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1.0 Executive Summary

Buildings are the top consumers of electricity and contributors of greenhouse gas emissions in the U.S. and have been for decades. In the information age of today, building energy modeling has become increasingly popular and globally necessary to understand how a building is operating and where inefficiencies can be resolved. It allows owners to predict and estimate the cost of operation, efficiency, and carbon footprint of a building during both designing and maintaining.

Phipps Center for Sustainable Landscapes (CSL) is a new 24,350 square foot building in Pittsburgh, Pennsylvania. The building will be comprised of classrooms, offices, and conference rooms for Phipps employees and university researchers. By accepting the Living Building Challenge, Phipps strives for the Center for Sustainable Landscapes to exceed LEED® Platinum certification.

The **objective** of this second mechanical report is to fully understand the building design's HVAC loads as well as energy usage. A computer based method was used to perform block load estimates and an energy model simulation / analysis of the Center for Sustainable Landscapes

Software considered for this whole building load and energy simulation included: DOE's EnergyPlus, eQuest, Trane TRACE Trace, HAP, IES, & ASHRAE RTSM. Due to past experience, the software selected to create the energy model in this project was Trane **TRACE 700**. After running the simulation, the computed loads, annual energy consumption, and operating costs of the building were then compared to the standard loads and consumptions of various ASHRAE and EIA office building benchmarks.

Sections discuss: building overview, mechanical system overview, design load estimations, energy consumption & costs, and pollution estimation.

Integrated Project Delivery (IPD) was required by the owner, Phipps Conservatory. During the design process, everyone was present: owner, CFO, architect, landscape architect, structural engineer, mechanical engineer, water management, process consultant, and energy consultant, all working towards a holistic solution. Phipps Conservatory's Executive Director, Richard Piacentini, claimed that "The new Center for Sustainable Landscapes will be one of the world's first certified living buildings, a model of sustainability for architects, scientists, planners and anyone interested in living greener."

Load & energy results show that CSL strives to generate more electricity than it uses and was simulated to consume 19,926 BTU/SF annually for electricity. Compared to other buildings of its size, function, and location from an Energy Information Administration study, CSL consumes an average of 75% less energy. By far exceeding nearly every building benchmark, the Center for Sustainable Landscapes sets a new standard for performance and efficiency.

2.0 Building Overview

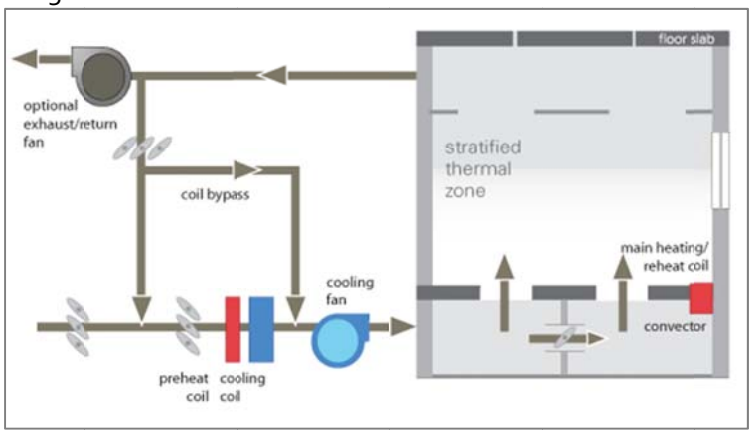
Name	**Phipps Conservatory, Center for Sustainable Landscapes (CSL)** Figure 1 Location Map
Location	One Schenley Park Drive Pittsburgh, PA 15213
Occupant	Phipps Employees / University Researchers 367 persons [*1st: 140, 2nd: 112, 3rd: 115*]
Function	Classroom / Office / Conference Education / Administration / Research
Size	24,350 SF [*1st: 11,209 SF, 2nd: 11,151 SF, 3rd: 1,990 SF*]
Floors	3 stories
Construction	Dec. 2010 - Apr. 2012
Cost	$20 million
Team	Integrated Project Delivery (IPD) required by the owner
Sustainability Goals	1. LEED Platinum 2. Living Building Challenge 3. SITES Certification for landscapes

2.1 Room Categories

The rooms of the Center for Sustainable Landscapes were divided into 12 different categories according to their type of use / function. These categories will be used as templates for the energy analysis. This block type analysis as opposed to a space by space is more time efficient.

Table 1 Room Categories			
Atrium	Conference	Lobby	Reception
Break Room	Corridor	Mechanical	Restroom
Classroom	Elevator	Office	Storage

3.0 Mechanical System Overview

Heating & Cooling	A **ground-source geothermal system** satisfies 70% of the CSL's heating and cooling loads. Ten to fourteen geothermal wells bored 500 ft deep into the ground sink, which remains at a consistent temperature of 57 °F, create a ground source heat exchanger. One **rooftop energy recovery unit** supports the geothermal system in heating, cooling, ventilation and dehumidification. A desiccant wheel in the energy recovery unit pre-cools and dehumidifies outside air to reduce cooling loads by removing the humidity from warmer incoming air. Air is distributed throughout the majority of the building (offices, classrooms, conference rooms) through an **under floor air distribution** VAV with baseboard heating.  Figure 2 Underfloor Air Distribution Schematic The large, three-story atrium/lobby is uniquely 100% passively cooled. Passive heating strategies are supplemented by **radiant floors** heated by an evacuated tube solar hot water system and heat from the upper campus conservatory and green house. To provide both insulation and thermal storage a **green roof** was added to CSL while also reducing the heat island effect.
Ventilating	A **demand controlled ventilation system** (DCV) uses **CO2 sensors** throughout the building to track building occupancy levels and tailors the ventilation rate to provide for the current occupancy level. A **natural ventilation sensor system** inside the building automatically notifies building occupants when conditions are appropriate to open the operable windows. Through natural ventilation and humidity reduction, a comfort setpoint of 78°F reduces the mechanical cooling load and HVAC system fan energy usage.
Controls	A **Direct Digital Control (DDC) Building Management System** will monitor, control, and provide feedback to various building systems for optimal energy efficient operations. The DDC uses past historical weather patterns and current conditions to predict daily ambient temperatures, humidity swings and optimize building systems. **Energy data meters** will also provide building managers and occupants building operating profiles and trend data to monitor energy efficiency.

3.1 Zones

In order to analyze the heating & cooling load according to the building area in proximity to the outdoor conditions, zones were created. This type of analysis as opposed to a full space by space analysis is more time efficient for a whole building analysis. Figure 3 below depicts the designated zones for CSL. The northern rooms on the first floor were considered to be internal since they are covered by soil in grade thus having no air to air heat transfer. The third floor only includes a small enclosed lobby, surronded by a green roof.

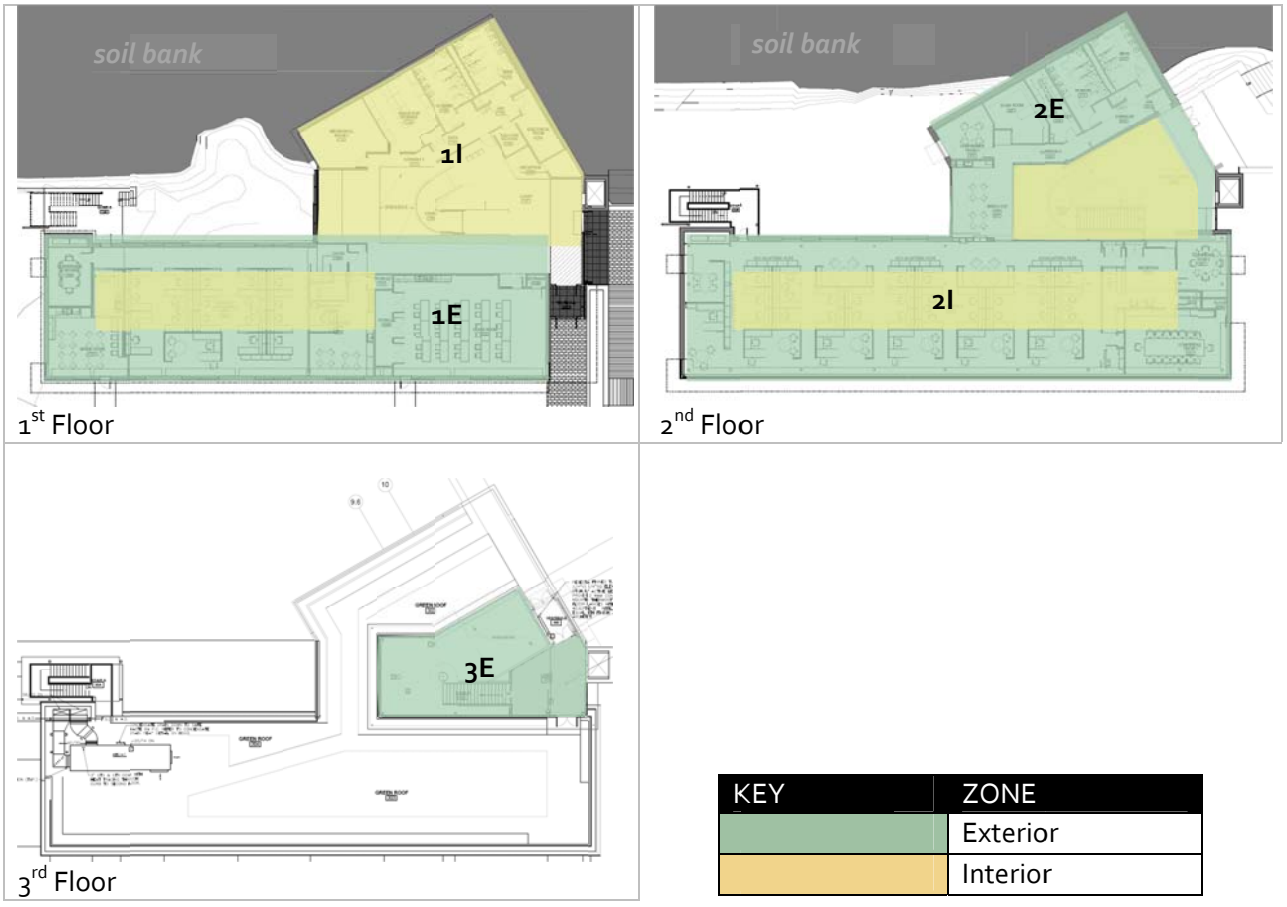


Figure 3 Zones

4.0 Heating & Cooling Loads

To begin the modeling of the Center for Sustainable Landscapes, actual take-offs based upon design documents / specifications, and assumption based on ASHRAE std. 62.1-2007, ASHRAE 90.1-2007, or ASHRAE Handbook of Fundamentals were inputted into TRACE to simulate / estimate the heating & cooling load.

The main load sources on the building are weather (ambient conduction/convection & direct solar gain), occupancy (# people in a space), and lighting / electrical / mechanical power densities (including equipment, appliances, & computers). Factors that affect the total load include schedules (percent of total load in relation to the time of day), airflow (ventilation & infiltration) and construction. Each

assumption, often based on room function, was assigned to room categories in order to make a block load estimation. Typical Trane TRACE templates are details in Appendix A1.

4.1 Weather

The Center for Sustainable Landscapes is located and modeled in Pittsburgh, PA (in the northeast corner of the US). The outdoor air condition values in Table 2 were imported into TRACE from a Pittsburgh, PA, Allegheny County typical meteorological year (TMY) file (shown in Figure 3). The coldest month in Pittsburgh is January and the hottest is August. The indoor air conditions for heating & cooling were taken from ASHRAE Handbook of Fundamentals 2005.

Table 2 Design Conditions & Setpoints

Design Outdoor Conditions for	Summer	Winter	Desired Indoor Conditions	
Dry Bulb Temp.	84 F	9 F	Heating & Cooling Setpoint	75 F
Wet Bulb Temp.	73 F	-	Relative Humidity	50%

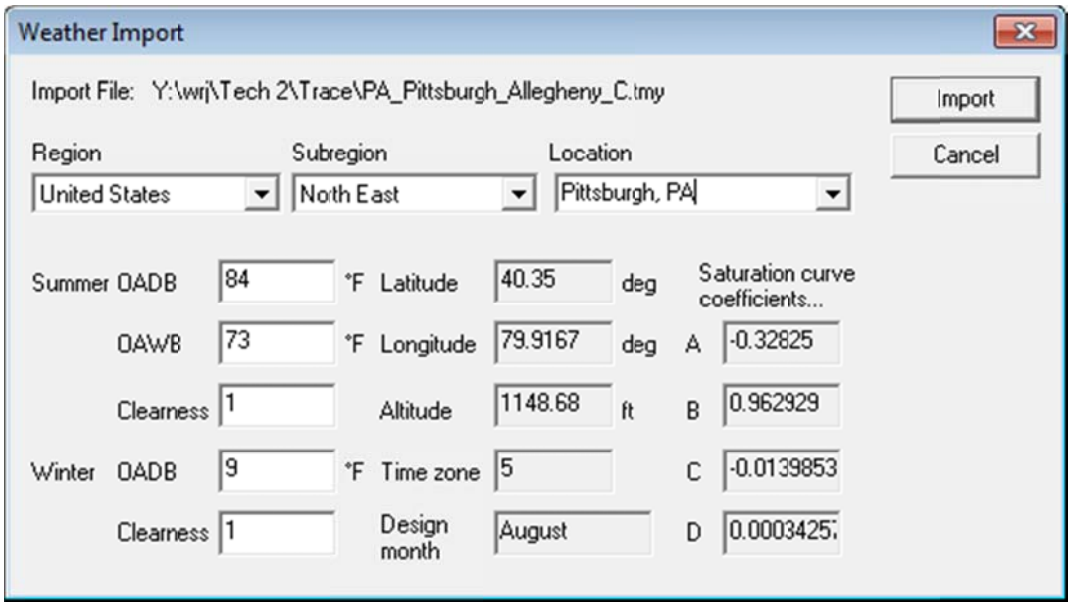


Figure 4 Pittsburgh, PA Weather Import for Trane TRACE

4.2 Occupancy

Occupancy is based upon number of people per space during scheduled hours. People density in a space was determined by the number of chairs in a room on the furniture plan of the design documents for the majority of spaces. For unique spaces such as the atrium, lobbies, & reception, occupancy standards were used from ASHRAE 62.1: Table 6-1 (Pg.15-17) and are summarized below in Table 3. The office category occupies a staggering 20 people since all offices in this building are open office style research spaces as opposed to personal one person offices. Scheduled hours of occupant loads are outlined later in this document.

Table 3 Occupancy Density by Room Category			
CATEGORY	People Density	CATEGORY	People Density
Atrium	200 sqft/person	Lobby	200 sqft/person
Break Room	16 people	Mechanical	0 people
Classroom	31 people	Office	20 people
Conference	10 people	Reception	143 sqft/person
Corridor	0 people	Restroom	0 people
Elevator	0 people	Storage	0 people

4.3 Schedules

In order to provide an accurate representation for the building, load conditions schedules were made for occupancy, lighting, miscellaneous, and ventilation. Table 5 shows typical times of use (or schedules) selected through ASHRAE standards for the primary office use of the building and added to each room category. The Center for Sustainable Landscapes is assumed to operate in general from 6am – 7pm. The typical 8am – 5pm time schedule was extended in order to accommodate for researchers extended hours. Additional, highly unique schedules for CSL's various water pumps are outlined later in section 5.1 [Heating & Cooling plants].

Table 4 Times of Use		
SCHEDULE	TIMES	PERCENT LOAD
Office (Weekdays Year-Round)	6am-8am 8am-5pm 5pm-7pm	50 100 50

4.4 Lighting, Electrical, Mechanical

Because the building is mixed use, load input based on lights, equipment, & computers (workstations) often time varies greatly from space to space. The lighting power densities and miscellaneous equipment loads used on a W/sqft basis shown below in Table 4. The lighting power density assumptions were taken from ASHRAE 90.1-2007, Table 9.6.1. For CSL, these lighting power densities may in fact be high since most lights are high performance, energy efficient T-5 fluorescents or LEDs. ASHRAE was used for time and simplicity reasons. Miscellaneous equipment loads (which include electrical, mechanical equipment, appliances, and computers) were taken from the ASHRAE Fundamentals and design documents. According to a respected professional engineer, the following are rules of thumb values for miscellaneous loads: large mechanical/electrical rooms use 20W/SF, and elevators use 10W/SF. According to ASHRAE Fundamentals a workstation (or computer) consumes about 350W and a projector consumes between 200-400W. The design specs detail that the classroom has one computer and one projector (since their wattages are very similar, the classroom was assumed to have 2 workstations for simplicity).

Table 5 Power Densities by Room Category					
CATEGORY	Lighting Power	Miscellaneous	CATEGORY	Lighting Power	Miscellaneous

	Densities [W/sqft]			Densities [W/sqft]	
Atrium	1.3		Lobby	1.3	
Break Room	1.1		Mechanical	1.5	20 W/SF
Classroom	1.4	2 workstations	Office	1.1	20 workstations
Conference	1.3	1 workstation	Reception	1.3	1 workstation
Corridor	0.6		Restroom	0.9	
Elevators	0.6	10 W/SF	Storage	0.8	

4.5 Airflow

Ventilation and infiltration are both considered in analyzing the airflow and their effect on the load of the building. Area based ventilation rates and exhaust rates were taken from ASHRAE 62.1-2007, Table 6-1. ASHRAE standards were used because airflow rates were not explicitly defined within the design schedules. Air is considered to be supplied to the majority of the building through an under floor distribution system. As a whole, the building is assumed to have a neutral, tight construction infiltration with 0.3 air changes/hour. This infiltration is not subject to a schedule since a building leaks all of the time.

Table 6 Airflow Rates by Category

CATEGORY	Area [cfm/SF]	Exhaust [cfm]	CATEGORY	Area [cfm/SF]	Exhaust [cfm]
Atrium	0.06	0	Lobbies	0.06	0
Break Room	0.06	0	Mechanical	0.06	185
Classroom	0.12	0	Office	0.06	0
Conference	0.06	0	Reception	0.06	0
Corridor	0.06	0	Restroom	0.1	375
Elevators	0.12	300	Storage	0.12	0

4.6 Construction

The wall and glass type construction details were taken from the architectural drawings. The façade is covered with wood salvaged from deconstructed Western Pennsylvania barns for exterior building. The green roof insulates the building to reduce HVAC cooling in summer & heating in winter. Light shelves, louvers and overhangs minimize summer cooling loads by increasing the shading coefficient and contributing to building heating in the winter. Additional progressive green designs such as translucent window shades & brise-soleil screens / internal shades were ignored for minimizing the complexity/error of this simulation, yet in theory will reduce nighttime heat losses & reduce summer cooling loads. Construction material properties are detailed in Table 7.

Table 7 Construction Material Properties

LAYER	CONSTRUCTION	U-Factor	Shading

		[BTU/hr sqft F]	Coefficient
Slab	4" LW Concrete	0.213	-
Roof	Custom Green Roof, 6" soil depth, variety of plants	0.385	-
Wall	Face Salvage Barn Siding, 6" LW Conc blk, 3" Ins	0.060	-
Partition	0.75" Gypsum Fram	0.385	-
Windows	Single Clear ¼"	0.95	0.95
Windows in Atrium	Double Clear ¼"	0.6	0.82
Rooftop Skylight	Triple Coated ¼"	0.14	0.55
Door	Standard Door	0.2	-

4.7 Load Results & Baseline Comparison

To summarize the simulated energy model, the heating & cooling load and ventilation rate from the Trane TRACE Systems Checksums was used. The full Systems Checksums tabulated data is shown in Appendix A2. Standard heating, cooling, & ventilation air values were taken from the Air Conditioned Load Data of a pocket guide of ASHRAE Fundamentals. The Center for Sustainable Landscapes is an small office facility, thus the given hi and low SF/ton & cmf/SF range from the pocket guide is used as the standard. The computed/simulated cooling SF/ton falls right within this range. The supply air rate [cmf/SF] computed also falls right within the standard range for office facilities as expected. The atrium radiant floors is a supplemental system provided by evacuated tube solar hot water that collects heat from the sun to heat water and the atrium. The heating coil load is higher than expected in comparison to the heating coil peak of the underfloor air distribution system (which supplies much many more spaces). This may be a result of the atrium being almost completely covered in glazing. The comparison is outlined below in Table 8.

Table 8 Simulated vs. Standard Load & Ventilation for Entire Building

SYSTEM		Simulated	Standard for Office Buildings (General)
Underfloor Air Distribution & Geothermal Heating/Cooling	Cooling [SF/ton]	388.19	390-190
	Heating [BTU/hr SF]	24.58	-
	Supply & Ventilation Air [cfm/SF]	1.08	0.9-2.0
	Cooling Coil Peak [BTU/hr]	431,926	-
	Heating Coil Peak [BTU/hr]	397,007	-
Atrium Radiant Floors	Heating Coil Peak [BTU/hr]	324,341	-

Table 9 below shows the simulated load & ventilation by assigned zone (which was introduced in Section3.1, Figure 3 above). For reference below, 1E stands for 1st Floor, Exterior. In analyzing the results, it was expected that the majority of the load would come from the exterior ambient

conduction/convection & direct solar gain. The loads found on the interior are typically solely due to people and miscellaneous equipment and computers. Explanations for the outcomes are detailed below:

- This load analysis shows the internal loads to be higher. This is more than likely due to the fact that the atrium was lumped into the internal loads. If more time was available, separating the atrium into its own zone could provide more reasonable interior cooling loads.
- The heating load on 1st floor interior rooms is noticeably lower as expected. This is due to the upper campus conservatory and greenhouse serving as a heat "bank" for heat.
- The 3rd Floor Exterior (3E) that was referenced earlier but not shown below were minimal in comparison to the other zones.

Table 9 Simulated Load & Ventilation by Zone

ZONE	Cooling [SF/ton]	Heating [BTU/hr SF]	Ventilation [Cfm/SF]	Cool. Peak [BTU/hr]	Heat. Peak [BTU/hr]
1E	287.49	27.87	1.87	229,853	237,369
1I	608.41	19.72	1.13	96,352	134,114
2E	340.74	24.72	1.34	268,325	279,035
2I	654.58	18.33	0.39	40,366	34,703

5.0 Energy Consumption & Costs

Trane TRACE 700 was also used to calculate an annual energy simulation of the Center for Sustainable Landscapes using the same ventilation rates, and internal generation, and envelop as used in the load estimation section above. Having been last updated in 2006, Trane TRACE 700 is not very accommodating for new progressive green designs. Geothermal heating/cooling, underfloor air distribution, and a rooftop energy recovery unit made the energy analysis incredibly difficult in comparison to more traditional systems used to heat/cool/ventilate a building. Thus, it will not be possible to capture every energy benefit of CSL's design through this analysis.

5.1 Utilities

Phipps' dynamic new center for education, research and administration has high ambitions of generating all of its own energy while capturing and treating all of its own water on site. This, coupled with the geothermal heating & cooling system (which eliminates the need for natural gas for a boiler), has resulted in CSL only using one utility, electricity, for mechanical systems. For reference, fuel rates for Pittsburgh, Pennsylvania were taken from the U.S. Energy Information Administration (EIA) and Pittsburgh Water & Sewer Administration. Additionally, domestic hot water for a low rise office building was found to be 0.135 gpm. Table 10 gives an explanation of CSL's utility sustainability and the PA referenced rates.

Table 10 CSL Utility Sustainability & Pennsylvania Rates

UTILITY	Sustainability at CSL	Pennsylvania Rates *for reference*

Electricity	• **Solar Photovoltaics** contribute to the net zero energy approach of offsetting 100% of the annual energy consumption of the CSL facility. Installed during construction & used throughout CSL's life, solar PVs on adjacent facilities building and Special Events Hall roof surfaces provide ideal near-southern orientation. Excess generated energy will serve upper campus electricity needs • **Vertical Axis Wind Turbines** generate renewable electricity from wind.	$ 0.10 / kWh
Natural Gas	• Natural gas is piped into the site but is not used for the mechanical systems. • Rather than a boiler (which consumes gas), a geothermal heat pump system is energized when economizer and desiccant wheel cannot maintain comfort conditions due to extremes in outside weather conditions.	$ 0.76 / Therm
Water	• Three progressively sustainable systems were chosen to greatly reduce impact on municipal sewage treatment and energy-intensive potable water systems. • **Rainwater Harvesting** from upper campus glass roofs and lower site will be captured and stored in two 1,700 gallon underground cisterns • **Lagoon System** replicates natural water treatment process that occurs in wetlands and marshes through a 7-step process where plants and their symbiotic root microbes absorb organic and mineral nutrients • **Constructed Wetland** treat all sanitary water from CSL and adjacent maintenance building through a 2-stage wetland treatment cell system	$7.74 / 1,000 gallons

The electricity utility costs were manually inputted into the computerized energy analysis in order to develop the total monthly energy consumption & costs for an entire year broken down by individual energy source.

5.2 Heating & Cooling Plants

Due to the water source heat pump as opposed to a typical AHU, the plants had to be custom built and the heating plants had to be creatively added in order to give Trane TRACE. Figure 5 & 6 shows the configuration and assignments respectively. Since there were not simple methods to input CSL's progressive system, the plants took hours of trial and error to figure out in order to get a reasonable energy output.

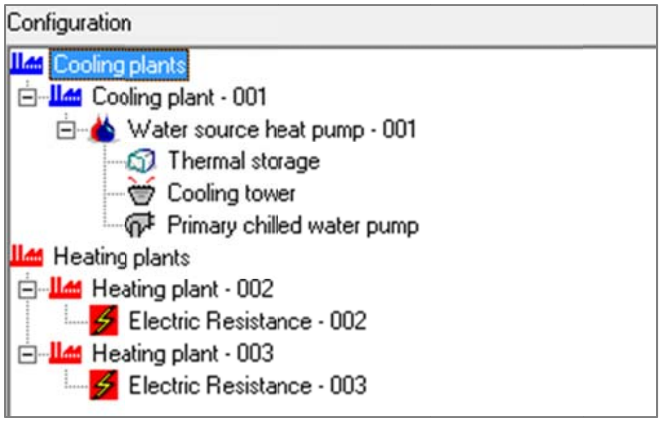


Figure 5 Cooling & Heating Plants Setup

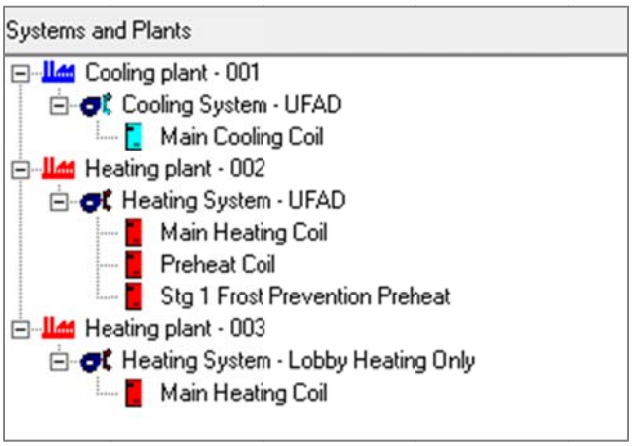


Figure 6 Systems Assignments to Plants

Although the rainwater harvesting, lagoon system, and constructed wetland reduces the need for off-site water, it increases the electricity demand with additional pumps. The demand for the following pumps / equipment is directly from design documents. In addition to the equipment characteristics below, the rooftop energy recovery unit is 93% efficient. Schedule details were pulled from the design specifications. Table 10 below details these values, which had to be inputted into TRACE as a miscellaneous stand-alone base utility in order to capture their effects on the energy analysis.

Table 11 Pumps / Equipment / Stand-alone Base Utilities Demands & Schedules

TYPE	HOURLY DEMAND [kW]	SCHEDULE
Elevator Fan	0.0373	Office Schedule (Table 5)
Parking Lot Lights	2.973	6pm – 7am: 100%
Elevator	18	Office Schedule (Table 5)
Wetland Pumps (2)	0.2487	1 hr / day
Sand Filter Pump	0.373	1 hr / day
Lagoon Pump	1.492	April – October: 100%
Stormwater Pump	0.9325	1 hr / day

5.3 Energy Consumption by Subsystem

Electric energy fraction of subsystems (HVAC, lighting, office equipment) is desirable to provide a basis for energy efficiency improvement claims of redesign. Table 12 and Figure 7 highlight CSL's energy consumption by subsystem. In total, CSL only consumes 485,206 kBTU/yr.

The total source energy in Table 12 calculated by TRACE is inaccurate as most energy will be renewably produced and consumed on site, thus, without the need to transport electricity, the differential between building energy and source energy will be dramatically less in reality.

Table 12 Energy Consumption by Subsystem

SUBSYSTEM	Electrical Consumption (kWh)	Total Building Energy [kBTU/yr]	Total Source Energy [kBTU/yr]
Primary Heating	5,230	17,849	53,551
Primary Cooling	15,017	51,5253	153,774
Supply Fans	16,197	55,280	165,855
Pumps & Equipment	31,920	108,183	326,867
Lighting	40,141	137,000	411,041
Receptacles	33,660	114,880	344,675
TOTAL	**142,164**	**485,206**	**1,455,762**

Figure 7 depicts a much different energy consumption distribution than the traditional building. Amongst many other factors (detailed later in section 5.5), a geothermal system eliminates the need for inefficient fans which decreased the consumption percentage of heating & cooling in CSL. At the same time, the several water management systems increased the energy percentage consumed by pumps & equipment. Receptacles (dominated by the computers of the office building) and lighting distributions result as expected.

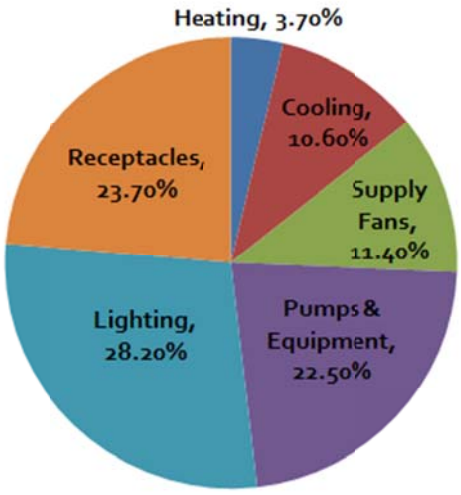


Figure 7 Subsystem Energy Consumption

5.4 Energy Costs per Month

The monthly utility cost for a full year for the Center for Sustainable Landscapes can be viewed in Table 13 and Figure 8 below. Proving that CSL's progressive green design discussed throughout this report is in fact worth its upfront cost, the total cost of electricity at CSL totals only $14,216. This number could in fact be even lower if the installed solar photovoltaic work properly with the ambition of producing more energy than consumed.

In addition to the below data, TRACE also predicted that the annual cost / square foot to operate building is only 0.68 $ / SF. Unfortunately, actual utility billing data to test the validity of these simulated costs were unavailable since the building is under construction during the writing of this report and will be until April 2012.

Table 13 Monthly Utility Costs [Electricity]

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
$1,097	$919	$1,144	$1,097	$1,281	$1,396	$1,422	$1,476	$1,173	$1,171	$1,015	$1,027	$14,216

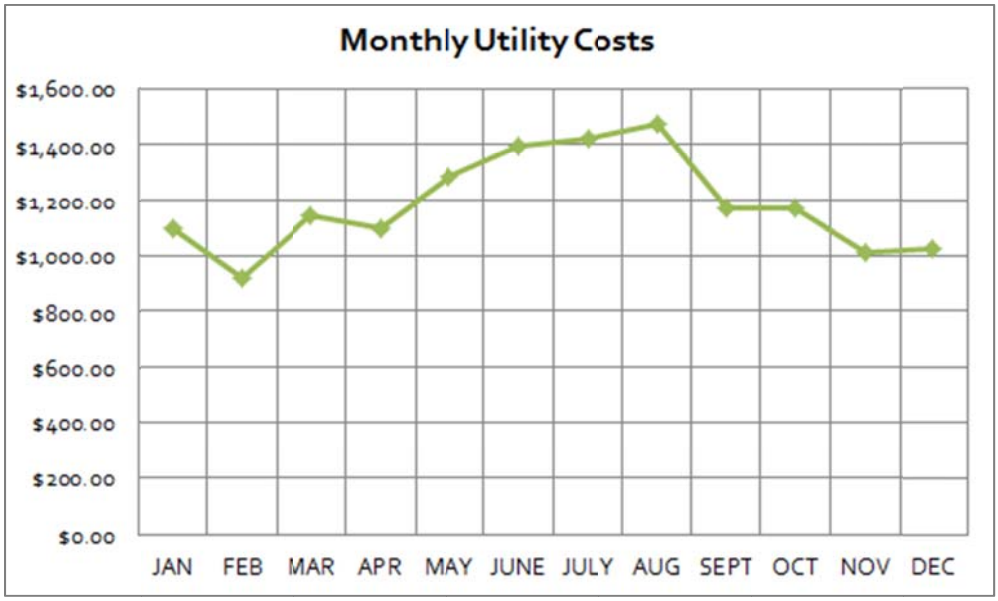


Figure 8 Monthly Utility Costs [Electricity]

5.5 Energy Baseline Comparison

Building energy consumption results are of little use unless compared to other simulations or energy benchmarks. To standardize the energy results, BTU/SF was calculated by multiplying the total building energy [485,206 kBTU/yr] in Table 12 by 1,000 and then dividing CSL's square footage [24,350 SF]. Thus, through the above outlined simulation conducted with Trane TRACE software, the Center for Sustainable Landscapes is predicted to consume 19,926 BTU/SF annually.

The best comparison of this progressive design would be with the mechanical contractor. After getting connected to the right contact person, it was confirmed that an energy analysis was performed. But since the mechanical designer's involvement with the project was over three years ago, the engineers were unfortunately not able to locate the correct files.

Thus, the annual energy consumption was compared to the Commercial Buildings Energy Consumption Survey (CBECS) 2003. In Table E2A (Major Fuel Consumption Intensities by End Use for all Buildings) of CBECS a building with the similar range square footage as CSL consumed an average of 71,000 BTU/SF. A building of the same office function consumed an average of 92,900 BTU/SF and a building of the same location in the Northeast consumed an average of 99,800 BTU/SF. All of these averages are dramatically higher than the Center for Sustainable Landscapes (specific percentages are shown in Figure 9.

Potential reasons for this impressive performance is that the Center for Sustainable Landscapes:

- Focused on the "**outside-in, passive-first**" strategy.
- Maximized northern & southern exposure for effective daylighting and passive solar controls through its **orientation**.
- Leveraged **geothermal heating & cooling** rather than using inefficient air to air systems. This same system, in conjunction with the Rooftop Energy Recovery Unit, provides heating, cooling, ventilation, and dehumidification. In summer, heat removed from the Heat Pump refrigeration cycle is absorbed by the water circulated in the wells and the cool ground. In winter, warmth stored over the course of the summer season is recovered from the wells to heat the building spaces.
- Employed a computational fluid dynamics study to determine **optimal window location for natural ventilation** which inevitably reduces HVAC fan energy usage.
- Is comprised of **on-site solar photovoltaics & a vertical axis wind turbine** to contribute to the net-zero energy approach of offsetting 100% of the annual energy consumption.
- Contains state of the art solar and thermally controlled construction to produce a **robust building envelope**.
- Has a **minimally conditioned atrium** with passive heating strategies and winter solar collection to take advantage of thermal massing in walls, ceilings, and floors.
- **Harvests, treats, & uses rainwater** on site to eliminate the need for off-site water.
- Uses only one primary commodity [electricity] for its mechanical system

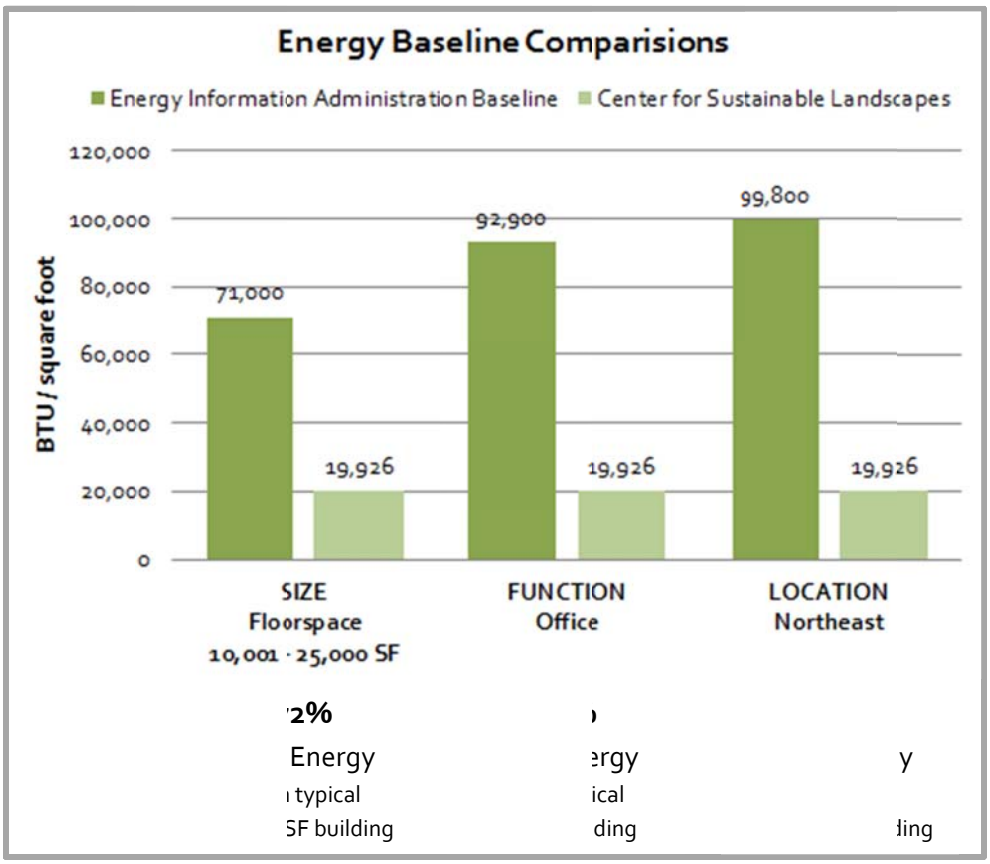


Figure 9 Energy Consumption Baseline Comparisons

6.0 Pollution Estimation

Emissions profiles associated with any on-site combustion system [such as electricity] are desirable in order to estimate a building's carbon footprint. The emission rates for pollutants such as CO_2, NOx, and SOx were calculated based on the total energy consumption of CSL. Since there is not a gas boiler, the total amount of electricity from the TRACE model previously discussed was used. According to the National Renewable Energy Laboratory (NREL), Pennsylvania is located in the Eastern Region, shown in pink below, in Figure 10.

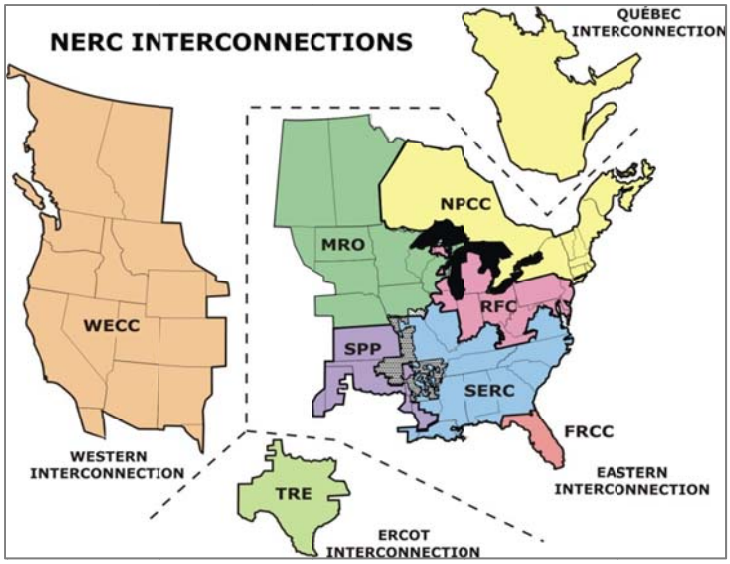


Figure 10 North American Electrical Grid Interconnections

The emission factors were taken from tables found in the National Renewable Energy Laboratory (NREL). As is shown in Table 14, CO_2e pollution is expected to be the major product of electric utilization with 220,354 lbs/year, while Lead, Mercury, and N_2O pollutants emit the least annually.

Table 14 Emissions from Delivered Electricity

POLLUTANT	Emission Factor for PA [lb/kWh]	Electric Consumption [kWh/year]	Electric Total [lbs/year]
CO_2e	1.55E+00	142,164	220,354
CO_2	1.48E+00	142,164	210,403
CH_4	2.70E-03	142,164	384
N_2O	3.22E-05	142,164	5
NOx	2.91E-03	142,164	414
Sox	8.88E-03	142,164	1,262
CO	6.01E-04	142,164	85
TNMOC	5.46E-05	142,164	8
Lead	1.17E-07	142,164	nearly zero
Mercury	2.70E-08	142,164	nearly zero
PM10	7.14E-05	142,164	10
Solid Waste	1.78E-01	142,164	25,305

Note that this pollution estimation analysis could be repeated during redesign in order to quantify the emissions footprint enhancements of the redesigned facility.

7.0 Conclusion

After going through the very tedious and time consuming simulation process using the less than perfect TRACE, it is evident that there is a **great need for an easier modeling solution**. As more owners want to predict and estimate the cost of operation, efficiency, and carbon footprint of a building during both designing and maintaining, this market need will exponentially grow.

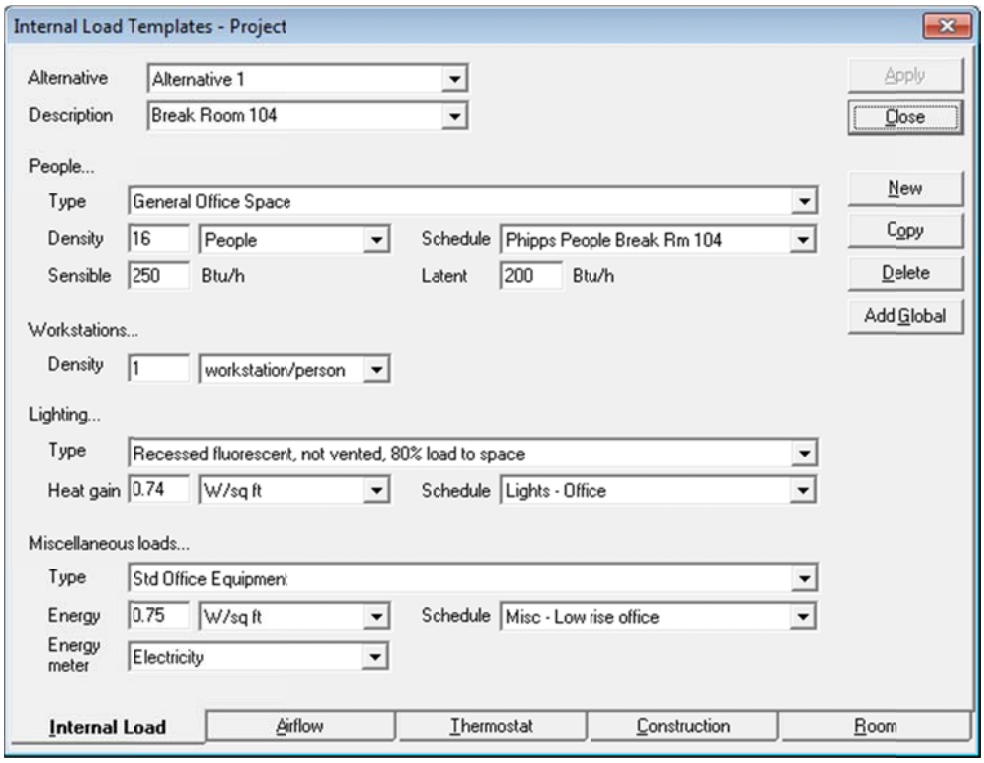
Any **discrepancies** in the simulation could be a result of potential software bugs of TRACE (when designing the energy model). A known bug in Trace adds an additional load to partitions and roofs by incorrectly recognizing thermal transfer. There is no heat transfer between interior spaces because there is no temperature difference across the wall. Other variations from simulation to actual performance (yet to be determined) may be due to block assumptions (where multiple rooms with the same functions were combined).

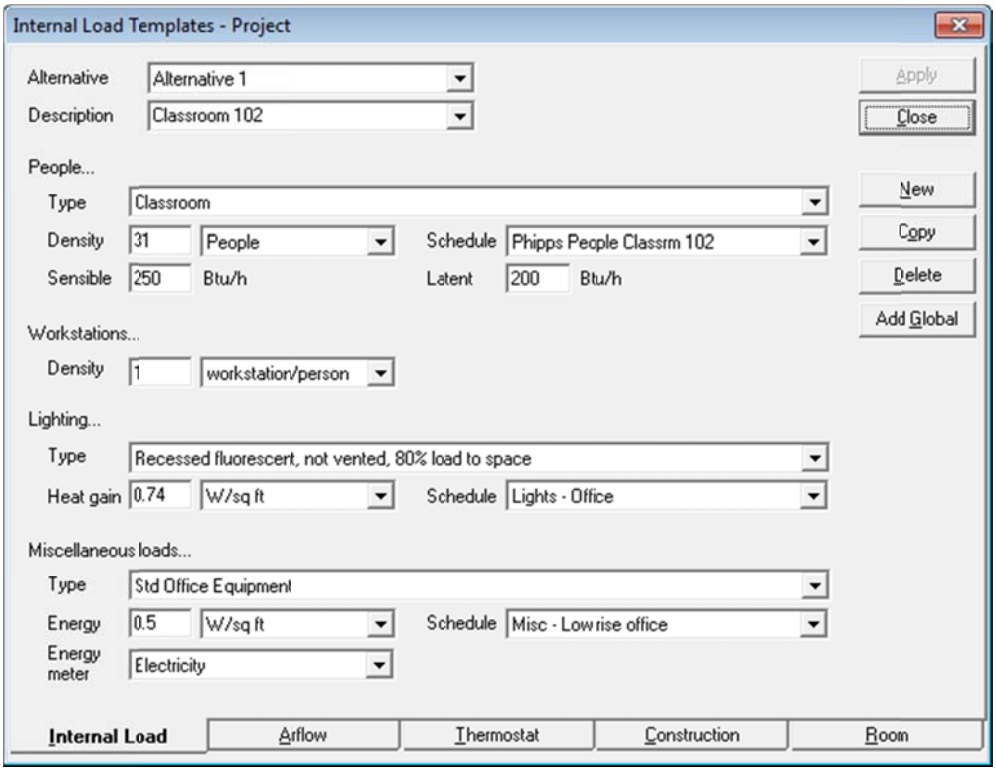
Overall, this report was very effective in both fully understanding all of the different variables that must be accounted for when conducting an energy simulation for a highly green design as well as highlighting / proving just how incredibly well designed the Center for Sustainable Landscapes is from an energy perspective.

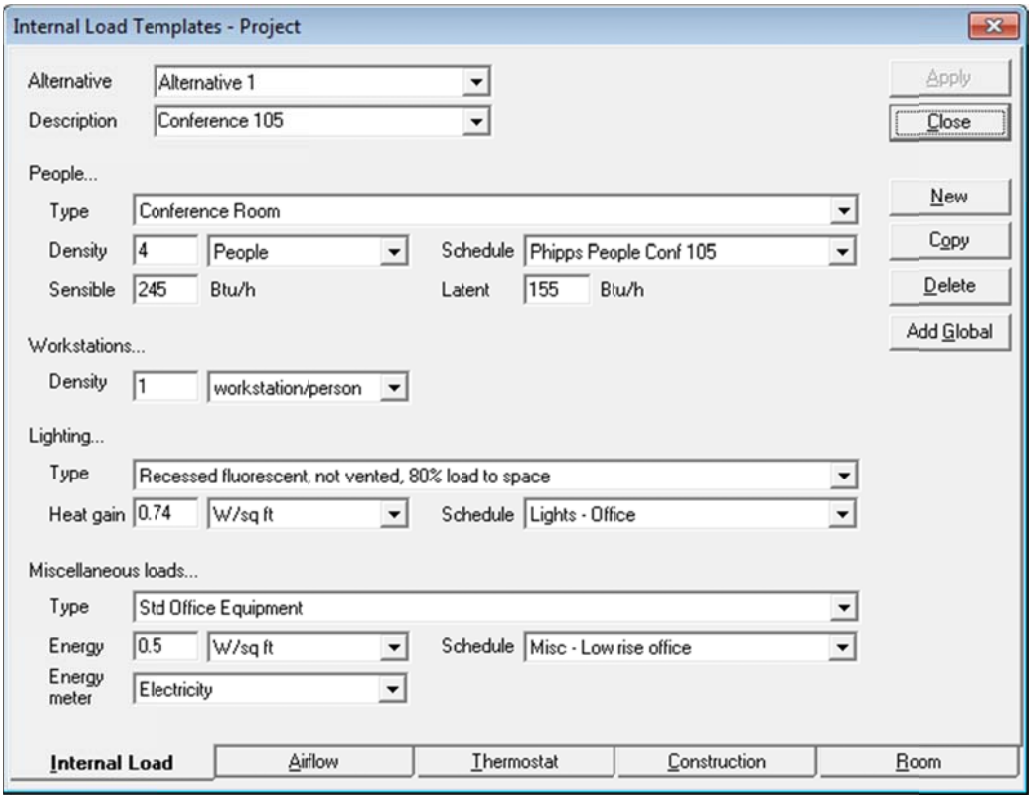
Sustainable architecture and mechanical design are taking a giant step forward at Phipps. The new Center for Sustainable Landscapes, scheduled for completion in Spring 2012, will be one of the world's first certified living buildings, a model of sustainability for architects, scientists, planners and anyone interested in living greener.

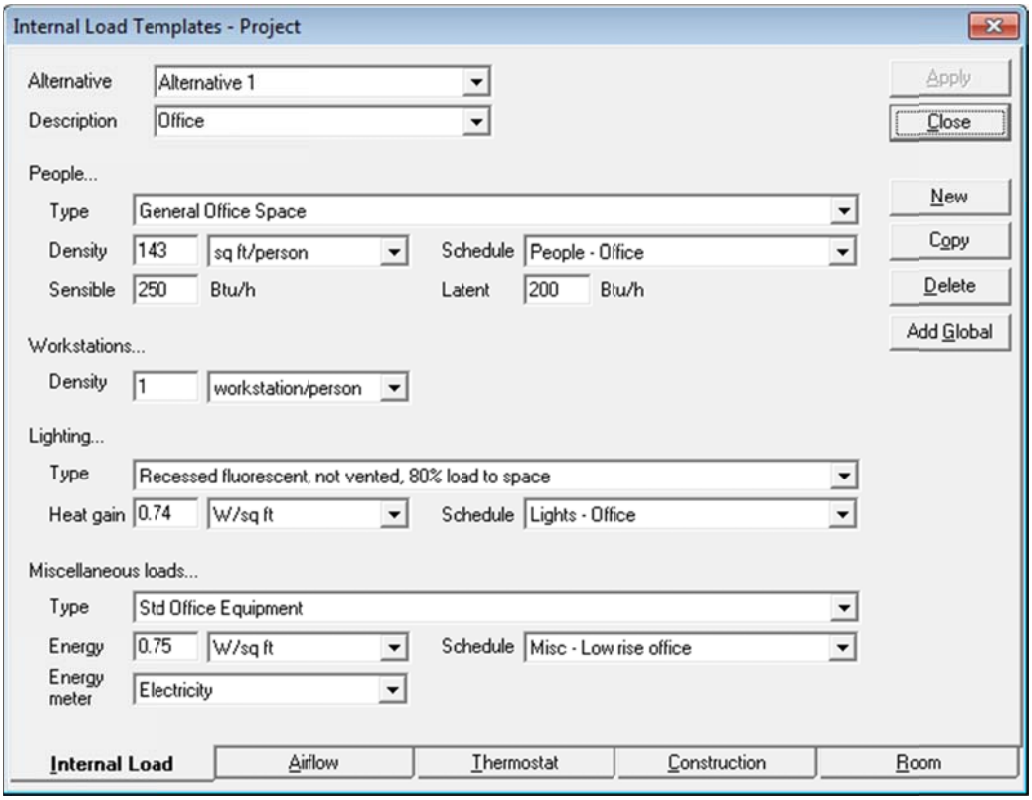
8.0 Appendix

[A1] Typical Trane TRACE Templates






Internal Load Templates - Project
Alternative
Alternative 1
Description
Conference 105
Apply
Close
People...
Type
Conference Room
Density
4
People
Schedule
Phipps People Conf 105
Sensible
245
Btu/h
Latent
155
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
1
workstation/person
Lighting...
Type
Recessed fluorescent not vented, 80% load to space
Heat gain
0.74
W/sq ft
Schedule
Lights - Office
Miscellaneous loads...
Type
Std Office Equipment
Energy
0.5
W/sq ft
Schedule
Misc - Low rise office
Energy meter
Electricity
Internal Load
Airflow
Thermostat
Construction
Room


Internal Load Templates - Project
Alternative
Alternative 1
Description
Office
Apply
Close
People...
Type
General Office Space
Density
143
sq ft/person
Schedule
People - Office
Sensible
250
Btu/h
Latent
200
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
1
workstation/person
Lighting...
Type
Recessed fluorescent not vented, 80% load to space
Heat gain
0.74
W/sq ft
Schedule
Lights - Office
Miscellaneous loads...
Type
Std Office Equipment
Energy
0.75
W/sq ft
Schedule
Misc - Low rise office
Energy meter
Electricity
Internal Load
Airflow
Thermostat
Construction
Room

System Checksums

By ACADEMIC

UFAD — **UFAD VAV w/ Baseboard Heating**

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 9 / 17
Outside Air: OADB/WB/HR: 81 / 73 / 117

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	644	644	0
Glass Solar	141,513	0	141,513	33
Glass/Door Cond	2,518	2,518	5,035	1
Wall Cond	2,755	4,229	6,984	2
Partition/Door	20,976		20,976	5
Floor	1,354		1,354	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	169,116	7,391	176,507	41
Internal Loads				
Lights	14,034	21,051	35,084	8
People	40,238	16,693	56,931	13
Misc	13,294	13,294	26,588	6
Sub Total ==>	67,565	51,037	118,602	27
Ceiling Load	2,158	-2,158	0	0
Ventilation Load	0	0	64,394	15
Adj Air Trans Heat	8,317		8,317	2
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-2,643	-2,643	-1
Sup. Fan Heat			66,749	15
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	247,156	53,627	431,926	100.00

CLG SPACE PEAK

Mo/Hr: 10 / 16
OADB: 73

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	151,866	68
Glass/Door Cond	-2,171	-1
Wall Cond	1,970	1
Partition/Door	20,578	9
Floor	96	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	172,340	77
Internal Loads		
Lights	14,086	6
People	17,793	8
Misc	12,748	6
Sub Total ==>	44,627	20
Ceiling Load	1,424	1
Ventilation Load	0	0
Adj Air Trans Heat	5,815	3
Exhaust Heat		
Sup. Fan Heat		
Ret. Fan Heat		
Duct Heat Pkup		
Underflr Sup Ht Pkup		
Supply Air Leakage	0	0
Grand Total ==>	224,207	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 2

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-12,077	3.04
Glass Solar	0	0	0.00
Glass/Door Cond	-75,169	-75,169	18.93
Wall Cond	-9,688	-12,421	3.13
Partition/Door	-68,880	-68,880	17.35
Floor	-11,346	-11,346	2.86
Adjacent Floor	0	0	0
Infiltration	-26,083	-26,083	6.57
Sub Total ==>	-191,174	-205,984	51.88
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-7,143	0	0.00
Ventilation Load	0	-109,552	27.59
Adj Air Trans Heat	-4,394	-4,394	1
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		2,523	-0.64
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-24,100	6.07
Additional Reheat		-55,500	13.98
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-202,711	-397,007	100.00

TEMPERATURES

	Cooling	Heating
SADB	63.0	68.0
Ra Plenum	80.8	66.4
Return	80.8	66.4
Ret/OA	80.8	48.9
Fn MtrTD	0.4	0.0
Fn BldTD	1.0	0.0
Fn Frict	2.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	15,038	5,586
Terminal	15,038	5,586
Main Fan	15,038	5,586
Sec Fan	0	0
Nom Vent	2,287	2,643
AHU Vent	2,287	2,643
Infil	0	366
MinStop/Rh	5,586	5,586
Return	13,654	4,387
Exhaust	903	1,444
Rm Exh	1,383	1,565
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	15.2	47.3
cfm/ft²	1.08	0.40
cfm/ton	420.22	
ft²/ton	388.19	
Btu/hr·ft²	30.91	-24.58
No. People	189	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	35.8	429.4	350.1	14,666	80.8	66.2	76.7	58.8	56.9	68.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	35.8	429.4								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	13,891		
Part	6,117		
Int Door	0		
ExFlr	620		
Roof	8,131	0	0
Wall	9,629	3,051	32
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-258.2	0	0.0	0.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-83.3	2,643	29.5	58.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-341.5			

Project Name: Phipps Center for Sustainable Landscapes
Dataset Name: PHIPPS CSL - Copy.TRC

TRACE® 700 v6.2.6.5 calculated at 12:38 AM on 10/18/2011
Alternative - 1 System Checksums Report Page 2 of 2

[A3] Energy Information Administration Consumption Intensities by End Use for All Buildings

Revised: December, 2008

Table E2A. Major Fuel Consumption (Btu) Intensities by End Use for All Buildings, 2003

	Major Fuel Energy Intensity (thousand Btu/square foot)										
	Total	Space Heating	Cooling	Ventilation	Water Heating	Lighting	Cooking	Refrigeration	Office Equipment	Computers	Other
All Buildings	91.0	33.0	7.2	6.1	7.0	18.7	2.7	5.3	1.0	2.2	7.9
Building Floorspace (Square Feet)											
1,001 to 5,000	99.0	30.7	6.7	2.7	7.1	13.9	7.1	19.9	1.1	1.7	8.2
5,001 to 10,000	80.0	30.1	5.5	2.6	6.1	13.6	5.2	8.2	0.8	1.4	6.6
10,001 to 25,000	71.0	28.2	4.5	4.1	4.1	14.5	2.3	4.5	0.8	1.6	6.5
25,001 to 50,000	79.0	29.9	6.8	5.9	6.3	14.9	1.7	3.9	0.8	1.8	7.1
50,001 to 100,000	88.7	31.6	7.6	7.6	6.5	19.6	1.7	3.4	0.7	2.0	8.1
100,001 to 200,000	104.2	39.1	8.2	8.9	7.9	22.9	1.1	2.9	Q	3.2	8.7
200,001 to 500,000	100.2	38.2	7.8	7.4	9.2	22.7	1.8	1.3	1.1	2.6	8.2
Over 500,000	118.2	38.2	11.8	8.8	10.6	28.7	2.3	2.4	Q	3.2	11.1
Principal Building Activity											
Education	83.1	39.4	8.0	8.4	5.8	11.5	0.8	1.6	0.4	3.3	4.0
Food Sales	199.7	28.9	9.8	5.9	2.9	36.7	8.6	94.8	1.6	1.5	9.1
Food Service	258.3	43.1	17.4	14.8	40.4	25.4	63.5	42.1	1.0	1.0	9.5
Health Care	187.7	70.4	14.1	13.3	30.2	33.1	3.5	2.6	1.2	3.2	16.1
Inpatient	249.2	91.8	18.6	20.0	48.4	40.1	5.6	2.0	1.1	3.6	18.1
Outpatient	94.6	38.1	7.2	3.3	2.5	22.6	Q	3.5	1.3	2.6	13.2
Lodging	100.0	22.2	4.9	2.7	31.4	24.3	3.2	2.3	Q	1.2	7.0
Mercantile	91.3	24.0	9.9	6.0	5.1	27.5	2.3	4.4	0.7	1.0	10.3
Retail (Other Than Mall)	73.9	24.8	5.9	3.7	1.1	25.7	0.6	5.0	0.6	0.9	5.6
Enclosed and Strip Malls	102.2	23.6	12.4	7.5	7.7	28.6	3.4	4.0	0.8	1.1	13.2
Office	92.9	32.8	8.9	5.2	2.0	23.1	0.3	2.9	2.6	6.1	9.0
Public Assembly	93.9	49.7	9.6	15.9	1.0	7.0	0.8	2.2	Q	Q	6.5
Public Order and Safety	115.8	49.9	8.9	9.5	14.0	16.5	1.3	2.9	0.6	1.5	10.6
Religious Worship	43.5	26.2	2.9	1.4	0.8	4.4	0.8	1.7	0.1	0.2	4.9
Service	77.0	35.9	3.8	6.0	1.0	15.6	Q	2.1	0.3	0.8	11.4
Warehouse and Storage	45.2	19.3	1.3	2.0	0.6	13.1	Q	3.5	0.2	0.5	4.8
Other	164.4	79.4	10.5	6.1	2.1	34.1	Q	6.0	Q	2.9	18.9
Vacant	20.9	14.4	0.6	0.4	0.1	1.7	Q	Q	Q	0.0	3.1
Year Constructed											
Before 1920	80.2	47.7	1.8	2.9	4.4	9.1	4.4	4.4	0.5	0.9	3.9
1920 to 1945	90.4	45.5	3.8	4.4	6.2	13.2	2.9	3.7	0.4	1.2	9.1
1946 to 1959	80.9	39.1	4.5	4.9	6.3	12.9	1.9	3.7	0.6	1.5	5.7
1960 to 1969	91.5	40.8	5.6	6.1	7.8	14.7	1.7	4.8	0.8	2.2	6.9
1970 to 1979	97.0	32.3	7.9	7.0	8.3	21.6	2.6	5.2	1.1	2.3	8.6
1980 to 1989	100.0	28.8	9.8	6.6	8.2	23.9	2.7	6.0	1.3	3.1	9.6
1990 to 1999	90.2	25.2	9.2	7.2	6.0	21.0	2.9	6.5	1.3	2.6	8.4
2000 to 2003	81.6	19.4	8.8	5.9	6.3	21.7	3.3	6.5	0.7	1.6	7.4
Census Region and Division											
Northeast	99.8	48.2	3.9	5.4	6.7	17.1	2.7	4.5	0.9	2.3	8.1
New England	99.8	53.9	3.0	4.5	5.8	16.0	1.9	6.0	0.7	2.0	6.0
Middle Atlantic	99.7	46.3	4.2	5.7	7.0	17.4	3.0	4.0	1.0	2.4	8.7

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2003 Commercial Buildings Energy Consumption Survey: Energy End-Use Consumption Tables

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