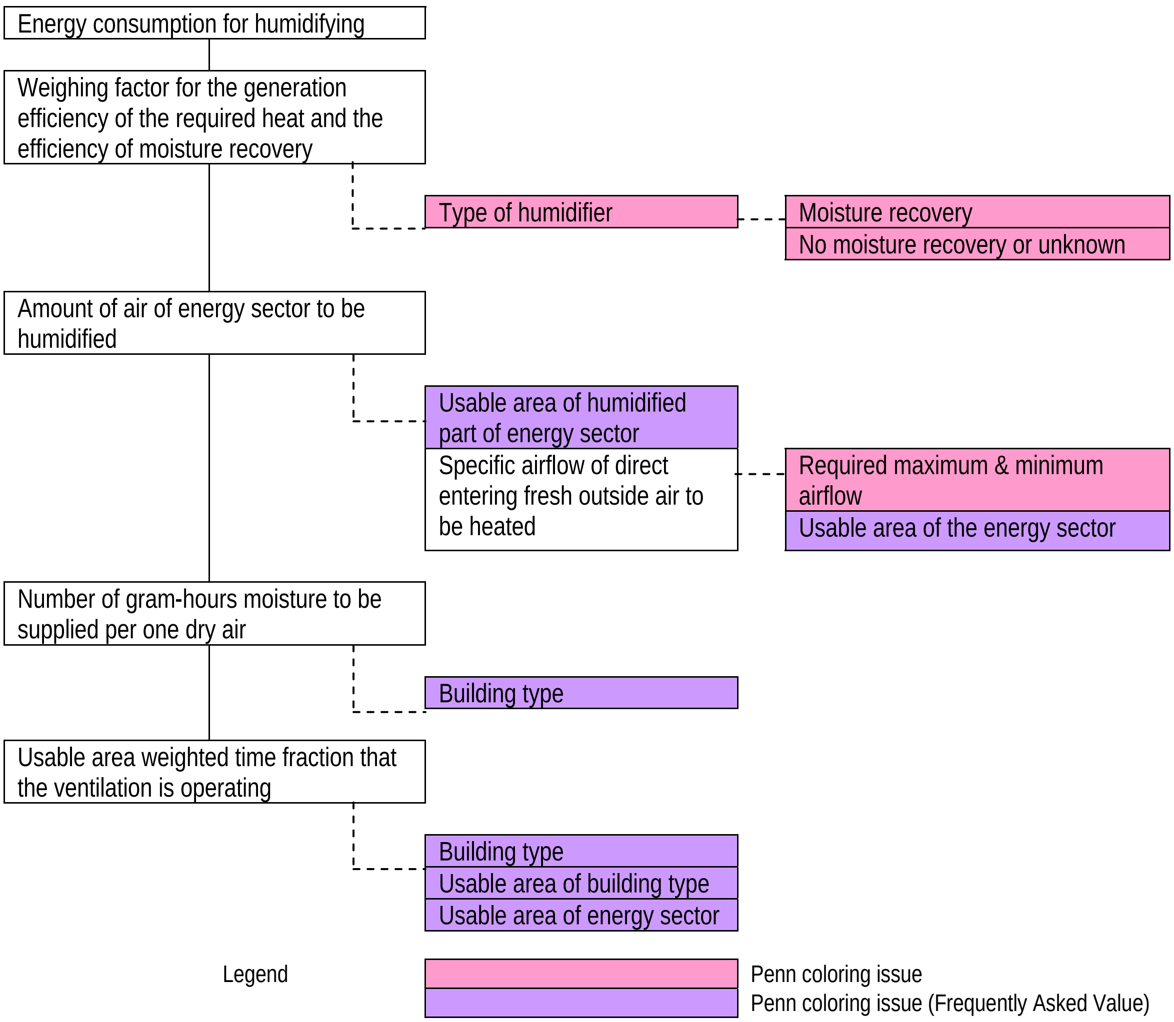

Table 12 Calculation Procedure of Energy Consumption for Humidifying

A.1.8 Energy Consumption for Preparation of Domestic Hot Water

The energy consumption for preparation of domestic hot water is determined for the whole building. This procedure is indicated in Table 13. This calculation uses a net heat demand, determined for energy sectors provided with taps for domestic hot water, based on imposed demand per square meter. The determination of the final energy consumption accounts for energy losses by the applied distribution system and heat generators. These losses are expressed in distribution system efficiency and generation efficiency respectively. The applied installation with most taps in the building determines this efficiency.

The net heat demand for domestic hot water depends on building type and usable area of energy sector situated part of the building types provided with taps for domestic hot water. To calculate the efficiency of distribution or generation, distances between taps and heat generation appliance and the type of heat generator should be surveyed. If there is a solar domestic hot water system, the yearly energy contribution is considered and this is affected by the orientation, angle and area of solar collectors.

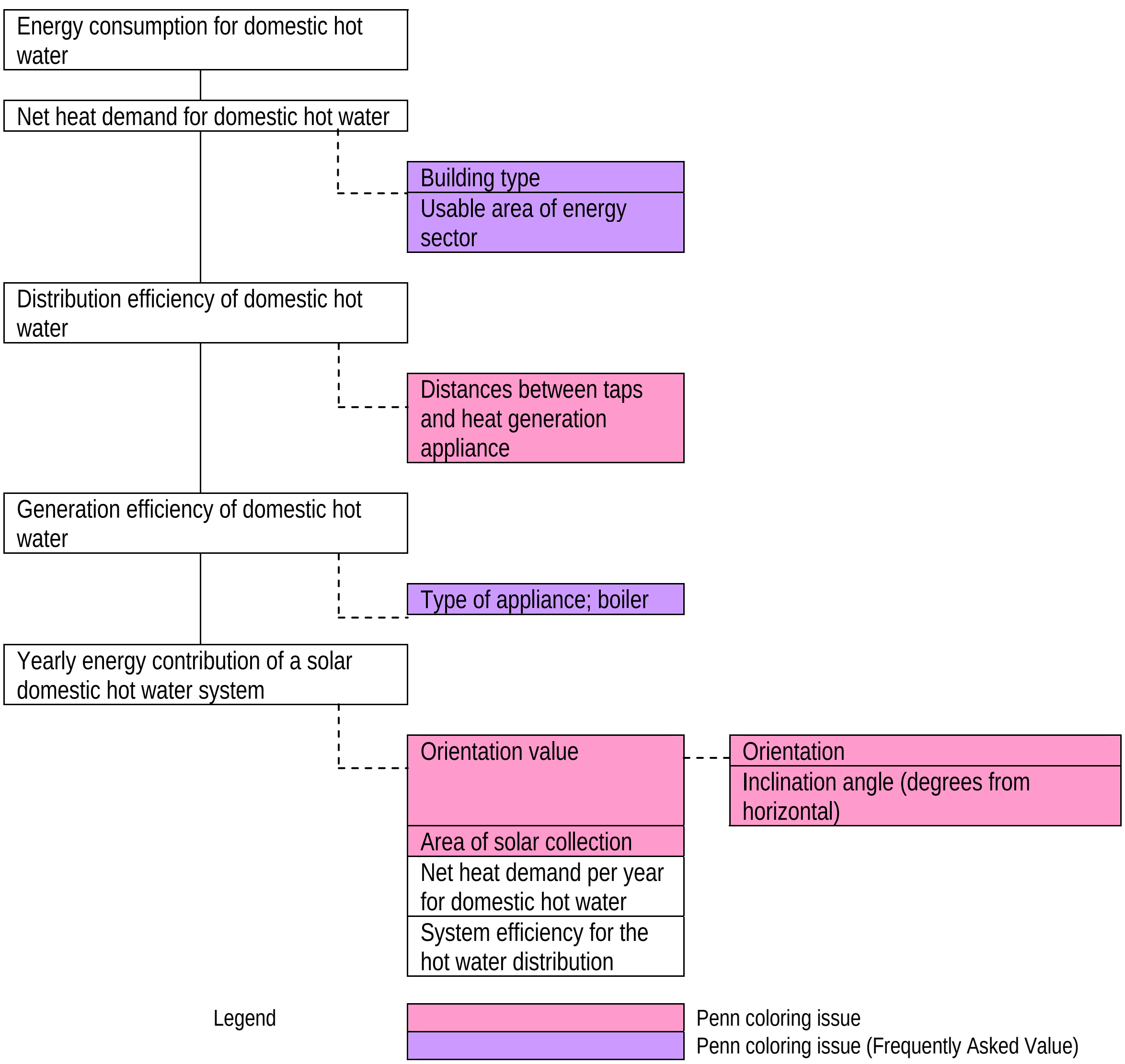

Table 13 Calculation Procedure for Energy Consumption of Domestic Hot Water

A.1.9 Summary

As indicated in the preceding sections, there is a great deal of information necessary to calculate the total energy consumption of a single building. Additionally, there are numerous factors within NEN 2916 that are specific to European buildings, and these must be re-evaluated in order to apply the calculations to American and specifically to Penn buildings. BPAT+ has been constructed by carefully modifying certain NEN 2916 factors to conform either to American building standards, to the Philadelphia climate, or to Penn campus systems. In certain cases, an even greater specificity was desired, and an actual value was determined based on audits of individual campus buildings.

A. 2 Complete BPAT+ Results for Phase II Buildings

Note: All data is presented in order of increasing energy consumption.

Total Energy Consumption – Normalized (kBtu per square foot per year)

Building Name	Heating (kBtu/Sf)	Cooling (kBtu/Sf)	Electric (kBtu/Sf)	Total Energy (kBtu/Sf)
Hutchinson Gym	47.81	0.00	12.82	60.63
Harnwell House	37.18	19.90	23.18	80.26
Harrison House	39.76	19.25	24.90	83.91
Logan Hall	45.12	7.33	31.95	84.39
Palestra	74.79	0.00	12.47	87.26
Rodin House	38.84	20.23	28.70	87.76
Annenberg Center	56.99	3.99	31.38	92.36
Fisher Fine Arts	52.88	6.21	38.72	97.81
College Hall	32.15	7.65	59.70	99.50
Colonial Penn	46.50	17.64	42.84	106.97
Duhring Wing	53.58	14.81	41.59	109.98
Morgan	92.09	11.56	6.96	110.61
Sansom East	35.50	47.88	27.67	111.05
McNeil	41.32	12.08	61.08	114.48
Levine	20.81	23.87	74.13	118.82
Houston Hall	91.33	2.19	26.12	119.64
Sansom West	40.64	49.50	31.16	121.30
Caster	62.49	12.68	49.44	124.61
Hillel	60.03	5.68	60.82	126.54
GSE	46.51	18.55	62.57	127.63
Evans	52.59	21.41	58.09	132.09
Van Pelt	33.74	13.97	90.26	137.97
Gimbel Gym	75.68	0.00	63.10	138.78
Addams	38.18	18.59	83.28	140.05
Williams	98.32	9.57	40.14	148.03
Pottruck	66.35	15.80	66.52	148.67
ICA	86.45	8.51	55.46	150.43
Franklin Building	21.79	30.28	100.39	152.46
Meyerson	66.60	10.81	79.28	156.70
3401 Walnut	8.33	26.18	124.43	158.95
Actual Campus Avg (FY06)	76.00	23.50	61.70	161.20
Huntsman	50.03	6.98	106.85	163.87
Music	89.63	17.71	57.34	164.67
1920 Commons	70.24	11.28	86.41	167.93
Stiteler	78.73	16.38	74.06	169.18
Schattner	44.97	32.24	94.68	171.89
Music Annex	105.45	18.44	56.06	179.94
Chem - Cret Wing	88.55	9.40	87.64	185.58
Chem - 1958 Wing	108.01	3.78	89.45	201.24
Chem - 1973 Wing	97.63	11.95	163.54	273.13

Total Energy Consumption – Intensity (MBtu per year)

Building Name	Heating (Mbtu)	Cooling (Mbtu)	Electric (Mbtu)	Total Energy (Mbtu)
Music Annex	417.67	73.03	229.73	720.43
Colonial Penn	792.77	300.69	755.08	1848.54
Morgan	1782.07	223.74	140.90	2146.71
Duhring Wing	1137.29	314.43	903.69	2355.41
Music	1580.55	312.36	1038.39	2931.29
Caster	1539.51	312.41	1250.33	3102.25
ICA	2161.77	212.87	1457.95	3832.59
Chem - Cret Wing	2005.15	212.80	2050.85	4268.80
Hillel	2105.33	199.17	2208.93	4513.42
Levine	984.40	1129.35	3591.31	5705.06
Stiteler	2731.24	568.22	2663.89	5963.35
GSE	2156.53	860.30	2982.43	5999.26
Addams	1694.10	824.75	3916.79	6435.64
Fisher Fine Arts	3548.75	416.68	2706.80	6672.23
Hutchinson Gym	5260.53	0.00	1504.28	6764.81
Logan Hall	3984.35	647.11	2913.01	7544.47
Gimbel Gym	3979.28	0.00	3628.67	7607.96
1920 Commons	3364.90	540.39	4213.41	8118.70
Chem - 1958 Wing	4551.86	159.17	3926.67	8637.70
Palestra	7543.52	0.00	1319.09	8862.61
Pottruck	4464.56	1062.87	4756.93	10284.36
Annenberg Center	6474.80	453.44	3789.49	10717.73
College Hall	3650.53	869.16	7026.35	11546.05
Houston Hall	8743.92	209.96	2602.25	11556.13
Schattner	3210.82	2301.58	6857.83	12370.23
McNeil	4973.63	1453.67	7523.45	13950.75
Meyerson	6115.07	992.55	7504.15	14611.78
Franklin Building	2200.84	3057.59	10379.94	15638.37
Evans	6311.33	2569.59	7066.30	15947.22
Williams	12790.94	1244.79	5508.17	19543.90
Harnwell House	11627.66	6225.17	7422.88	25275.71
Sansom West	8588.39	10460.05	6629.48	25677.92
Harrison House	12380.73	5995.88	7926.24	26302.85
Rodin House	12074.78	6288.41	9136.30	27499.49
3401 Walnut	1446.84	4545.63	22240.78	28233.25
Sansom East	9836.62	13267.13	7718.84	30822.59
Van Pelt	7520.89	3114.32	21373.14	32008.35
Chem - 1973 Wing	14243.86	1743.71	24277.48	40265.05
Huntsman	16505.69	2301.52	36400.25	55207.46

Heating Consumption – Normalized (kBtu per sf per year) and Intensity (MBtu per year)

Building Name	Heating (kBtu/Sf)
3401 Walnut	8.33
Levine	20.81
Franklin Building	21.79
College Hall	32.15
Van Pelt	33.74
Sansom East	35.50
Harnwell House	37.18
Addams	38.18
Rodin House	38.84
Harrison House	39.76
Sansom West	40.64
McNeil	41.32
Schattner	44.97
Logan Hall	45.12
Colonial Penn	46.50
GSE	46.51
Hutchinson Gym	47.81
Huntsman	50.03
Evans	52.59
Fisher Fine Arts	52.88
Duhring Wing	53.58
Annenberg Center	56.99
Hillel	60.03
Caster	62.49
Pottruck	66.35
Meyerson	66.60
1920 Commons	70.24
Palestra	74.79
Gimbel Gym	75.68
Actual Campus Avg (FY06)	76.00
Stiteler	78.73
ICA	86.45
Chem - Cret Wing	88.55
Music	89.63
Houston Hall	91.33
Morgan	92.09
Chem - 1973 Wing	97.63
Williams	98.32
Music Annex	105.45
Chem - 1958 Wing	108.01

Building Name	Heating (Mbtu)
Music Annex	417.67
Colonial Penn	792.77
Levine	984.40
Duhring Wing	1137.29
3401 Walnut	1446.84
Caster	1539.51
Music	1580.55
Addams	1694.10
Morgan	1782.07
Chem - Cret Wing	2005.15
Hillel	2105.33
GSE	2156.53
ICA	2161.77
Franklin Building	2200.84
Stiteler	2731.24
Schattner	3210.82
1920 Commons	3364.90
Fisher Fine Arts	3548.75
College Hall	3650.53
Gimbel Gym	3979.28
Logan Hall	3984.35
Pottruck	4464.56
Chem - 1958 Wing	4551.86
McNeil	4973.63
Hutchinson Gym	5260.53
Meyerson	6115.07
Evans	6311.33
Annenberg Center	6474.80
Van Pelt	7520.89
Palestra	7543.52
Sansom West	8588.39
Houston Hall	8743.92
Sansom East	9836.62
Harnwell House	11627.66
Rodin House	12074.78
Harrison House	12380.73
Williams	12790.94
Chem - 1973 Wing	14243.86
Huntsman	16505.69

Cooling Consumption – Normalized (kBtu per sf per year) and Intensity (MBtu per year)

Building Name	Cooling (kBtu/Sf)
Hutchinson Gym	0.00
Palestra	0.00
Gimbel Gym	0.00
Houston Hall	2.19
Chem - 1958 Wing	3.78
Annenberg Center	3.99
Hillel	5.68
Fisher Fine Arts	6.21
Huntsman	6.98
Logan Hall	7.33
College Hall	7.65
ICA	8.51
Chem - Cret Wing	9.40
Williams	9.57
Meyerson	10.81
1920 Commons	11.28
Morgan	11.56
Chem - 1973 Wing	11.95
McNeil	12.08
Caster	12.68
Van Pelt	13.97
Duhring Wing	14.81
Pottruck	15.80
Stiteler	16.38
Colonial Penn	17.64
Music	17.71
Music Annex	18.44
GSE	18.55
Addams	18.59
Harrison House	19.25
Harnwell House	19.90
Rodin House	20.23
Actual Campus Avg (FY06)	23.50
Evans	21.41
Levine	23.87
3401 Walnut	26.18
Franklin Building	30.28
Schattner	32.24
Sansom East	47.88
Sansom West	49.50

Building Name	Cooling (Mbtu)
Hutchinson Gym	0.00
Gimbel Gym	0.00
Palestra	0.00
Music Annex	73.03
Chem - 1958 Wing	159.17
Hillel	199.17
Houston Hall	209.96
Chem - Cret Wing	212.80
ICA	212.87
Morgan	223.74
Colonial Penn	300.69
Music	312.36
Caster	312.41
Duhring Wing	314.43
Fisher Fine Arts	416.68
Annenberg Center	453.44
1920 Commons	540.39
Stiteler	568.22
Logan Hall	647.11
Addams	824.75
GSE	860.30
College Hall	869.16
Meyerson	992.55
Pottruck	1062.87
Levine	1129.35
Williams	1244.79
McNeil	1453.67
Chem - 1973 Wing	1743.71
Huntsman	2301.52
Schattner	2301.58
Evans	2569.59
Franklin Building	3057.59
Van Pelt	3114.32
3401 Walnut	4545.63
Harrison House	5995.88
Harnwell House	6225.17
Rodin House	6288.41
Sansom West	10460.05
Sansom East	13267.13

Electricity Consumption – Normalized (kBtu per sf per year)

Building Name	Lights (kBtu/Sf)	Plug Loads (kBtu/Sf)	Fans and Pumps (kBtu/Sf)	Total Electric (kBtu/Sf)
Morgan	2.76	3.00	1.20	6.96
Palestra	5.58	5.74	1.16	12.47
Hutchinson Gym	7.57	3.97	1.28	12.82
Harnwell House	4.87	14.09	4.22	23.18
Harrison House	5.02	15.45	4.43	24.90
Houston Hall	9.48	11.61	5.02	26.12
Sansom East	1.52	24.03	2.12	27.67
Rodin House	5.93	17.19	5.57	28.70
Sansom West	2.03	27.27	1.86	31.16
Annenberg Center	17.83	2.93	10.61	31.38
Logan Hall	9.50	20.82	1.63	31.95
Fisher Fine Arts	14.60	7.16	16.96	38.72
Williams	19.56	12.87	7.72	40.14
Duhring Wing	8.08	28.58	4.94	41.59
Colonial Penn	13.05	21.75	8.03	42.84
Caster	12.54	28.14	8.76	49.44
ICA	25.78	14.97	14.72	55.46
Music Annex	17.70	37.25	1.10	56.06
Music	14.71	41.50	1.12	57.34
Evans	7.20	23.25	27.64	58.09
College Hall	20.22	32.38	7.10	59.70
Hillel	18.67	25.66	16.49	60.82
McNeil	11.89	40.77	8.42	61.08
Actual Average*	--	--	--	61.70
GSE	15.21	44.09	3.26	62.57
Gimbel Gym	52.36	9.51	1.23	63.10
Pottruck	37.07	26.07	3.38	66.52
Stiteler	23.71	38.50	11.85	74.06
Levine	15.21	40.88	18.04	74.13
Meyerson	22.95	47.36	8.97	79.28
Addams	43.57	24.70	15.01	83.28
1920 Commons	12.88	62.19	11.34	86.41
Chem - Cret Wing	25.21	46.32	16.10	87.64
Chem - 1958 Wing	34.32	38.57	16.56	89.45
Van Pelt	50.33	35.89	4.05	90.26
Schattner	12.18	36.93	45.57	94.68
Franklin Building	21.82	65.22	13.36	100.39
Huntsman	33.43	53.14	20.29	106.85
3401 Walnut	32.49	85.77	6.18	124.43
Chem - 1973 Wing	24.41	105.96	33.18	163.54

**The average value for electricity represents the average metered value of the selected group of buildings, not that of the campus as a whole.*

Electricity Consumption – Intensity (MBtu per year)

Building Name	Lights (MBtu)	Plug Loads (MBtu)	Fans and Pumps (MBtu)	Total Electric (MBtu)
Morgan	53.35	58.11	23.18	134.64
Music Annex	70.12	147.55	4.37	222.05
Colonial Penn	222.50	370.83	136.98	730.31
Duhring Wing	171.53	606.59	104.78	882.90
Music	259.49	731.89	19.75	1011.13
Caster	308.99	693.20	215.89	1218.08
Palestra	562.72	578.58	116.76	1258.06
ICA	644.54	374.35	368.00	1386.89
Hutchinson Gym	833.32	436.75	140.75	1410.83
Chem - Cret Wing	570.93	1048.95	364.68	1984.56
Hillel	654.83	900.03	578.25	2133.11
Houston Hall	907.99	1111.64	480.71	2500.33
Stiteler	822.48	1335.64	411.09	2569.21
Fisher Fine Arts	979.78	480.51	1138.11	2598.39
Logan Hall	838.61	1838.62	144.23	2821.45
GSE	705.43	2044.37	151.29	2901.08
Gimbel Gym	2753.04	500.20	64.55	3317.80
Levine	719.60	1933.94	853.15	3506.69
Annenberg Center	2026.09	333.02	1205.65	3564.76
Addams	1933.19	1096.09	665.83	3695.10
Chem - 1958 Wing	1446.55	1625.33	697.80	3769.68
1920 Commons	617.15	2979.07	543.02	4139.24
Pottruck	2494.43	1754.49	227.25	4476.17
Williams	2543.96	1674.23	1003.79	5221.99
Sansom West	428.95	5762.66	393.87	6585.48
Schattner	869.75	2636.47	3253.01	6759.23
College Hall	2295.96	3677.05	805.72	6778.73
Evans	864.18	2790.57	3316.79	6971.53
Harnwell House	1522.93	4407.43	1319.15	7249.51
Meyerson	2107.49	4348.78	823.26	7279.53
McNeil	1431.70	4907.73	1013.36	7352.78
Sansom East	422.04	6658.83	587.87	7668.73
Harrison House	1561.72	4812.41	1380.47	7754.61
Rodin House	1844.74	5344.83	1732.67	8922.23
Franklin Building	2203.34	6586.33	1348.79	10138.46
Van Pelt	11218.63	8000.88	901.97	20121.48
3401 Walnut	5639.96	14889.49	1072.04	21601.48
Chem - 1973 Wing	3560.48	15458.03	4840.38	23858.89
Huntsman	11026.40	17530.69	6692.08	35249.16

Electricity Used for Lighting – Normalized (kBtu per sf per year) and Intensity (MBtu per year)

Building Name	Lights (kBtu/Sf)
Sansom East	1.52
Sansom West	2.03
Morgan	2.76
Harnwell House	4.87
Harrison House	5.02
Palestra	5.58
Rodin House	5.93
Evans	7.20
Hutchinson Gym	7.57
Duhring Wing	8.08
Houston Hall	9.48
Logan Hall	9.50
McNeil	11.89
Schattner	12.18
Caster	12.54
1920 Commons	12.88
Colonial Penn	13.05
Fisher Fine Arts	14.60
Music	14.71
Levine	15.21
GSE	15.21
Music Annex	17.70
Annenberg Center	17.83
Hillel	18.67
Williams	19.56
College Hall	20.22
Franklin Building	21.82
Meyerson	22.95
Stiteler	23.71
Chem - 1973 Wing	24.41
Chem - Cret Wing	25.21
ICA	25.78
3401 Walnut	32.49
Huntsman	33.43
Chem - 1958 Wing	34.32
Pottruck	37.07
Addams	43.57
Van Pelt	50.33
Gimbel Gym	52.36

Building Name	Lights (MBtu)
Morgan	53.35
Music Annex	70.12
Duhring Wing	171.53
Colonial Penn	222.50
Music	259.49
Caster	308.99
Sansom East	422.04
Sansom West	428.95
Palestra	562.72
Chem - Cret Wing	570.93
1920 Commons	617.15
ICA	644.54
Hillel	654.83
GSE	705.43
Levine	719.60
Stiteler	822.48
Hutchinson Gym	833.32
Logan Hall	838.61
Evans	864.18
Schattner	869.75
Houston Hall	907.99
Fisher Fine Arts	979.78
McNeil	1431.70
Chem - 1958 Wing	1446.55
Harnwell House	1522.93
Harrison House	1561.72
Rodin House	1844.74
Addams	1933.19
Annenberg Center	2026.09
Meyerson	2107.49
Franklin Building	2203.34
College Hall	2295.96
Pottruck	2494.43
Williams	2543.96
Gimbel Gym	2753.04
Chem - 1973 Wing	3560.48
3401 Walnut	5639.96
Huntsman	11026.40
Van Pelt	11218.63

Electricity Used for Plug Loads – Normalized (kBtu per sf per year) and Intensity (MBtu per year)

Building Name	Plug Loads (kBtu/Sf)
Annenberg Center	2.93
Morgan	3.00
Hutchinson Gym	3.97
Palestra	5.74
Fisher Fine Arts	7.16
Gimbel Gym	9.51
Houston Hall	11.61
Williams	12.87
Harnwell House	14.09
ICA	14.97
Harrison House	15.45
Rodin House	17.19
Logan Hall	20.82
Colonial Penn	21.75
Evans	23.25
Sansom East	24.03
Addams	24.70
Hillel	25.66
Pottruck	26.07
Sansom West	27.27
Caster	28.14
Duhring Wing	28.58
College Hall	32.38
Van Pelt	35.89
Schattner	36.93
Music Annex	37.25
Stiteler	38.50
Chem - 1958 Wing	38.57
McNeil	40.77
Levine	40.88
Music	41.50
GSE	44.09
Chem - Cret Wing	46.32
Meyerson	47.36
Huntsman	53.14
1920 Commons	62.19
Franklin Building	65.22
3401 Walnut	85.77
Chem - 1973 Wing	105.96

Building Name	Plug Loads (MBtu)
Morgan	58.11
Music Annex	147.55
Annenberg Center	333.02
Colonial Penn	370.83
ICA	374.35
Hutchinson Gym	436.75
Fisher Fine Arts	480.51
Gimbel Gym	500.20
Palestra	578.58
Duhring Wing	606.59
Caster	693.20
Music	731.89
Hillel	900.03
Chem - Cret Wing	1048.95
Addams	1096.09
Houston Hall	1111.64
Stiteler	1335.64
Chem - 1958 Wing	1625.33
Williams	1674.23
Pottruck	1754.49
Logan Hall	1838.62
Levine	1933.94
GSE	2044.37
Schattner	2636.47
Evans	2790.57
1920 Commons	2979.07
College Hall	3677.05
Meyerson	4348.78
Harnwell House	4407.43
Harrison House	4812.41
McNeil	4907.73
Rodin House	5344.83
Sansom West	5762.66
Franklin Building	6586.33
Sansom East	6658.83
Van Pelt	8000.88
3401 Walnut	14889.49
Chem - 1973 Wing	15458.03
Huntsman	17530.69

Electricity Used for Fans and Pumps – Normalized (kBtu per sf per year) and Intensity (MBtu per year)

Building Name	Fans and Pumps (kBtu/Sf)
Music Annex	1.10
Music	1.12
Palestra	1.16
Morgan	1.20
Gimbel Gym	1.23
Hutchinson Gym	1.28
Logan Hall	1.63
Sansom West	1.86
Sansom East	2.12
GSE	3.26
Pottruck	3.38
Van Pelt	4.05
Harnwell House	4.22
Harrison House	4.43
Duhring Wing	4.94
Houston Hall	5.02
Rodin House	5.57
3401 Walnut	6.18
College Hall	7.10
Williams	7.72
Colonial Penn	8.03
McNeil	8.42
Caster	8.76
Meyerson	8.97
Annenberg Center	10.61
1920 Commons	11.34
Stiteler	11.85
Franklin Building	13.36
ICA	14.72
Addams	15.01
Chem - Cret Wing	16.10
Hillel	16.49
Chem - 1958 Wing	16.56
Fisher Fine Arts	16.96
Levine	18.04
Huntsman	20.29
Evans	27.64
Chem - 1973 Wing	33.18
Schattner	45.57

Building Name	Fans and Pumps (MBtu)
Music Annex	4.37
Music	19.75
Morgan	23.18
Gimbel Gym	64.55
Duhring Wing	104.78
Palestra	116.76
Colonial Penn	136.98
Hutchinson Gym	140.75
Logan Hall	144.23
GSE	151.29
Caster	215.89
Pottruck	227.25
Chem - Cret Wing	364.68
ICA	368.00
Sansom West	393.87
Stiteler	411.09
Houston Hall	480.71
1920 Commons	543.02
Hillel	578.25
Sansom East	587.87
Addams	665.83
Chem - 1958 Wing	697.80
College Hall	805.72
Meyerson	823.26
Levine	853.15
Van Pelt	901.97
Williams	1003.79
McNeil	1013.36
3401 Walnut	1072.04
Fisher Fine Arts	1138.11
Annenberg Center	1205.65
Harnwell House	1319.15
Franklin Building	1348.79
Harrison House	1380.47
Rodin House	1732.67
Schattner	3253.01
Evans	3316.79
Chem - 1973 Wing	4840.38
Huntsman	6692.08

Comparison of Total Electricity Consumption Calculated by BPAT+ and Metered Electricity Consumption Data (FY2006)

Building Name	BPAT+ Calculated Electricity (Mbtu)	Metered Electricity (Mbtu)	Difference (%)
Sansom East	7668.734	7718.84	0.65%
Sansom West	6585.482	6629.48	0.66%
Evans	6971.532	7066.30	1.34%
Schattner	6759.234	6857.83	1.44%
Chem - 1973 Wing	23858.89	24277.48	1.72%
1920 Commons	4139.239	4213.41	1.76%
Harrison House	7754.605	7926.24	2.17%
McNeil	7352.784	7523.45	2.27%
Duhring Wing	882.901	903.69	2.30%
Franklin Building	10138.464	10379.94	2.33%
Harnwell House	7249.508	7422.88	2.34%
Rodin House	8922.234	9136.30	2.34%
Levine	3506.69	3591.31	2.36%
Caster	1218.075	1250.33	2.58%
Music	1011.127	1038.39	2.63%
GSE	2901.084	2982.43	2.73%
3401 Walnut	21601.479	22240.78	2.87%
Meyerson	7279.533	7504.15	2.99%
Logan Hall	2821.45	2913.01	3.14%
Huntsman	35249.163	36400.25	3.16%
Chem - Cret Wing	1984.555	2050.85	3.23%
Colonial Penn	730.31	755.08	3.28%
Music Annex	222.045	229.73	3.34%
Hillel	2133.114	2208.93	3.43%
College Hall	6778.725	7026.35	3.52%
Stiteler	2569.207	2663.89	3.55%
Houston Hall	2500.333	2602.25	3.92%
Chem - 1958 Wing	3769.678	3926.67	4.00%
Fisher Fine Arts	2598.392	2706.80	4.01%
Morgan	134.64	140.90	4.44%
Palestra	1258.057	1319.09	4.63%
ICA	1386.891	1457.95	4.87%
Williams	5221.985	5508.17	5.20%
Addams	3695.101	3916.79	5.66%
Van Pelt	20121.475	21373.14	5.86%
Pottruck	4476.171	4756.93	5.90%
Annenberg Center	3564.758	3789.49	5.93%
Hutchinson Gym	1410.825	1504.28	6.21%
Gimbel Gym	3317.799	3628.67	8.57%

Lighting -- Peak Loads and Peak Intensities for Surveyed Buildings

Building Name	Lights (Watts/Sf)
Sansom East	0.30
Sansom West	0.33
Hill	0.44
Hutchinson	0.53
Palestra	0.67
The Arch	0.73
Harrison	0.75
Hamilton	0.79
Bennett	0.81
Kelly Writers	0.86
Harnwell	0.86
3537 Locust Walk	0.89
Chem 1958	0.89
1920 Commons	0.90
Music	0.91
Duhring	0.93
McNeil Building	0.94
Morgan	1.02
Schattner Center	1.03
Sweeten Alumni	1.08
Houston Hall	1.08
Chem 1973	1.08
Pottruck	1.09
Solomon	1.11
Logan Hall	1.12
Huntsman	1.23
3401 Walnut St	1.25
Meyerson	1.26
Chem Cret	1.27
Evans Building	1.28
Williams	1.30
Stiteler	1.30
Fisher	1.45
College Hall	1.45
Jaffe	1.48
Franklin Building	1.55
Caster	1.57
Gimbel	1.59
Music Annex	1.60
Levine	1.60
Hillel	1.73
ICA	1.76
GSE Building	1.94
Colonial Penn	2.00
Van Pelt Library	2.15

Building Name	Lights (Watts)
3537 Locust Walk	3737
Kelly Writers House	4903
Music Annex	4956
Sweeten Alumni	10101
Music	12723
Jaffe	14762
Duhring	16548
Morgan	16806
The Arch	18381
Chem Cret	24512
Colonial Penn	27935
Chem 1958	32763
Caster	34506
1920 Commons	36572
ICA	37280
Stiteler	39221
Hillel	49968
Hutchinson	52729
Bennett	53051
Solomon	53389
Palestra	55204
Sansom West	61014
Schattner Center	61422
Squash	61497
Levine	62926
Pottruck	65643
Hill	70663
Sansom East	71444
Gimbel	73032
Logan Hall	74901
Fisher	76922
GSE Building	78344
Houston Hall	86260
Addams	91168
McNeil Building	101529
Meyerson	101600
College Hall	124043
Evans Building	128449
Franklin Building	136625
Williams	138545
Chem 1973	144358
Harrison	193409
3401 Walnut St	194000
Hamilton	206105
Harnwell	206105

Addams	2.43
Squash	2.62
Annenberg Center	3.38

Annenberg Ctr	311087
Huntsman	347055
Van Pelt Library	432180

Plug Loads -- Peak Loads and Peak Intensities for Surveyed Buildings

Building Name	Plug Loads (Watts/Sf)
Hutchinson	0.25
Gimbel	0.26
Squash	0.27
Annenberg Center	0.50
Palestra	0.62
Fisher	0.64
Pottruck	0.69
Williams	0.77
Chem 1958	0.90
ICA	0.92
Morgan	1.00
Houston Hall	1.19
Addams	1.24
Van Pelt Library	1.38
Bennett	1.43
Huntsman	1.76
Stiteler	1.90
Hamilton	2.06
Harrison	2.08
College Hall	2.09
Chem Cret	2.10
Hillel	2.14
Logan Hall	2.21
Harnwell	2.24
Music	2.31
Meyerson	2.34
Solomon	2.56
Kelly Writers	2.64
The Arch	2.65
Schattner Center	2.81
McNeil Building	2.90
Duhring	2.96
3401 Walnut St	2.97
Colonial Penn	3.00
Music Annex	3.03
Caster	3.17
Jaffe	3.55
Hill	3.70
Evans Building	3.72
Levine	3.87
1920 Commons	3.91
Sansom West	3.99
Franklin Building	4.17
Chem 1973	4.22
Sweeten Alumni	4.22

Building Name	Plug Loads (Watts)
Squash	6271
Music Annex	9397
Gimbel	11850
Kelly Writers House	15109
Morgan	16536
ICA	19621
Hutchinson	25252
3537 Locust Walk	25268
Music	32349
Chem 1958	33084
Fisher	34012
Jaffe	35454
Sweeten Alumni	39491
Chem Cret	40415
Pottruck	41358
Colonial Penn	41869
Annenberg Ctr	45833
Addams	46563
Palestra	51587
Duhring	52557
Stiteler	57479
Hillel	61859
The Arch	66432
Caster	69785
Williams	82311
Bennett	93425
Houston Hall	94514
Solomon	123309
Logan Hall	147209
Levine	151966
1920 Commons	158283
Schattner Center	167226
College Hall	178592
Meyerson	189162
GSE Building	203968
Van Pelt Library	276952
McNeil Building	312694
Franklin Building	368646
Evans Building	372565
3401 Walnut St	460714
Huntsman	496811
Hamilton	534376
Harnwell	534376
Harrison	534376
Chem 1973	562135

Sansom East	4.26
GSE Building	5.06
3537 Locust Walk	5.99

Hill	600736
Sansom West	735577
Sansom East	1015802

A.3 EnergyStar Results for Selected Phase II Buildings

EnergyStar 75% Target Data for Offices

Office Buildings	EnergyStar 75% (kBtu/SF)	BPAT+ Results (kBtu/SF)	% Difference (ES75 & BPAT+)
Logan Hall	64.5	84.39	30.8%
Levine	81.5	118.82	45.8%
Fisher	62.7	97.81	56.0%
College Hall	63.2	99.50	57.4%
McNeil Building	70.5	114.48	62.4%
Colonial Penn Center	61.9	106.97	72.8%
GSE Building	73.4	127.63	73.9%
Duhring	59.2	109.98	85.8%
Caster	67	124.61	86.0%
Van Pelt Library	69.5	137.97	98.5%
Meyerson	77.4	156.70	102.4%
Houston Hall	58.8	119.64	103.5%
Morgan	53.3	110.61	107.5%
Hillel at Steinhardt Hall	60.3	126.54	109.8%
3401 Walnut St	75.5	158.95	110.5%
Huntsman Hall	76.2	163.87	115.0%
Addams	64.7	140.05	116.5%
Franklin Building	69.5	152.46	119.4%
Williams	60.9	148.03	143.1%
Stiteler	61.9	169.18	173.3%
Music	59.5	164.67	176.8%
Music Annex	56	179.94	221.3%

EnergyStar 75% Target Data for Residence Halls

Residence Halls	EnergyStar 75% (kBtu/SF)	BPAT+ Results (kBtu/SF)	% Difference (ES75 & BPAT+)
Harnwell	80.26	80.26	-0.2%
Harrison	80.4	83.91	4.4%
Rodin	80.4	87.76	9.2%
Nichols (Sansom East)	81.4	111.05	36.4%
Grad B (Sansom West)	83	121.30	46.1%

A.4 Complete List of Phase II and III Buildings

Penn Sustainability Plan Buildings			
Phase	Count	Building No.	Building Name
II	1	9865	250 S. 36th St. (Castle)
II	2	10	Annenberg Center
II	3	50	Caster Building
II	4	525	Charles Addams Hall
II	5	65	Chemistry Laboratories- 1958 Wng
II	6	70	Chemistry Laboratories- 1973 Wng
II	7	60	Chemistry Laboratories- Cret Wng
II	8	80	Class of 1920 Commons
II	9	95	College Hall
II	10	100	Colonial Penn Center
II	11	120	Duhring Wing
II	12	130	Education Building
II	13	140	Evans Building
II	14	170	Fisher Fine Arts Library
II	15	25	Fisher-Bennett Hall
II	16	155	Franklin Building
II	17	175	Gimbel Gymnasium
II	18	205	Harnwell House
II	19	210	Harrison House
II	20	225	Hill House, Robert C.
II	21	245	Houston Hall
II	22	617	Huntsman Hall, Jon M.
II	23	250	Hutchinson Gymnasium
II	24	253	Institute of Contemporary Art
II	25	415	Jaffe History of Art Building
II	26	55	Kelly Writers House
II	27	293	Levine Hall
II	28	9883	Locust House
II	29	390	Locust Walk, 3537
II	30	310	Logan Hall
II	31	325	McNeil Building
II	32	340	Meyerson Hall
II	33	350	Morgan Building, Randall
II	34	365	Music Building
II	35	370	Music Building Annex
II	36	450	Palestra
II	37	515	Penn Hillel @ Steinhardt Hall
II	38	176	Pottruck Health and Fitness
II	39	505	Ringe Squash Courts
II	40	220	Rodin College House
II	41	380	Sansom East - Nichols House
II	42	190	Sansom West - Graduate Tower B
II	43	173	Schattner Center

Penn Sustainability Plan Buildings (Cont.)			
Phase	Count	Building No.	Building Name
II	44	475	Solomon Laboratories
II	45	550	Stiteler Hall
II	46	560	Sweeten Alumni House
II	47	75	The Arch
II	48	580	Van Pelt Library
II	49	416	Walnut Street, 3401
II	50	620	Williams Hall
III	51	5	Anatomy Chemistry
III	52	15	Annenberg Schl for Communication
III	53	22	Biomedical Research Building 2
III	54	30	Blockley Hall
III	55	241	Carolyn Hoff Lynch Biology Lab
III	56	460	Carriage House
III	57	565	Chancellor Street, 3216
III	58	405	Civic House
III	59	385	Claire M. Fagin Hall
III	60	85	Class of 1923 Ice Skating Rink
III	61	90	Class of 1925 House
III	62	92	Clinical Research Building
III	63	103	Cyclotron
III	64	510	David Rittenhouse Laboratory
III	65	110	Dietrich Graduate Library
III	66	115	DuBois House
III	67	615	Dunning Coaches' Center
III	68	125	Edison Building
III	69	135	English House
III	70	145	Fels Center of Government
III	71	160	Franklin Building Annex
III	72	165	Franklin Field
III	73	285	Gittis Hall
III	74	180	Goddard Laboratories
III	75	185	Grad Rsch Wing Moore School
III	76	195	Greenfield Intercultural Center
III	77	197	Greenfield Intercultural, Rear
III	78	215	Hayden Hall
III	79	150	Hollenback Annex
III	80	235	Hollenback Center
III	81	255	Irvine Auditorium
III	82	260	Johnson Pavilion, Robert Wood
III	83	265	Kaplan Wing
III	84	270	Kings Court
III	85	280	Laboratory, Structure of Matter
III	86	284	Lauder-Fischer Hall
III	87	73	Left Bank
III	88	290	Leidy Laboratories of Biology
III	89	295	Levy Ctr for Oral Health Rsch
III	90	300	Levy Tennis Pavilions

Penn Sustainability Plan Buildings (Cont.)			
Phase	Count	Building No.	Building Name
III	91	9090	Literary Research Center
III	92	395	Locust Walk, 3609
III	93	396	Locust Walk, 3611
III	94	9855	Locust Walk, 3615
III	95	4897	Locust Walk, 3619
III	96	320	Mayer Residence Hall
III	97	230	McNeil Center for Early American Study
III	98	345	Moore School Building
III	99	335	Morgan Building, John
III	100	355	Mudd Biology Research Lab
III	101	575	Museum Archaeology/Anthropology
III	102	7029	Penn Police
III	103	287	Pepper Hall
III	104	470	Presidents House
III	105	490	Quadrangle
III	106	500	Richards Medical Research Labs
III	107	520	Rosenthal Building, Gladys Hall
III	108	595	Ryan Veterinary Hospital
III	109	7244	Sansom Common (Retail)
III	110	485	Sansom Street, 3808-10
III	111	305	Silverman Hall
III	112	456	Skirkanich Hall
III	113	9204	Spruce House
III	114	410	Spruce Street, 3905
III	115	610	Steinberg Conference Center
III	116	535	Steinberg Hall - Dietrich Hall
III	117	27	Stellar-Chance Laboratories
III	118	330	Stemmler Hall, Edward J.
III	119	555	Stouffer Triangle
III	120	286	Tanenbaum Hall, Nicole E.
III	121	650	Thirty-sixth Street, South 133
III	122	570	Towne Building
III	123	7051	Translational Labs
III	124	576	University Museum Academic Wing
III	125	227	Vagelos Laboratories
III	126	585	Van Pelt House
III	127	590	Vance Hall
III	128	630	Vernon and Shirley Hill Pavilion
III	129	600	Veterinary Medicine Old Quad
III	130	420	Walnut Street, 3808-10
III	131	7039	Walnut Street, 3809
III	132	480	Walnut Street, 3815
III	133	430	Walnut Street, 4015
III	134	7040	Walnut Street, 4046
III	135	605	Weightman Hall