PENNSTATE

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[existing mechanical systems]

PHIPPS

center for sustainable landscapes

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option. mechanical
advisor. Dr. William Bahnfleth
building location. Pittsburgh, PA

by JOSH WENTZ








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1.0 Executive Summary

New energy efficiency policies, a global social responsibility to "live greener", information technology advancements, and energy efficiency pressures from other industries have all raised the standard to which mechanical systems in buildings are expected to perform. The owner of Phipps Conservatory expected the highest performing, sustainable building that technology has to offer with a new facility currently under construction.

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. The estimated date of construction completion is April 2012. Phipps strives for CSL to exceed the United State Green Building Council's highest certification, LEED Platinum (Leadership in Energy and Environmental Design).

The **objective** of this third of three technical reports is to describe the building's designed mechanical systems, including design requirements, external influences on design, major hardware components, system configuration, control logic, and operating characteristics. An overall system evaluation and critique was performed on this existing mechanical system in order to determine areas that can potentially be redesigned. **Sections discuss**: building overview, mechanical system overview, space requirements, heating/cooling/ventilating details, controls, energy, costs, LEED sustainability, and an overall evaluation.

Providing **optimal comfort** with minimal space, the existing mechanical system was designed with one 12,400 cfm capacity air handling unit (or energy recovery ventilator) on the roof. Geothermal wells on site condition piped water that runs through them, which is then sent to the first floor mechanical room and pumped up to the rooftop AHU. After heat energy from the water is transferred to air in the AHU, it is ducted to an under floor air distribution system that supplies both conditioned and outside air to the spaces. Mechanical systems account for 835 SF of the building, which equates to 3.5% of lost usable architectural space.

Providing a **highly energy efficient performance**, 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.

Providing **higher up-front yet lower costs throughout its life**, the mechanical system initial cost is $714,000 (approximately 3.6% of the total budget), and annual operating costs is estimated to be $14,216. In order to achieve LEED Platinum, Phipps hired 10 consultants (which increased initial services costs yet was not able to be captured in the up-front costs amount). The mechanical system first cost and annual operating costs break down to $29.32 and $0.68 per square foot respectively. Both the system first cost and annual energy costs reside below the building industry's average range.

While the mechanical design is extremely high performing for an office building, there are several **maintainability issues** that are likely to occur due to the **complexity of the controls** that result from the use of highly new and progressive systems. There are several potential design changes that may:

- improve & simplify energy model & metering accessibility
- streamline the controls coordination
- decrease time in operations education

A further analysis of these **opportunities for improvement** will be provided in future reports.

2.0 Building Overview

<table>
<tr><td>Name</td><td>Phipps Conservatory, Center for Sustainable Landscapes (CSL)

Figure 1 Rendering & Location Map</td></tr>
<tr><td>Location</td><td>One Schenley Park Drive
Pittsburgh, PA 15213</td></tr>
<tr><td>Occupant</td><td>Phipps Employees / University Researchers
367 persons [1st: 140, 2nd: 112, 3rd: 115]</td></tr>
<tr><td>Function</td><td>Classroom / Office / Conference
Education / Administration / Research</td></tr>
<tr><td>Size</td><td>24,350 SF [1st: 11,209 SF, 2nd: 11,151 SF, 3rd: 1,990 SF]</td></tr>
<tr><td>Floors</td><td>3 stories</td></tr>
<tr><td>Construction</td><td>Dec. 2010 - Apr. 2012</td></tr>
<tr><td>Cost</td><td>$20 million</td></tr>
<tr><td>Team</td><td>Integrated Project Delivery (IPD) required by the owner</td></tr>
<tr><td>Influences</td><td>Center for Sustainable Landscapes is a part of Phipps Conservatory and Botanical Gardens, which is a complex of buildings and grounds set in Schenley Park, Pittsburgh, Pennsylvania (near the Carnegie Museums in Oakland). Phipps is a Pittsburgh historic landmark and is listed on the National Register of Historic Places. The conservatory's overall purpose is to educate and entertain the people of Pittsburgh with formal gardens (Roman, English, etc.) and various species of exotic plants (palm trees, succulents, bonsai, orchids, etc.). Center for Sustainable Landscapes must conform to Phipps high green standards and progressive architecture, yet, unlike the rest of the campus, is not open to the public.</td></tr>
<tr><td>Sustainability Goals</td><td>1. LEED Platinum
2. Living Building Challenge
3. SITES Certification for landscapes</td></tr>
</table>

3.0 Mechanical System Overview

Objectives	The primary factor in the mechanical system design was Phipps' ambition to achieve the **three highest green standards**: the ILBI (International Living Building Institute) Living Building Challenge, LEED Platinum, and SITES Certification for landscapes (all of which were required by the owner in the building program). These standards are expected to be a way to emphasize more green and sustainable building practices and operations. Phipps' new center for education, research, and administration will **generate all of its own energy** and capture and treat all of its own water on site. Other compliance factors included the Uniform Construction Code of Pennsylvania 2006, International Building Code 2006, National Electric Code, and ASHRAE ventilation requirements.
Heating & Cooling	A **geothermal ground-source closed-loop system** satisfies 70% of CSL's heating and cooling loads. Geothermal wells, bored into the ground sink, create a ground source heat exchanger by remaining at a consistent temperature of 57 °F. In winter, warmth stored over the course of the summer season is recovered from the wells to heat the building spaces. In summer, heat removed from the heat pump refrigeration cycle is absorbed by the water circulated in the wells and the cool ground. A 12,400 cfm capacity **rooftop energy recovery unit** supports the geothermal system in heating, cooling, ventilating, 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** variable air volume (VAV) with baseboard diffusers. This system was chosen to reduce duct costs while accommodating for fluctuations in occupancies throughout the day. The large, three-story atrium/lobby is 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.
Ventilating	A **demand controlled ventilation system** (DCV) uses **CO_2 sensors** throughout the building to track building occupancy levels and tailors the ventilation rate to provide for the current occupancy level.**Ultraviolet duct lamps** were also added to increase the indoor air quality in response to the tighter, high performance envelope. 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 set point 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.

4.0 Space

Mechanical system equipment from air handling units to pumps and ductwork are essential to the operation of the mechanical system but nevertheless occupy lost usable architectural space.

Table 1 summarizes the areas that are taken up by both the mechanical & electrical system as a way to gauge lost area due to major building systems. Included in the summary are the mechanical & electrical equipment room on the first floor, rooftop energy recovery unit on the roof (otherwise covered with a functional green roof), and vertical duct shafts, all totaling 3.5% of the entire building area. The use of geothermal heating/cooling as well as a rooftop energy recovery unit dramatically decreases the amount of indoor lost usable space in comparison to traditional systems.

Table 1 Lost Usable Space due to Mechanical/Electrical Systems

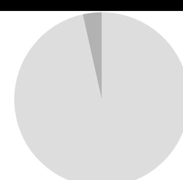
SYSTEMS SPACE	AREA	TOTAL LOST SPACE
Mechanical Room	330 SF	5 SF / 50 SF / l area  3.5% building area due to mechanical/electrical
Electrical Room	226 SF	
Rooftop Energy Recovery Unit	133 SF	
Vertical Duct Shafts	164 SF	

Figure 2 and 3 visually shows the 3.5% loss in mechanical space. The mechanical room size in Figure 2 is smaller than traditional mechanical rooms because the air handling unit is on the roof (Figure 3).

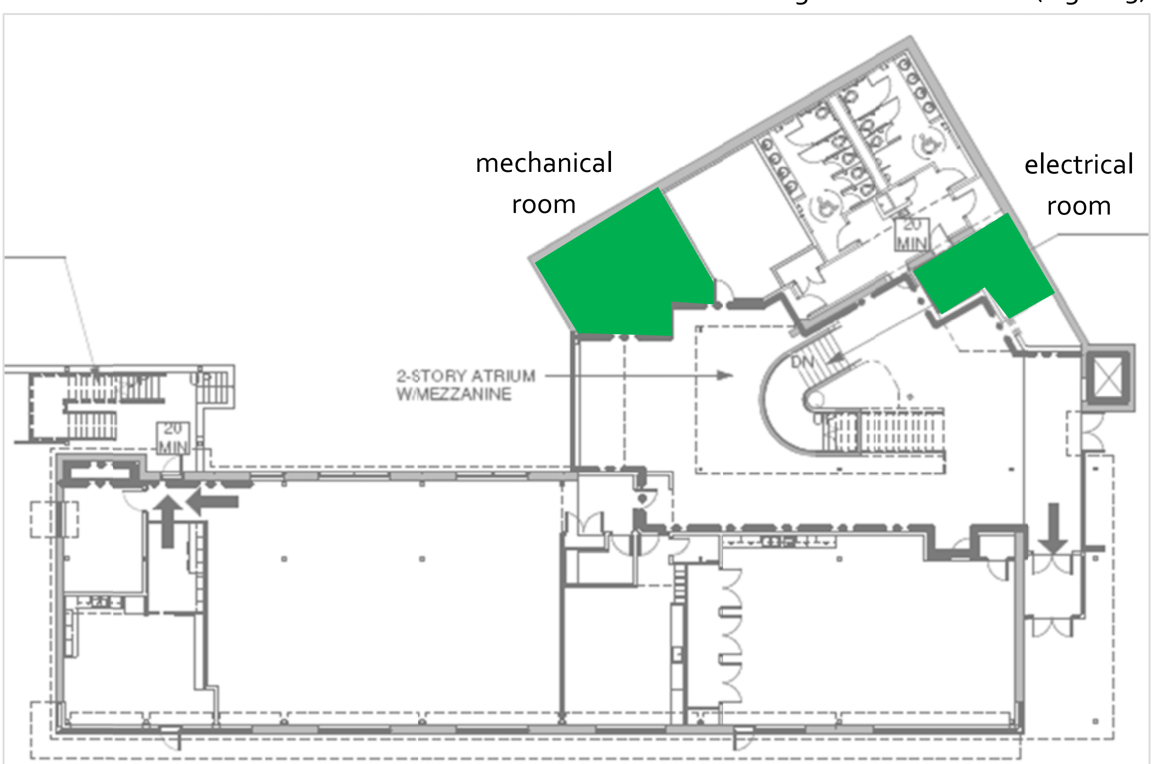


Figure 2 First Floor Mechanical & Electrical Rooms

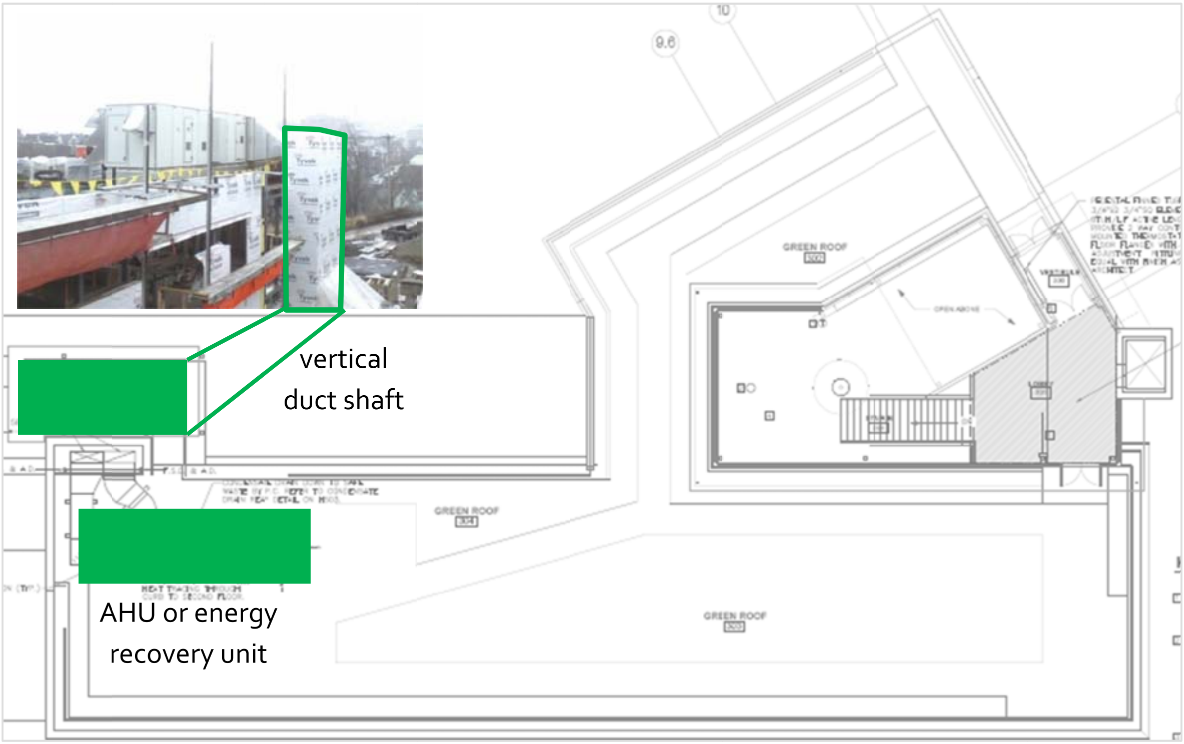


Figure 3 Rooftop Energy Recovery Unit & Vertical Ducts Shaft

5.0 Heating, Cooling, Ventilating

Mechanical systems are meant to heat, cool, and ventilate a building in order to provide optimal comfort and health for its occupants. In order to analyze the design requirements & external influences of the existing conditions, actual take-offs based upon CSL's design documents / specifications as well as assumptions based on ASHRAE std. 62.1-2007, ASHRAE 90.1-2007, or ASHRAE Handbook of Fundamentals were referenced.

5.1 Loads

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. The software used to simulate block loads of the building was Trane TRACE 700. Table 2 summarizes heating, cooling, ventilating loads of CSL (which was discussed in more detail in Technical Report one and two).

Table 2 Heating, Cooling, Ventilating Loads Summary	
Weather	Design Outdoor Conditions • Dry Bulb Temp: 84 F (summer), 9 F (winter) • Wet Bulb Temp: 73 F (summer) Desired Indoor Conditions • Heating & Cooling Setpoint: 75 F • Relative Humidity: 50%
Occupancy	367 persons [*1st: 140, 2nd: 112, 3rd: 115*] • Atrium: 200 sqft/person • Break Room: 16 people • Classroom: 31 people • Conference: 10 people • Lobby: 200 sqft/person • Office: 20 people • Reception: 143 sqft/person
Schedules	Office (Weekdays Year-Round) • 6am-8am: 50% load • 8am-5pm: 100% load • 5pm-7pm: 50% load
Power Densities *Lighting, Electrical, Mechanical*	Lights for the open office areas are high performance, energy efficient T-5 fluorescents or LEDs. • Classrooms: 1.4 W/sqft, 2 workstations • Conference: 1.3 W/sqft, 1 workstation • Mechanical: 20 W/sqft • Open Office: 1.1 W/sqft, 20 workstations (based upon the number of chairs from design documents) • Reception: 1.3 W/sqft, 1 workstation
Envelope Construction	The facade is a combination of: • Salvage barn siding • Motorized upper glazing • Metal light shelf • Operable windows: High performance, low-e (low-emissivity) windows provide solar and thermal control and energy efficiency, while admitting maximum daylight. • Glass Fiber Reinforced Concrete Precast Panels • Backup of exterior studs • High performance wall and roof insulation reduce winter heat losses and summer heat gains 

Table 3 below provides various heating and cooling design load results. Engineering check values for the designed Center for Sustainable Landscapes were not provided by the mechanical engineer. Therefore, the calculated cooling and heating loads were compared to the ASHRAE 2009 Pocket Guide.The computed/simulated cooling [SF/ton] falls right within this range. The supply air rate [cfm/SF] computed also falls right within the standard range for office facilities as expected. The atrium radiant floors, which is a supplemental system provided by evacuated tube solar hot water, is higher than expected at 324,341 BTU/hr. This may be due to its roof façade being covered entirely by glazing. An issue with this energy model to potentially be further investigated in future reports is that the cooling coil peak (431,926 BTU/hr) is less than the converted 388.19 SF/ton cooling (720,000 BTU/hr). This might be an issue with the software used, Trane TRACE 700, or with the inputs for the complex building systems.

Table 3 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	-

5.2 Schematics & Equipment

The heating and cooling systems in the building are designed to ensure optimal comfort for the occupant. The following series of figures and tables outline the mechanical system configuration as well as major hardware / equipment components of the building. CSL is served by one air handling unit and supported by a geothermal well. This closed loop ground-source geothermal system satisfies 70% of the CSL's heating and cooling loads.

Geothermal Heating/Cooling

Figure 5 diagrams how this combined water and air geothermal heating / cooling system works.

1. **Water in Ground Pipes**: Water is conditioned by running through a closed loop, mile long, pipe in the ground. Water gains heat from the ground in the winter and loses heat in the summer. Fourteen wells bored 500 ft deep into the ground sink remain at a consistent temperature of 57 °F, which creates a ground source heat exchanger.
2. **Refrigerant in Heat Pump**: After traveling through the geothermal wells, water is pumped from the mechanical room on the first floor to the air handling unit on the roof. A heat exchanger in the air handling unit captures needed heat from the water in the geothermal pipes to use to condition air.
3. **Air in Space**: This conditioned air from the rooftop air handling unit is sent to the space through vertical duct shafts which lead to an under floor air distribution. Here, diffusers supply conditioned air to the space. Detailed temperature set points are discussed in Section 6.1, Sequence of Operations.

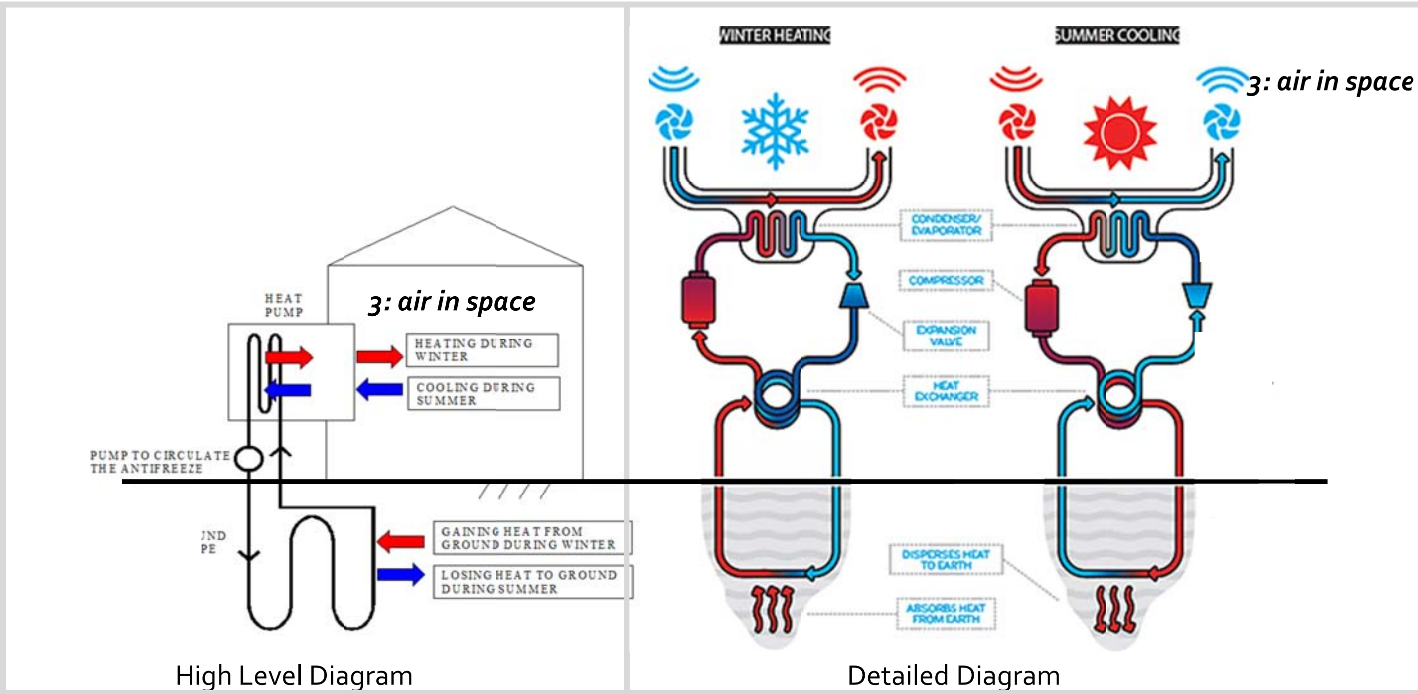


Figure 5 Geothermal Heating/Cooling System

Figure 6 is a schematic of the water side pipes and equipment that run throughout the building. The right side of the schematic depicts the pipes that travel to and from the ground wells to the mechanical room. P-1 and P-2 represent the water pumps in the mechanical room that take water from the first floor to the rooftop air handling unit (depicted on the left side of the diagram). Only one pump is on duty at a time, while the other is on stand-by. The controls sequence in Section 6.1 shows that the pump on duty will alternate operation at least daily.

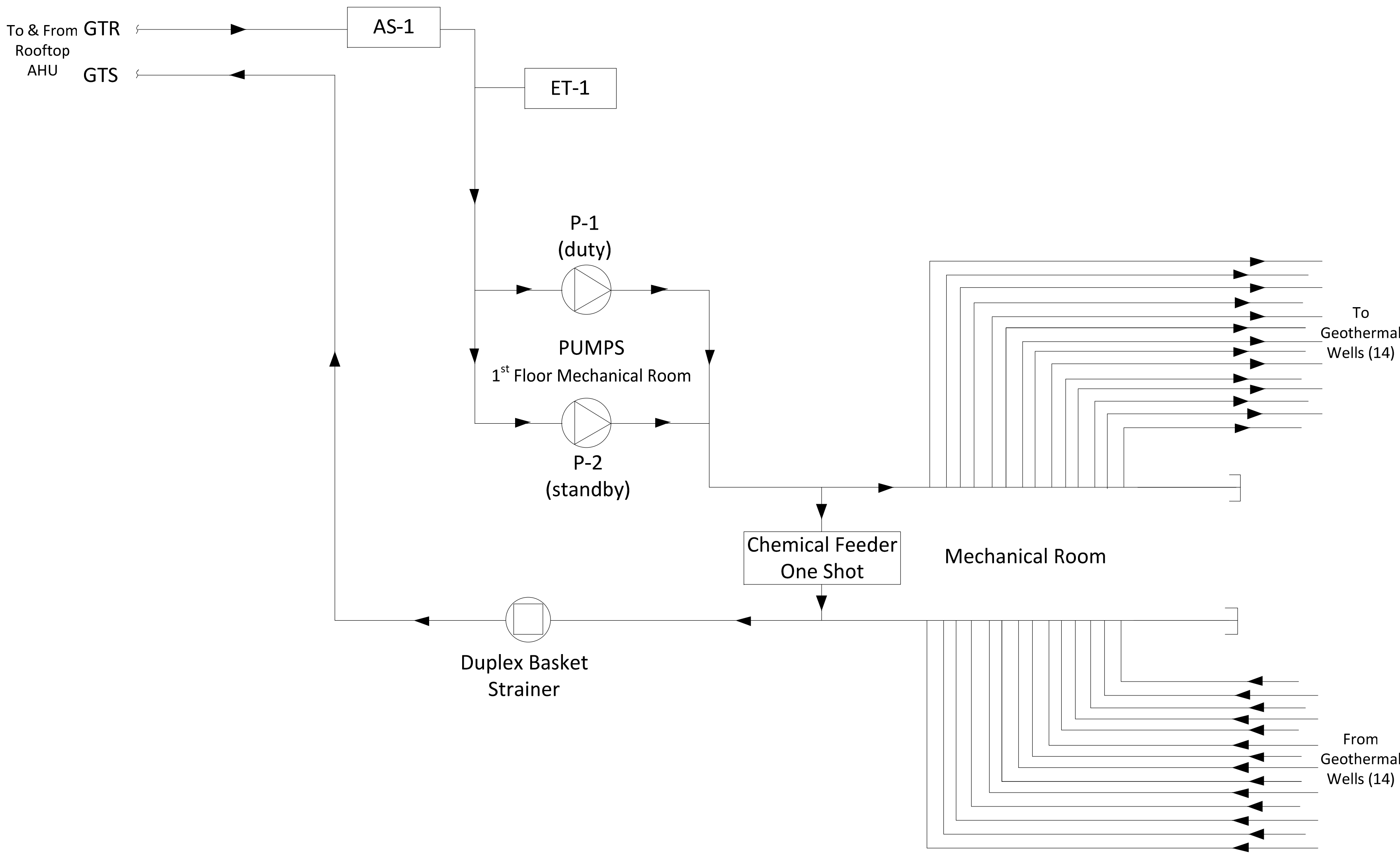


Figure 6 Water Side Schematic: Geothermal Pipes & Pumps

Figure 7 shows the first floor mechanical room in detail. The green circles and picture on the left represent the pipes from the geothermal wells. The green squares and picture on the right represent the water pumps (P-1 and P-2). Both pictures were taken during construction, prior to full installation, as of November 2011. Table 4 shows the pump equipment details from the design documents. Both water pumps are exactly the same. The duty of each pump is geothermal and their type is end suction.

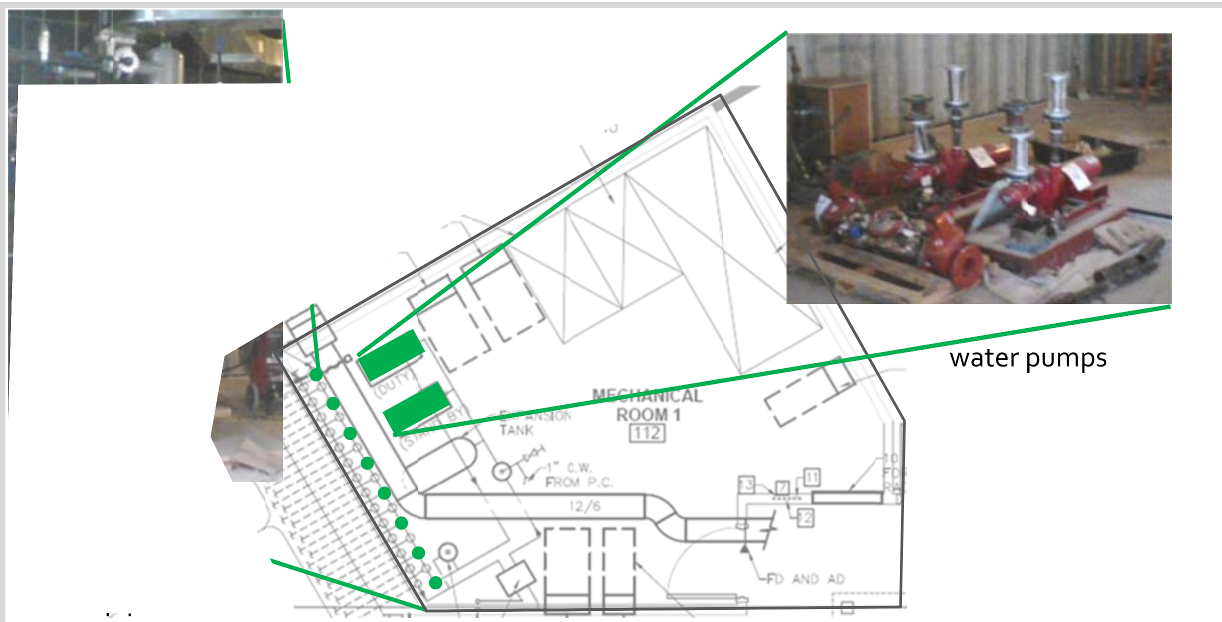


Figure 7 Mechanical Room Geothermal Pipes & Water Pumps

Table 4 Pump Schedule

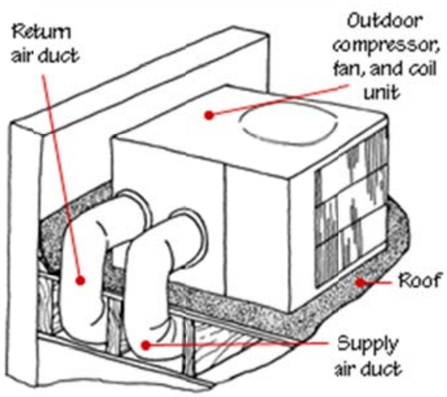
EQUIP. NO.	FLOW RATE [GPM]	TOTAL HEAD [ft]	MOTOR POWER [HP]	PUMP SPEED [RPM]	FLA [460V]	IMPELLER DIAMETER [in]	MAKE, MODEL
P-1	85	50	2	1750	4	7	Bell & Gossett, Series 1510
P-2	85	50	2	1750	4	7	Bell & Gossett, Series 1510

Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV)

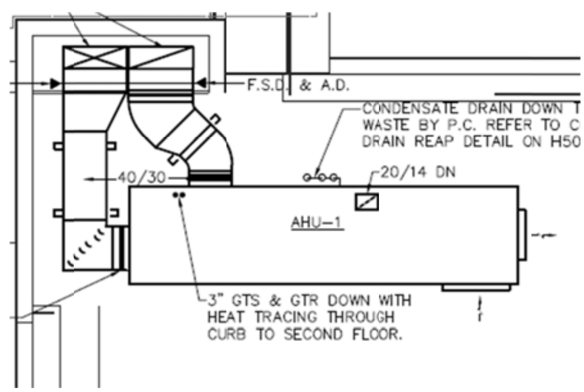
The air handing unit (AHU) (which is also an energy recovery ventilator) is located on the roof of CSL in the northwest corner. Figure 8 shows a series of photos and diagrams of the rooftop air handling unit. The upper left image shows a photo of a typical AHU by the selected manufacturer. Berner International Corp. was selected as the manufacturer due to their years of expertise with energy recovery systems. The upper right photo shows the installed Berner AHU (notice that the installed AHU is much larger than a typical Berner AHU most likely because of the energy recovery components). The bottom left image shows the typical external components of a rooftop AHU (internal components will be discussed later in this section). The bottom right image is the 2D drawing of the 133 SF air handling unit pulled from the design documents. Table 5 shows the 12,400 cfm capacity of this Berner Energy Recovery Unit, Model 9812.

Photo of Typical AHU by Berner

Photo of Installed AHU (Northwest corner of CSL)



3D Diagram of Typical Rooftop AHU



2D Diagram of AHU from Drawings

Figure 8 Rooftop Air Handling Unit (AHU) / Energy Recovery Unit (ERV)

Table 5 Rooftop Air Handling Unit (AHU) / Energy Recovery Unit (ERV)

UNIT NO.	TOTAL CFM	MIN OA CFM	MAKE, MODEL
AHU-1	12,400	2,720	Berner Energy Recovery, 9812

Figure 9 below shows the air side schematic of this rooftop air handling unit. Components and acronyms shown in the schematic are further explained in Table 6. After the water enters from the geothermal pipes in the upper left corner of the schematic, it enters the water source heat pump where heat is exchanged from the water into entering air from return air (RA) ducts and outside air (OA). After air travels through the air handling unit, it is then supplied to the space (SA). Operations and temperature set points details are discussed in section 6.1, Sequence of Operations.

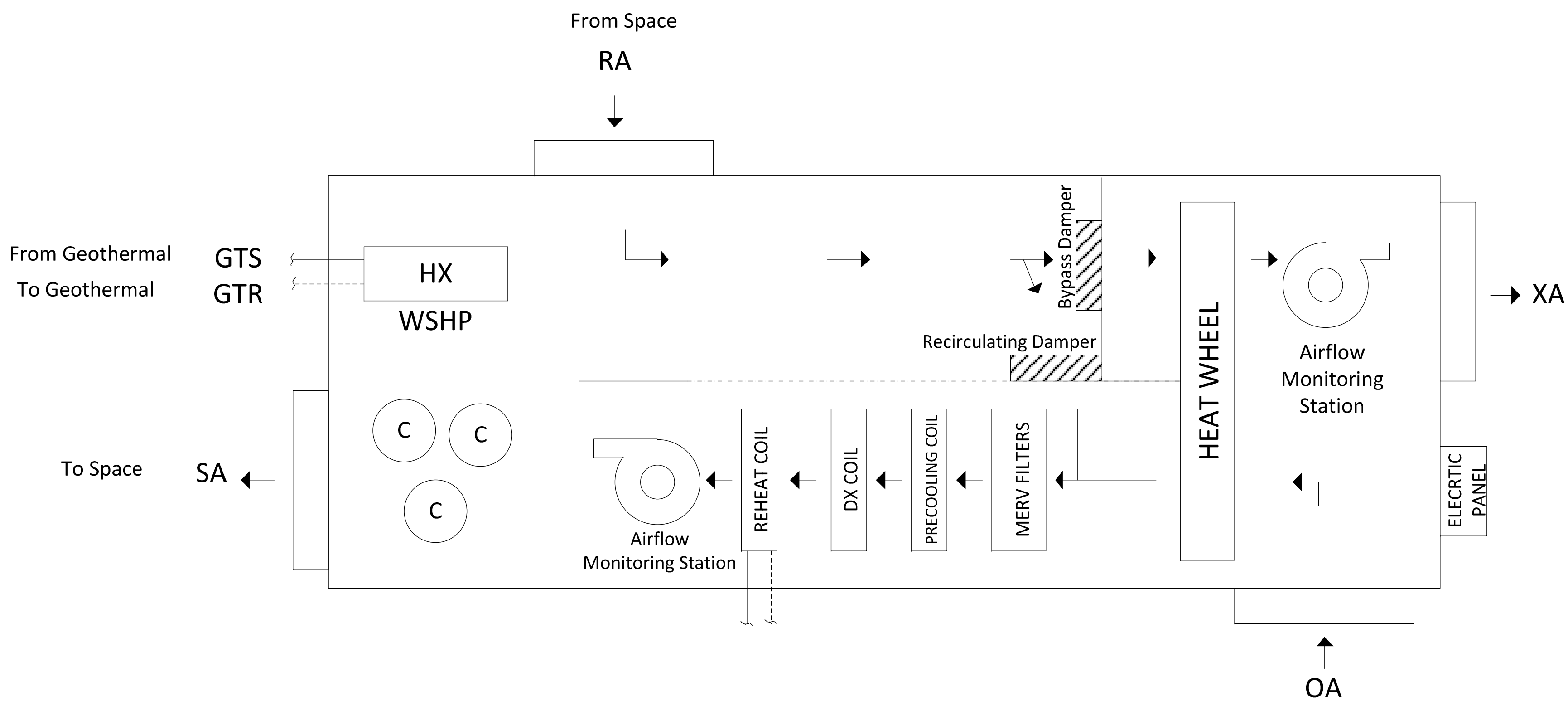


Figure 9 Air Side Schematic: Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV)

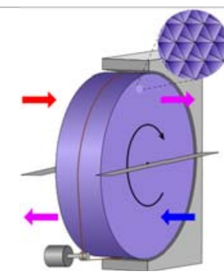
Table 6 Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV) Components		
Abbrev.	COMPONENTS	DESCRIPTION
GTS	Geothermal Supply	Water is received at 57 F from ground loop and pumped up to this AHU unit on the roof.
WSHP	Water Source Heat Pump	The heat pump utilizes the geothermal leaving water temperature (LWT) as supplemental hot water in order to maintain the reheat leaving air temperature (LAT) (in cooling) when all of available free reheat has been extracted.
HX	Heat Exchanger	The heat exchanger is simply a piece of equipment built for efficient heat transfer from one medium to another (in this case, from water to air).
RA	Return Air	This is air that is returned from the space.
	Bypass Damper	Capable of diverting 100% of the typical return air (10400 cfm) and combining with (2000 cfm) of exhaust for a combined total of (12,400 cfm) exhausted from the building.
	Recirculated Damper	Capable of modulating re-circulated air from (10400 cfm max) to (0 cfm min).
	Heat Wheel (Desiccant Wheel)	 The heat wheel (or desiccant wheel) is used to pre-cool and dehumidify outside air to reduce cooling loads of hot moist outside air in the summer; also pre-heats and humidifies incoming cold outside air in winter. A desiccant wheel is very similar to a thermal wheel, but with a coating applied for the sole purpose of dehumidifying or 'drying' the air stream. Figure 10 shows a 3D view of the heat wheel. A discussion of air entering and leaving the heat wheel is discussed in Section 5.3, Indoor Air Quality.
	Airflow Monitoring System	This air monitoring system monitors the quality and amount of air being exhausted outside or supplied to space.
XA	Exhaust Air	The exhaust air, typically stale from the space, is rejected outside so that it does not reduce the quality of the indoor air.
OA	Outside Air	Capable of modulating from (2000 cfm min) up to (12400 cfm max) of outside air. Outside air louver to be set at 0 cfm during night setback or unoccupied hours.
	MERV Filters	Maximized outside air and a high performance MERV13 air filter provide improved indoor air quality.
	Precooling Coil	This is where is air is precooled for warm summer conditions.
	DX Coil (Heating Coil)	HVAC coils that use this direct-expansion of refrigerants are commonly called DX coils. This is where air is heated during winter conditions.
	Reheat Coil	The Hot Water Modulating Valve (geothermal loop) modulates to provide additional reheat from the water source loop as needed when all of the available free reheat has been utilized.

Figure 11 shows the air circulation / flow from the air handling unit through vertical duct shafts. Note that air circulation throughout the building begins and ends on the roof. After air leaves the air handling unit, it then travels through the vertical supply air duct shaft to the under floor air distribution system. After air circulates the space, it is then returned with ceiling air diffusers. Air then travels up vertical return air duct shafts back to the air handling unit on the roof for treatment.

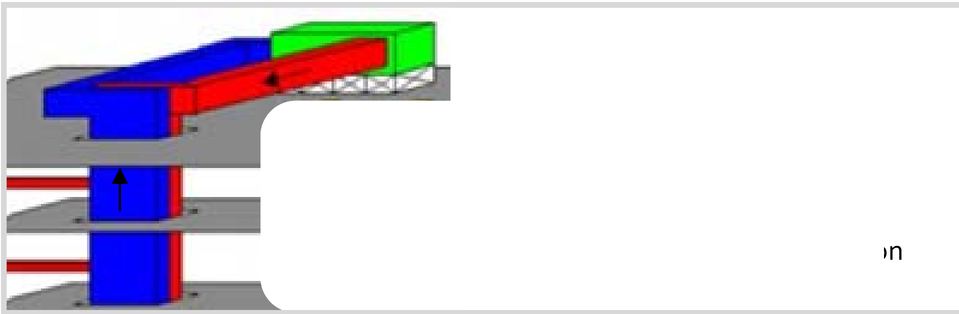


Figure 11 Airflow from Rooftop Air Handling Unit to Underfloor Air Distribution

Underfloor Air Distribution

The air is ultimately supplied to the space via an under floor air distribution (UFAD) system. UFAD systems use the air plenum beneath a raised floor to provide conditioned air through diffusers directly to the occupied zone. One of the advantages of this system is that is decreases duct runs. Figure 12 shows a diagram of how this system works during the summer. Cool air is supplied to the open office spaces throughout the building from perimeter and central diffusers in the floor. Air is then mixed with convective heat created from people, computers, and solar heat from the outside. Warmer, stale air is then collected via ceiling diffusers and sent up the return air ducts to the air handling unit for treatment.

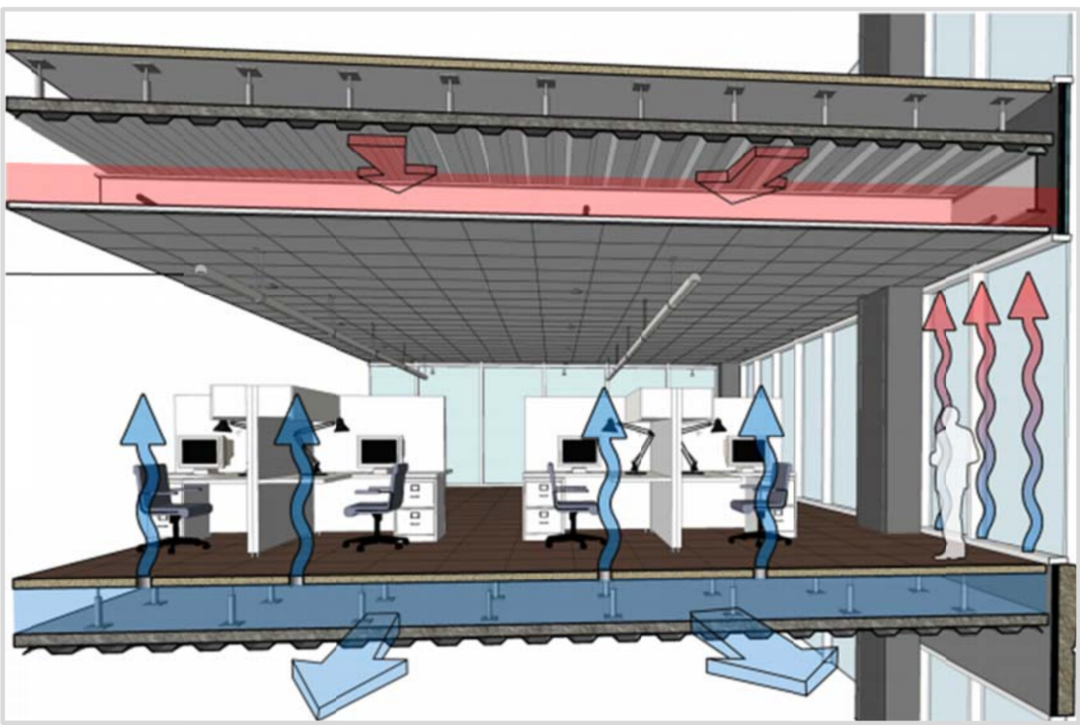


Figure 12 Underfloor Air Distribution Diagram

5.3 Indoor Air Quality

Indoor air quality problems have soared since the late 1970's when construction technology succeeded in developing energy efficient "tight" buildings. This section discussed each air quality measure taken by the designers of CSL in response to its high performance envelope.

Ventilation Rates

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 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. The AHU is capable of a maximum airflow of 12,400 total cfm, including 2,720 cfm of outdoor air.

Table 7 compares the designed and the calculated ventilation airflow rates for two of the air handling units. The designed airflow rates far exceed those calculated. The calculated airflow rates hover around the industry average of 20% of design load airflow. The increased design ventilation airflows can be attributed to the use of a variable air volume system. When the variable air volume system is turned down to its minimum position with a fully occupied space, the minimum ventilation requirements must still be met. This causes an increase in the outdoor airflow percentage. A full analysis of ventilation was discussed in Technical Report One.

Table 7 Designed & Calculated Ventilation Rates

UNIT	DESIGNED	CALCULATED
AHU-1: 100% OA Mode	12,400 cfm	2843 cfm

Air Quality Systems

Due to the high performance envelope (which creates a tighter building with less infiltration), the engineers of the Center for Sustainable Landscapes designed many systems to improve and ensure a healthy indoor air quality. Figure 13 is a diagram of all systems deployed within the building to improve air quality. Sub-sections following the figure discuss each air components in more detail.

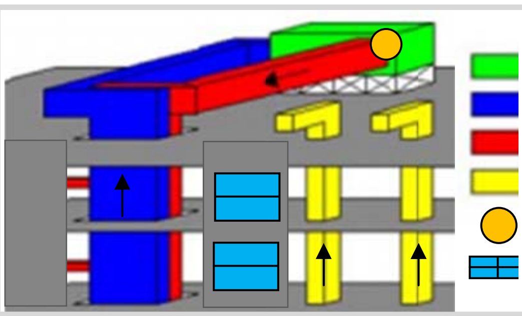


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Figure 13 Air Components & Circulation that Improve Air Quality

Rooftop Energy Recovery Ventilator & Enthalpy Wheel

The rooftop air handling unit has an economizer setting with an energy recovery, 100% outside air mode which increases energy efficiency while improving indoor air quality. Energy recovery includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub-system of the overall system with another. With an energy-recovery ventilator, the heat exchanger transfers a certain amount of water vapor along with heat energy. The key to efficient ventilation is the enthalpy wheel core (also called a heat wheel, thermal wheel, desiccant wheel, heat recovery wheel, or rotary heat exchanger).

The following are the **basic options of the enthalpy wheel** to be used and are discussed in more detail within each mode of operation in section 6.1.

1. Constant 100% speed allows for the greatest efficiency.
2. Varying the speed of the wheel allows you to maintain a leaving air temperature off the wheel.
3. Wheel stops for economizer mode, but runs in the background in jog mode.

Shown in Figure 14, the enthalpy wheel heats or cools incoming fresh outside air, recapturing 60 to 80 percent of the conditioned return air temperatures that would otherwise be lost. In parallel to saving energy, the 100% outside air mode is a great way to fight poor indoor air quality by bringing fresh air into the building while also expelling stale air.

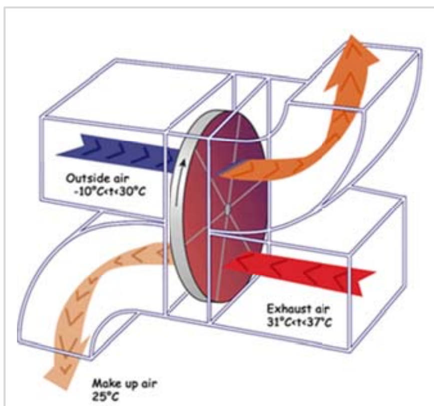


Figure 14 Enthalpy Wheel Diagram

Exhaust

Two exhaust systems are installed in the building to directly remove low quality air from the building to the outside. Shown in Figure 13 above, each bathroom has exhaust fans that take unpleasant air from the space and exhaust it directly outdoors. The AHU exhaust fan variable frequency drive varies based on outside air & return air bypass airflow amounts required, while allowing the system to provide maximum outside air loads without exceeding the design guidelines. Table 8 shows the equipment details for an exhaust fan in the ceiling over the elevator.

Table 8 Exhaust Fan Equipment

EQUIP. NO.	FAN [cfm]	STATIC PRESSURE [in wc]	RPM	DRIVE	HP	MAKE, MODEL
EF-1	300	0.375	1550	Direct	1/20	Greenheck, G085

Natural Ventilation

Natural ventilation was a main goal of the design of CSL from the very beginning. A Computational Fluid Dynamics study conducted by the architect determined optimal window location for natural airflow. Figure 15 shows a resulting diagram of the study, which highlights ventilation through CSL's atrium and open office space. An expanded upper comfort temperature set point of 78°F instead of a typical 75°F thermostat set point maximizes the number of hours of natural ventilation while reducing HVAC system fan energy usage. Providing additional occupant control of this natural ventilation, the administrative, educational, and support spaces have operable spaces. A notification system alerts building occupants when conditions are appropriate to open the windows.

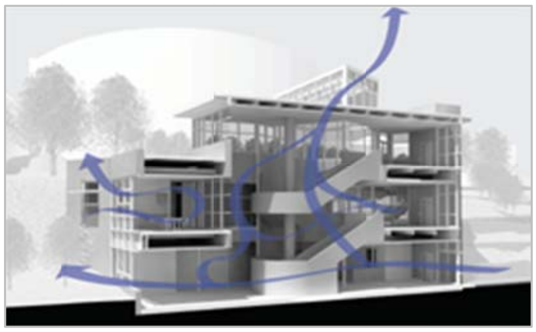


Figure 15 Natural Ventilation Diagram of Atrium

Ultraviolet Duct Lamps

The air in an office will pass through the HVAC system up to 75 times per day during the heating/cooling season. A downside to CSL's high performance, tight construction, is that air circulating in the ductwork of the office can be concentrated with contaminants including molds, bacteria, and viruses. The basic MERV filtering systems employed in CSL offer little help with these airborne contaminants because they can pass through a filter or collect on filter medium and grow. To combat this potential indoor air quality issue, ultraviolet duct lamps are installed in CSL. Ultraviolet light helps fill the indoor air quality gap and clean the contaminants in the air that filters can't. Figure 16 shows an image of an ultraviolet duct lamp and a microscopic view of the ultraviolet destroying mold and bacteria.

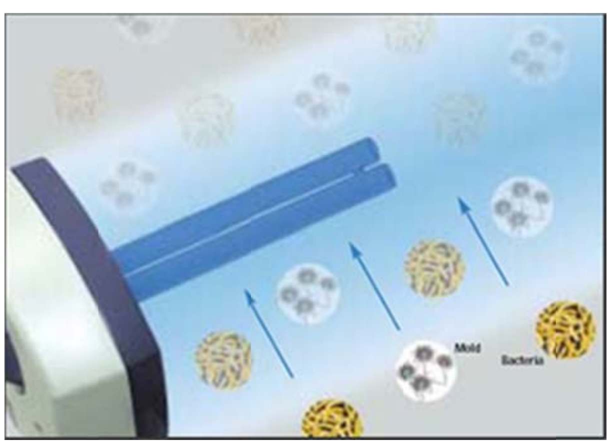


Figure 16 Ultraviolet Duct Lamps

6.0 Controls

In order to manage the various heating, cooling, ventilating systems listed above in section 5, an advanced controls system is prescribed for the operations of the building. This section outlines the sequence of operations, sensors, and automation ambitions of the designers. Due to the complexity of these new and progressive mechanical systems as well as the hundreds of sensors, the controls specifications may be too complex for the facility management staff to manage. The controls systems logic and usability could be a topic to further investigate during the redesign.

6.1 Sequence of Operations

The Center for Sustainable Landscapes was specified with a detailed sequence of operations due to the intricacies of the air and water systems. Table 9 summarizes the mechanical components with control points with respect to heating, cooling, or ventilating. The operation of each component is discussed following the table. All components are to be connected to the building automation system or BAS (which is interchanged in the specifications with "direct digital control" or DDC). The specified BAS is discussed in Section 6.3 Automation.

Table 9 Heating, Cooling, Ventilating Components with Control Points

FUNCTION	COMPONENTS WITH CONTROL POINTS
Heating	Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV) Geothermal Loop Water Pumps Floor & Ceiling Mounted Variable Air Volume Diffusers Atrium Radiant Heating Panels Atrium Supply/Return Heating Season
Cooling	Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV) Geothermal Loop Water Pumps Floor & Ceiling Mounted Variable Air Volume Diffusers
Ventilating	Energy Recovery Ventilator (ERV) Atrium Windows Exhaust Fan

Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV)

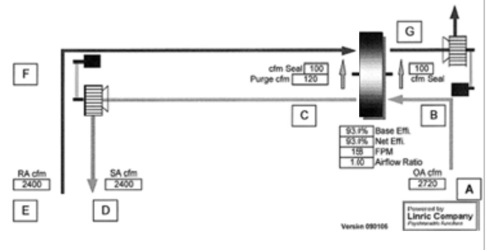
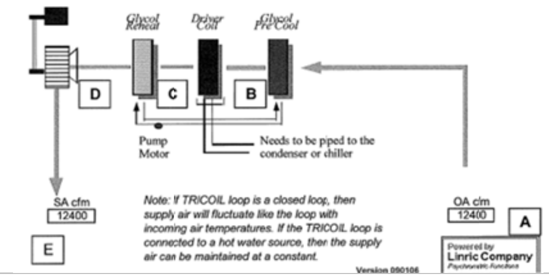
AHU-1 is a variable air volume system, which serve terminal diffuser fans in the under floor air distribution. The supply and return fans are equipped with variable frequency drive (VFD) speeds to accommodate the change in system volume.

The ***initial start sequence*** begins with the following components turning on, opening, closing, or running:

- **12+ sensors** within the AHU need to be ON and exchanging data with the BAS in order to continue.
- OPEN
  - **Outside Air (OA) Louver** to the minimum outside air cfm set point.
    - **Bypass Damper** equivalent to the amount of cfm above the minimum outside air requirement and to the amount of recirculated air reduced.
    - EX: 0 cfm of bypassed = 2,000 cfm of outside air = 10,400 cfm of recirculated
    - EX: 10,400 cfm of bypassed = 12,400 cfm of outside air = 0 cfm of recirculated
- CLOSED
  - **Recirculated Damper** equivalent to the amount of cfm above minimum outside air requirement and amount of cfm being bypass.
    - EX: 0 cfm of recirculated = 12,400 cfm of outside air = 10,400 cfm of bypassed
    - EX: 10,400 cfm of recirculated = 2,000 cfm of outside air = 0 cfm of bypassed
- RUN
  - **Supply Fan** to maintain duct static pressure.
  - **Exhaust Fan** to range from 2,000 cfm to 12,400 cfm max depending on minimum and maximum outside air cfm required.
  - **Enthalpy Wheel** (basic options were discussed earlier in Section 5.3)

The AHU is equipped with ***two modes***, shown in Table 10, that offer differing flows and advantages during different times of the year.

Table 10 Modes of Air Handling Unit

Modes	MODE #1: Energy Recovery Ventilator (ERV)	MODE #2: Dedicated Outdoor Air System (DOAS) [Berner manufacturer calls this mode: TRICOIL® System Only (TRO)]
Flow Diagram		
Enthalpy Wheel?	YES: *wheel typically between 20 – 100% speed*	NO: *wheel drops out & goes into jog mode (one of the economizer options)*
Reduces Energy By	Recovering recirculted air from return air ducts in conjunction with mechanical refrigeration	Using 100% outside air to heat or cool the building without mechanical refrigeration, which requires the LEAST amount of energy
Ideal For	Conditioning the air of worse case weather conditions	Providing load neutral make-up air requirements
Used When	Coldest Days of Winter Hotest Days of Summer	Temperate Weather (OA = 68 F to 78 F) Ambient temperatures are cooler & drier than indoor temperatures
Winter Heating Setpoints [db]	Outside Air 2.0 °F Supply Air 68.0 °F	Outside Air 68.1 °F Supply Air 83.0 °F
Summer Cooling Setpoints [db]	Outside Air 90.0 °F Supply Air 77.0 °F	Outside Air 78.2 °F Supply Air 63.7 °F

The AHU is equipped with ***economizer options***, dependent on the outdoor air dry bulb temperature. The outdoor air, return air, and relief air dampers are each controlled individually but are interlocked in order to provide adequate economizer control. The outdoor air dampers are to be at their minimum setting when the outdoor air temperature is above 55°F. CSL employs both air-side and water-side economizers.

- **Air-side Economizers** are used in cold and temperate climates. They save energy by using cool outside air as a means of cooling the indoor space. The economizer here includes turning the enthalpy wheel down or off and opening the outdoor air louver and recirculated damper, which provide an important energy conservation function by allowing the system to mix return air with outdoor air to minimize mechanical cooling and heating.
- **Water-Side Economizers** are used when the outside air's dry bulb and wet bulb temperatures are low enough. They save energy using water cooled by the geothermal well pipes to cool the building without operating a chiller. The economizer here is the heat exchanger (AHU component built for efficient heat transfer from water in pipes to air eventually supplied to space).

These options are accompanied by a sequence of operations specific to either winter heating or summer cooling. The intent of the energy saving strategies, summarized in Table 11, is primarily to:

- Reduce electrical load
- Increase amount of outside air

Table 11 AHU Heating & Cooling Sequence of Operation

<table>
<tr><th></th><th>WINTER HEATING</th><th>SUMMER COOLING</th></tr>
<tr><td>Primary</td><td colspan="2">Primarily, the AHU uses Mode #1: Energy Recovery Ventilator. In the summer, this option is to be used if the air is latent.</td></tr>
<tr><td>Mode #1</td><td>ON
Enthalpy Wheel at 100% speed
Wheel Entering / Leaving Air Temperature Sensors
Reduce speed based on desired leaving air temp before recirculated air
OFF
TRICOIL Pump motor
CLOSED
Bypass Valve to <u>prevent reheat to pass</u>
Hot Water Valve to prevent BTUs of the geothermal heat pump cool water leaving temperature from providing unwanted post cooling after heating (DX) coil.
Leaving Air Temperature Sensor on DX Coil is to adjust the variable frequency drive of the heat pump compressor to save energy.</td><td>ON
Enthalpy Wheel at 100% speed
Wheel Entering / Leaving Air Temperature Sensors
Reduce speed based on desired leaving air temp before recirculated air
TRICOIL Pump motor
OPEN
Bypass Valve to bypass heated return air, which reduces amount of warm return air to space
if Indoors Becomes TOO COLD (aka, reduction in bypass reheat), then
CLOSE: Bypass Valve for heated return air used to warm the building
OPEN: Hot Water Valve to use the BTUs of the geothermal heat pump rejected heat of the warm water temperature to warm the building
Leaving Air Temperature Sensor on DX Coil is to adjust the variable frequency drive of the heat pump compressor to save energy.</td></tr>
</table>

	WINTER HEATING	SUMMER COOLING
Secondary	Here, the AHU should be around 100% outside air, close to a dedicated outdoor air system in Mode #2. This is dependent on entering outside air & loop water temperatures. Using the following economizer options results in the LEAST amount of energy consumption. The water-side economizer geothermal heat pump option is energized when the air-side economizer enthalpy wheel option cannot maintain comfort conditions due to extremes in outside weather conditions. In the summer, these options can only be used if the air is sensible.	
Air-Side Economizer *Enthalpy Wheel Option*	Uses Mode #1: ERV Flow at Reduced Speed OPEN • **Outside Air Louver** • & **Recirculated Damper** to allow outside & return air to be blended and sent to space ON • **Enthalpy Wheel** at 100% for minimal outside air cfm and maximum recirculated air	Uses Mode #2: DOAS Flow (sensible air) OPEN • **Outside Air Louver** • & **Recirculated Damper** to allow outside & return air to be blended and sent to space (Note that if outside air temperature is dropping, allow 100% OA to go to space) OFF • **Enthalpy Wheel** (Mode #2)
Water-Side Economizer *Geothermal Heat Pump Option*	These operations basically allow more OA with lower air temperatures to go directly to space at *warmer temperatures without using the heat pump to achieve it*. OPEN • **Outside Air Louver** • **Bypass Valve** for 100% bypass if Loop Water Temp. < Precooling Coil Air Temp. • DO NOT use this method. Well water would provide unwanted post cooling. if Loop Water Temp. > Precooling Coil Air Temp., then OPEN • **Hot Water Valve** to provide extra heating in reheat coil, thus allowing 100% OA at 40 F to be heated to about 55 F to supply to space	These operations basically allow more OA with lower temperatures to go directly to space at *semi load-neutral conditions without requiring compressors to be on*. OPEN • **Outside Air Louver** • **Bypass Valve** for 100% bypass if Loop Water Temp. < Precooling Coil Air Temp., then OPEN • **Hot Water Valve** to use loop water for cooling in sync with precooling coil (which equates to a sensible tempering chilled water coil) if Loop Water Temp. > Precooling Coil Air Temp., then OPEN • **Hot Water Valve** to use loop water for reheating in sync with precooling coil (which equates to a sensible tempering reheat coil), thus allowing 100% OA at 55 F to be heated to about 70 F to supply to space

	CLOSE • **Recirculated Damper** because this warmer yet stale return air is not needed to bring up the air temperature (the geothermal water temperature mixed with outside air will suffice)	CLOSE • **Recirculated Damper** because this warmer yet stale return air is not needed to bring up the air temperature (the geothermal water temperature mixed with outside air will suffice)

Geothermal Loop Water Pumps (2)

The two geothermal loop water pumps are located in the first floor mechanical room. Since the geothermal system works in conjunction with the Rooftop Energy Recovery Unit to provide heating, cooling, ventilation, and dehumidification, they are to operate anytime the air handling unit heat pumps are operating. The geothermal loop water pumps are to follow the below sequence:

- **ON** (geothermal water pumps & heat pumps energized) when economizer and desiccant wheel cannot maintain comfort conditions due to extremes in outside weather conditions.
- **Flow Status Sensors & Supply/Return Temperature Sensors** are to monitor the water pumps continuously.
- **Pump Speed & Loop Pressure Sensors** are to monitor loop water differential pressure and pump variable frequency drive (VFD) speed.
    - Loop Water Differential Pressure = 12 lbf/in2
    - Min. Pump VFD Speed should not be < 20%
- **Duty / Standby or Lead / Lag Operation**: One pump is to be the duty (or lead) pump, while the other is to be the standby (or lag) pump.
    - *Rotate* duty / standby daily, weekly, monthly, exceeded pump runtime, or manually through BAS.
    - *Run in Unison* when decreasing loop water differential pressure to maintain set point.
    - *On Lead Pump Failure*, Lag Pump should run.
    - if Lead Pump VFD Speed is > set point of 90%, then Lag Pump VFD should turn ON
    - if Lead Pump VFD Speed = 60% below set point, then Lag Pump VFD should turn OFF
- **Alarms** & Heat Pump Shutdown
    - if NO FLOW in loop water
    - if Loop Water Supply Temp. > 92 F or < 58 F
    - if Loop Water Supply/Return Temp. > or < heat pump manufacturer's recommended temp. range
    - if Loop Water Differential Pressure is 25% > or 25% < set point

Floor & Ceiling Mounted Variable Air Volume (VAV) Diffusers

The diffuser's actuator should modulate to maintain space temperature with the following sequence:

- If COOLING, diffuser's actuator should be "direct acting."
    - **OPEN** damper on rising temperatures.

- If HEATING, diffuser's actuator should be "reverse acting."
    - **OPEN** damper on falling temperatures.
- When VENTILATING:
    - **CO_2 Sensors** in space are to be used by AHU to increase or decrease amount of outside air. Maintain maximum space CO_2 levels by resetting minimum outdoor airflow.
    - Space minimum ventilation provided by non-controlled supply air registers.
- LOCAL THERMOSTAT is to provide local occupant control (override button and LCD) for set point override.

Floor Supply Air Duct Static Pressure Control

Pressure Sensors should monitor static pressure of under floor air distribution plenum relative to the space. Corresponding supply air duct dampers should modulate to maintain the under floor plenum air static pressure set point.

Atrium Radiant Heating Panels

The radiant heating panels were intended as a supplemental system to provide additional control to occupants if the atrium space were to become too cold during winter months, thus they would typically be disabled.

- **OFF** (disabled) by default.
- **ON** if called by the owner in the direct digital control system. Heat is provided by Evacuated Tube Solar Hot Water system that collects heat from the sun to heat water and atrium. Panels should cycle to maintain an adjustable temperature set point of 60 F.

Note: *After talking with the contractor, these radiant heating panels may not be delivered or installed due to budget issues in the latter half of the project.*

Atrium Supply/Return Dampers, Heating Season

The atrium is intended to be minimally conditioned, thus duct dampers are intended to be closed and only open if called on by the owner.

- **CLOSED** by default. Passive heating strategies and winter solar collection, which take advantage of thermal massing in walls, ceilings and floors, are intended to satisfy the majority of heating needs. In addition, upper campus conservatory and greenhouse serves as a heat "bank" for atrium heat.
- **OPEN** if called by the owner in the direct digital control system.
    - if OCCUPIED, supply/return dampers should open 100%. The rest of the mechanical system should stay balanced. Once atrium temperature reaches 60 F, dampers should close.
    - if UNOCCUPIED, supply/return dampers should open 100%. Under floor air distribution dampers should move to 50% open. Supply air temperature should be 85 F. Once atrium temperature reaches 60 F, dampers should close.

Atrium Windows

Sensors are to monitor outdoor wind speed, wind direction, and precipitation. Atrium windows should open or close depending on indoor temperature (T), outdoor enthalpy (h), precipitation, and wind speeds.

- **CLOSED** by default, until the correct open conditions in the statements below are met. Once windows are open, they should close:
  - if PRECIPITATING
  - if WIND SPEED > 20 mph for 1 minute
  - if WIND SPEED > 30 mph
- **OPEN**
  - if atrium Temp. > set point Temp.
  - if outdoor enthalypy < indoor enthalpy

Exhaust Fan

The exhaust fan discussed in Section 5.3, Indoor Air Quality, is to be controlled by a reversing line voltage room thermostat. The fan should be energized (on) or de-energized (off) depending on the temperature in the space in comparison to the set point.

- **ON** when space temperature is above set point.
- **OFF** when space temperature is 2 F below set point.

6.2 Sensors

Each component discussed above has numerous hardware and software points associated with its sensors, all of which are intended to be inputted into the building management system. Table 12 shows the breakdown of the 236 total number of points for the control system. A further analysis of the data transfer of each of these points could be further investigated in the redesign.

Table 12 Hardware / Software Points of System Sensors

SYSTEM	HARDWARE PTS.	SOFTWARE PTS.
Air Handling Unit (AHU) / Energy Recovery Ventilator (ERV)	37	90
Atrium Windows	8	12
Floor & Ceiling Mounted Variable Air Volume Diffusers (VAV)	5 per zone	7 per zone
Floor Supply Air Duct Static Pressure Control	3	6
Electric Meter	1	8
BTU Meter	4	12
Geothermal Loop Make-Up Water, Gray Water, & Domestic Water Flow Meter	1	5
Geothermal Loop Water Pumps	12	25
Hardware / Software Totals	**71**	**165**
Overall Total Number of Points	**236**	

Electric Meter, BTU Meter, & Water Flow Meter

Three different meters were specified in CSL's specifications. The electric meter is to monitor electric consumption; the BTU meter is to monitor for energy consumption; and the water meter is to monitor geothermal loop make-up water, gray water, & domestic water consumption. The specifications outlines the generic goals of each meter (which follows in a bulleted list), but a specific system, meter, or sensor for the monitoring and visualization of this data was not specified.

- **Continuous Monitoring**: Each meter is to monitor its respective commodity on a continual basis.
- **Recording Frequency**: Readings are to be recorded on a daily, month-to-date, and year-to-date basis.
- **Peak Demand History**: Each meter should monitor and record peak (high and low) demand readings from the electric meter.
- **Usage History**: Each meter should monitor and record readings so as to provide a power consumption history.
- **Accessibility**: The values of each meter are to be made available to the system at all times.
- **Errors**: Alarm is to sound when a loss of pulse output or invalid reading occurs.

Additional Measurement & Verification

As a way to improve upon the building's performance throughout its life, additional sensors are to be added to CSL for educational / research purposes by Carnegie Mellon University's Architecture Department. Exact details on sensors retrofitted by Carnegie Mellon are yet to be determined. Additional sensors not yet discussed provided by Automated Logic, including motion sensors, surface temperature sensor, and mean radiant temperature sensors, are shown in Figures 17 and 18.

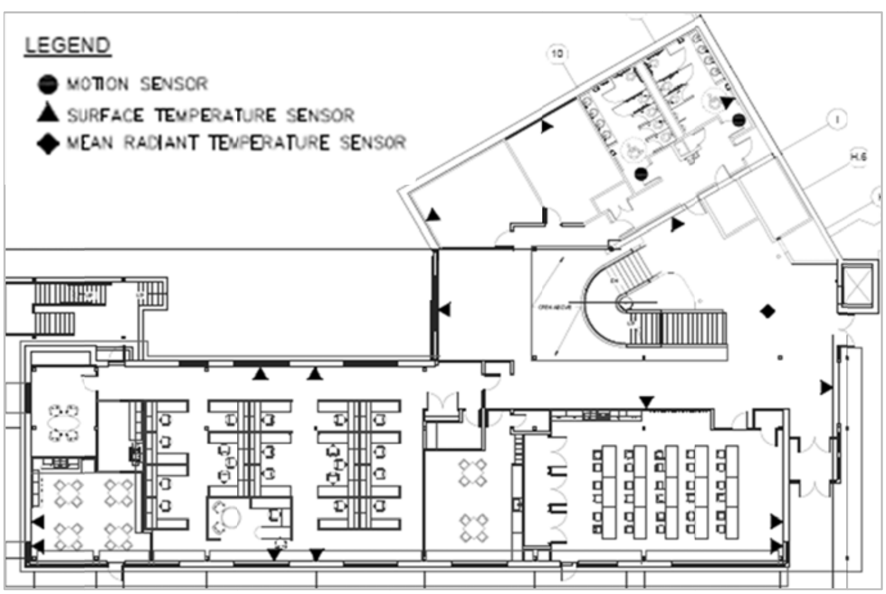


Figure 17 1st Floor Additional Measurement & Verification

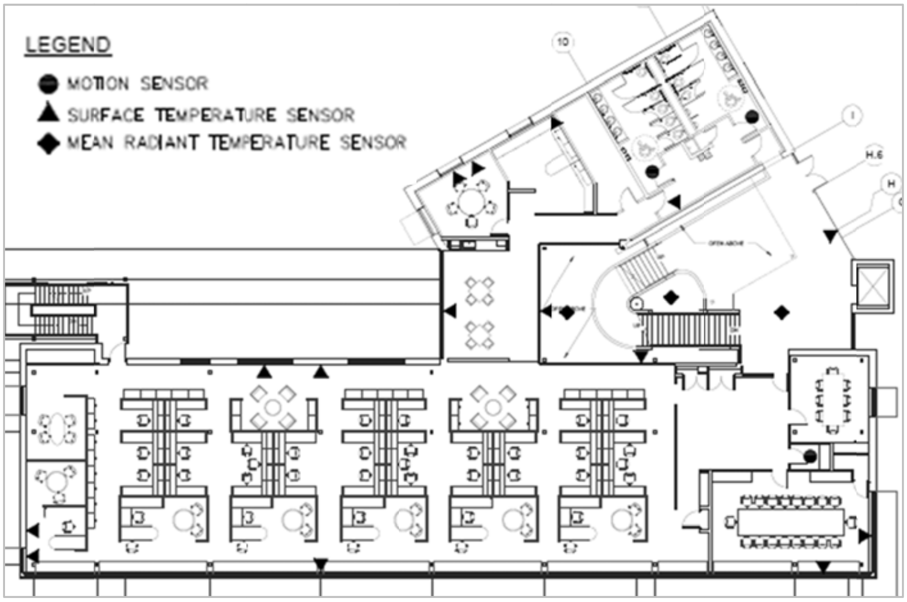


Figure 18 2nd Floor Additional Measurement & Verification

6.3 Automation

The Building Management System (BMS) is often interchanged with building automation system (BAS), distributed control network, direct digital control (DDC), or Building Automation Control Network (BACnet), yet the goal of each is to have a central system to view and manage the operations of each building system (including mechanical, lighting, electrical, and plumbing). The owner of the Center for Sustainable Landscapes hopes to closely monitor the energy performance of the building throughout its life. After further analyzing the building management system components and manufacturers, coordination of the controls automation seems extremely disparate.

- 5 different product manufacturers, shown in Table 13, must work together before installation to ensure interoperability throughout the life of the building.
- Measurement & Verification LEED credits are solely managed by CJL MEP engineers and Carnegie Mellon University.
- Additional advanced Measurement & Verification are to be provided by Carnegie Mellon University for research purposes, yet, funding for this has yet to be obtained.
- Controls contractor, Automated Logic, is directly managed through the owner (detached entirely from the architect and contractor). Requested meeting with Automated Logic by Carnegie Mellon University professors have shown that Automated Logic is also unwilling to collaborate to ensure sensor & BMS interoperability.

Table 13 Building Management System (BMS) Components & Manufacturers	
COMPONENT	MANUFACTURER / SUPPLIER
Air Handling Unit / Energy Recovery Unit	Berner Energy Control Panel (BERI)
Site Lighting Control System	Eaton / Cutler-Hammer
Indoor Distributed Lighting Control System	LutronEcoSystem
HVAC Controls	Argus Control System
Direct Digital Control (DDC) Network (Intended Overarching BMS, Building Management)	Automated Logic's WebCTRL supplied by Logical Automation Inc.

The AHU, manufactured from Berner, has various components within itself that complicate the controls automation. Table 14 below shows how certain AHU components discussed in Section 5.2 are to be powered by the Berner Energy Control Panel and controlled by the BMS while other components within the same AHU are to be powered and controlled by the BMS.

Table 14 Intricate Controls within the AHU	
POWERED by Berner Energy Control Panel & CONTROLLED by the BMS	POWERED & CONTROLLED by the BMS
Water Source Heat Pump Heat Wheel Variable Frequency Drive Supply & Exhaust Fan Variable Frequency Drive Ultraviolet Lighting Air Flow Monitoring Station	Bypass Damper Recirculated Damper Outside Air Louver Reheat Bypass Valve Hot Water Valve

Likely a result of the engineers anticipating interoperability concerns, a coordination meeting is discussed in the specifications. "The installer furnishing the DDC network (Automated Logic) shall meet with the installers furnishing each of the listed controls products to coordinate details of the interface between these products and the DDC network. The owner or his designated representative must be present at this meeting. Each Installer shall provide the owner and all other installers with details of the proposed interface including PICS for BACnet equipment, hardware and software identifiers for the interface points, network identifiers, wiring requirements, communication speeds, and required network accessories. The purpose of this meeting shall be to ensure there are no unresolved issues regarding the integration of these products into the DDC network. Submittals for these products shall not be approved prior to the completion of this meeting."

If one detail is left out of this meeting, interoperability will be jeopardized. If one system is to fail, other interconnected systems might be affected. If building management problems persist, the advanced system could be in jeopardy of not being used by the facility management staff (which would make the owner's initial investment of the progressive mechanical systems worthless). Components of CSL that are intended to work seamlessly together are very detached, which is very typical of current building designs. Further investigating the interoperability of these controls systems could be a relevant topic for redesign.

7.0 Energy

Trane TRACE 700 was also used to calculate an annual energy simulation of the Center for Sustainable Landscapes using the ventilation rates, internal generation, and envelope details outlined in Technical Report Two. 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 intricate in comparison to more traditional systems used to heat/cool/ventilate a building. Thus, it was not be possible to capture every energy benefit of CSL's design through this analysis. Further investigating ways to input all of these systems into an energy model could be a potential topic for redesign.

7.1 Utilities

The energy costs for the building are determined by resource providers. Show below in Figure 19 is the distribution map of electricity providers for Pennsylvania. Pittsburgh is located in the region shaded in orange. CSL's utility providers are Duquesne Light & Columbia Gas. Table 15 shows the $7.07 /kW electricity demand price charged by Duquesne Light.

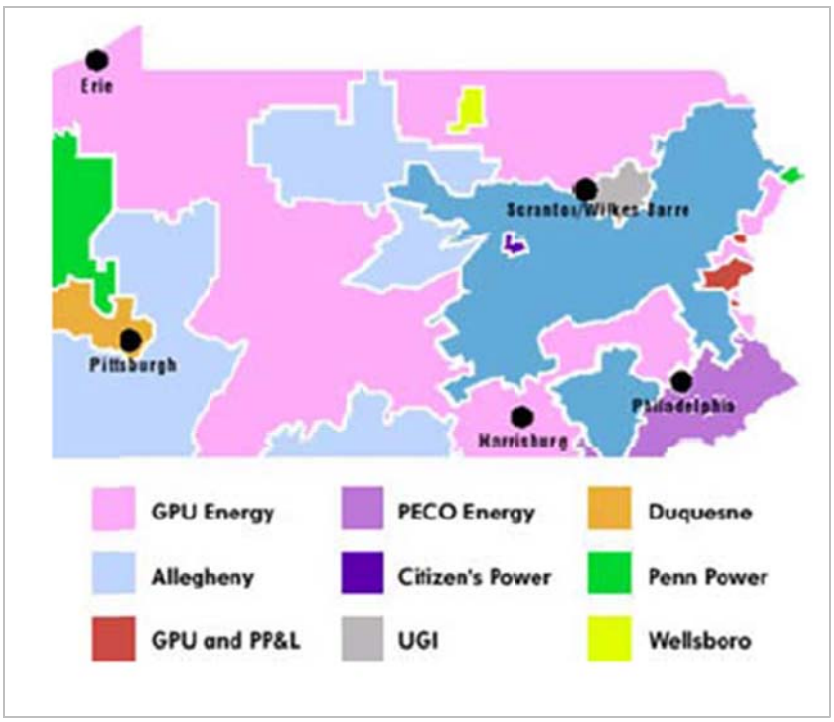


Figure 19 Pennsylvania Power Distribution

Table 15 Duquesne Light Electricity Rates	
DEMAND	USAGE
$7.07 /kW	0.1236 cents/kWh

Phipps' new center for education, research and administration has 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 in a boiler), has resulted in CSL only using one utility, electricity, for mechanical systems. For reference, domestic hot water for a low rise office building was found to be 0.135 gpm. Table 16 gives an explanation of CSL's utility sustainability and the rates of its utility suppliers, Duquesne Light, Columbia Gas, and Pittsburgh Water & Sewer Authority. Specific tax incentives due to this net-zero energy design are discussed in Section 8.3.

Table 16 CSL Utility Sustainability & Rates

UTILITY	Sustainability at CSL	UtilityRates
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 an adjacent Phipps 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** generates renewable electricity from wind. • *Note:* Electricity generated from PV & wind turbines offset all electricity demands of the building. Any additional electricity generated is supplied by the Duquesne Light's grid.	DEMAND $ 7.07 / kWh USAGE 0.1236 cents/kWh PROVIDED BY Duquesne Light
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.	PA RATE $ 0.76 / Therm PROVIDED BY Columbia Gas
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 PROVIDED BY Pittsburgh Water & Sewer Authority

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 system source.

7.2 Consumption

The fraction of electric energy consumed by subsystems (HVAC, lighting, office equipment) is desirable to provide a basis for energy efficiency improvement claims of redesign. Table 17 and Figure 20 highlight CSL's energy consumption by subsystem. In total, CSL consumes 485,206 kBTU/yr. In the section 7.3, this total will be compared to the 2003 Commercial Buildings Energy Consumption Survey (CBECS). The total end use and source energy consumption by subsystem calculated by Trane TRACE is shown in Table 17.

Table 17 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 20 depicts a much different energy consumption distribution than the traditional building. Amongst many other factors (detailed later in section 7.3), a geothermal system eliminates the need for inefficient fans which decrease the consumption percentage of heating & cooling in CSL. Yet, the heating consumption seems low for a typical Pittsburgh office. An explanation for this may be CSL's high performance building envelope. Higher than expected, the energy percentage consumed by pumps & equipment is likely larger than traditional designs due to various water management systems. Receptacles (dominated by the computers of the office building) and lighting distributions result as expected.

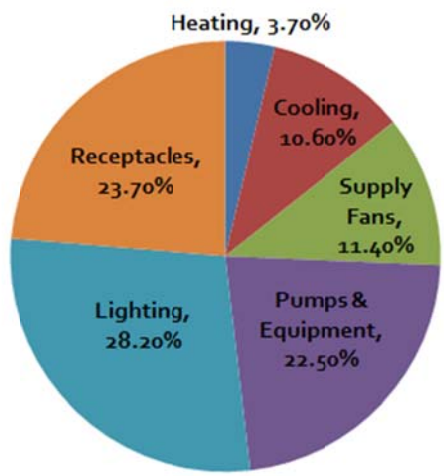


Figure 20 Subsystem Energy Consumption

7.3 Benchmark

To standardize the results for comparisons to energy benchmarks, BTU/SF was calculated by multiplying the total building energy [485,206 kBTU/yr] in Table 17 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 annual energy consumption was compared to the Commercial Buildings Energy Consumption Survey (CBECS) 2003. This report is based upon a building's end use not its source consumption. In Table E2A (Major Fuel Consumption Intensities by End Use for all Buildings) of CBECS (referenced in Appendix A2) the national average of all US buildings between 10,001-25,000 SF consumed an average of 71,000 BTU/SF. All US buildings of the same office function consumed an average of 92,900 BTU/SF and all buildings of the same location in Northeast US consumed an average of 99,800 BTU/SF. All of these averages are noticeably higher than the Center for Sustainable Landscapes (specific percentages are shown in Figure 21).

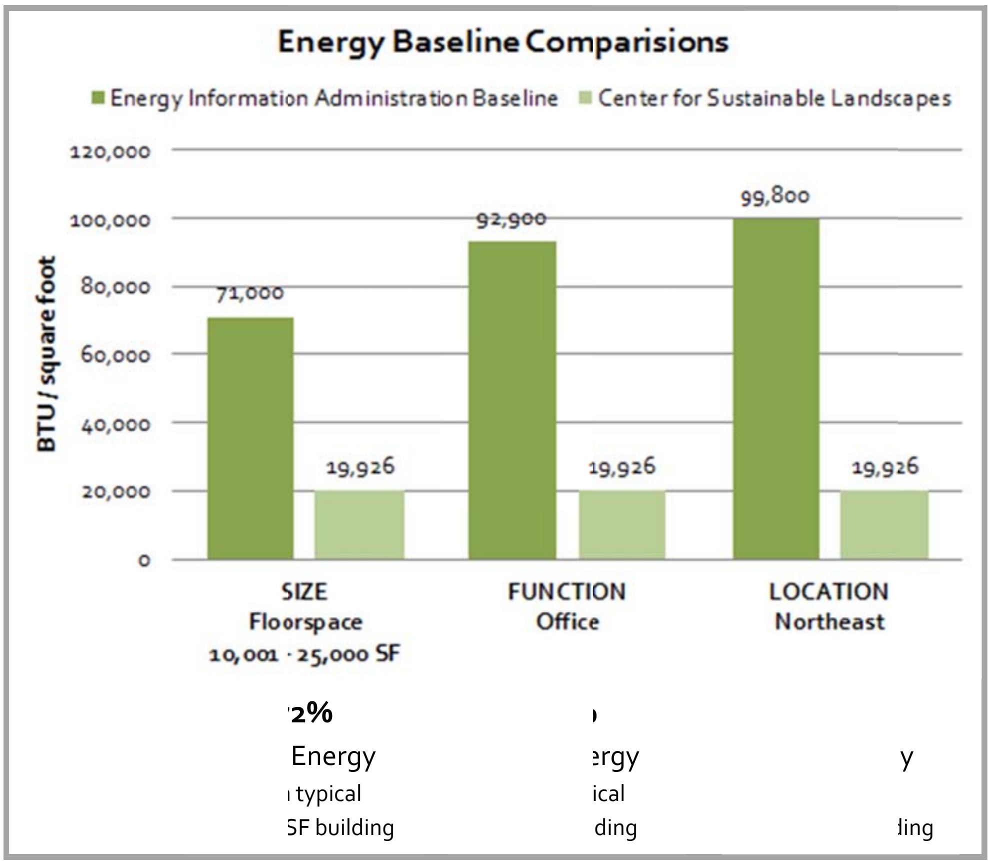


Figure 21 Energy Consumption Baseline Comparisons

Potential justifications 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 a **geothermal ground source heat pump** for heating and cooling rather than using inefficient air to air systems. A 2003 study by the US Department of Energy in Figure 22 proves that traditional systems, such as Air-Source Heat Pumps or Gas Furnace Air-Source AC systems consume much more energy on average than the chosen ground source heat pump for the Center for Sustainable Landscapes.

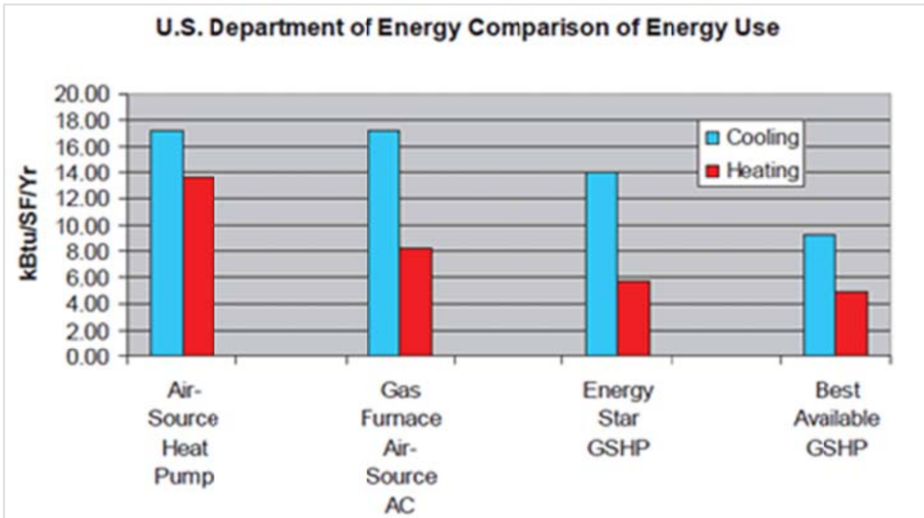


Figure 22 Comparison of Energy Use of Mechanical Systems

- 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.

8.0 Costs

Costs are one of the largest factors in designing the mechanical systems of a building. Initial, up-front costs must be balanced by operating costs throughout the life of the building. This section analyzes both, plus tax incentives that the Center for Sustainable Landscapes applies for due to its net-zero energy consumption operation.

8.1 Initial Costs

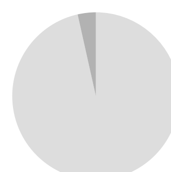
The total initial cost of the mechanical system for the Center for Sustainable Landscapes is $714,000 which equates to $29.32 per square foot. The price includes all mechanical equipment, distribution material, and labor for both the water and air systems. The equipment for the fire protection systems as well as mechanical system testing and balancing are excluded. A breakdown of the mechanical systems in terms of equipment and distribution can be found in Table 18. Note that advanced sensors discussed in section 6.2 are not included in the HVAC / Plumbing (since they are not managed by the contractor, but rather directly between the owner and Automated Logic). Equipment costs listed in Table 18 below include:

- **HVAC / Plumbing**: ductwork, piping, fans, indoor air quality components
- **Geothermal**: bore hole wells, pumps
- **AHU / ERV**: rooftop air handling unit including all of its internal components

Table 18 Mechanical System Costs

EQUIPMENT	COSTS
HVAC / Plumbing	$480,000
Geothermal	$100,000
AHU / ERV	$134,000

$714,000 / $20 million total costs = **$29.32** per SF



3.6%
building costs due to mechanical systems

Comparatively, initial costs of a less progressive mechanical systems is typically much more than that of CSL, averaging between around 15– 20% of the total building costs and around $70 - $100 per square foot. Although the Center for Sustainable Landscapes costs much less initially at 3.6 % of total cost and $29.32 per SF respectively, the costs of adding many sensors throughout the building to manage such systems will increase upfront costs dramatically. Either way, there is a strong perception that more progressive systems have higher upfront costs but minimized energy costs throughout its life. CSL contradicts this viewpoint by having lower upfront costs as well as operating costs. Yet, if the costs of the 10+ LEED consultant services and sensor costs were captured, it is likely that up-front costs would be higher than traditional designs.

8.2 Operating Costs

The monthly operating cost for a full year for the Center for Sustainable Landscapes can be viewed in Table 19 and Figure 23 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. Depending on the amount of on-site electricity generated from the PV panels and wind turbine, costs per month could vary from the simulated values in Table 19.

Table 19 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

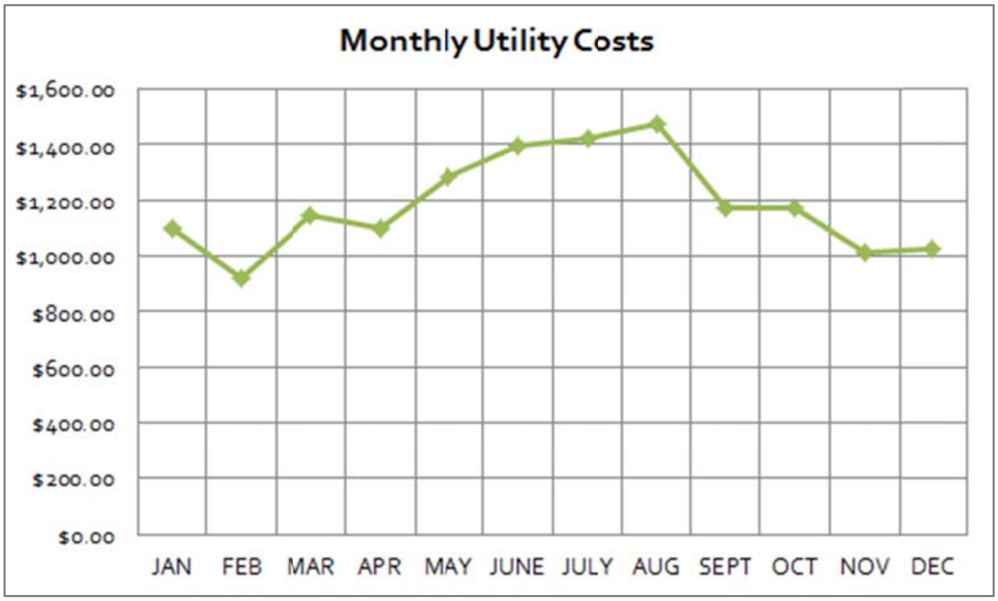


Figure 23 Monthly Utility Costs [Electricity]

In addition to the above data, Trane 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.

8.3 Tax Incentives

Exceeding the performance of net-zero buildings, the Center for Sustainable Landscapes is designed to generate more electricity than it uses (which is a requirement of the Living Building Challenge). Electricity generation is monitored by a Duquesne Light smart meter through a "net metering" process.

Net Metering is the means of measuring the difference between the electricity generated by a customer connected to the grid and the electricity provided by Duquesne Light. A bi-directional smart meter is used to measure and record the flow of electricity in both directions. The electricity generated by CSL's alternative energy generating system (including PV panels and a wind turbine) is planned to offset all of its kilowatt-hour usage. Any additionally generated electricity is supplied back to the electric grid while Phipps is reimbursed with "credits" which are in a way tax incentives. Through the Net Metering service, credits are received for the amount of electricity sent to Duquesne Light in excess of the power sent to the building during a monthly billing cycle.

Photovoltaic panels were installed on site prior to construction so that CSL can receive these credits throughout construction time.

Phipps will be compensated for these electricity generation credits once a year in May, when Duquesne Light calculates excess kilowatt-hours generated over the amount of kilowatt-hours delivered. As a customer participating in the Rider 21 Net Metering Service, Phipps must also submit a W-9 form (Request for Taxpayer Identification Number and Certification) to Duquesne Light, who is required to issue a Form 1099 if customers are entitled to a refund that meets or exceeds $600. After analyzing CSL's systems, it is very likely that it will exceed $600 refunds / year.
Even if Phipps CSL generates more power than used in a month, **it will still receive a bill** from Duquesne Light (which covers customer costs for meter reading, customer billing, service equipment, implementation of advanced metering technology and other expenses).

9.0 LEED Sustainability

The United States Green Building Council (USGBC) has created the Leadership in Energy and Environmental Design (LEED) certification system in order to implement more energy efficient designs in the building industry. With "sustainable" being in the name of the building, Phipps's main objective with the design of the building was making a statement about being one of the most sustainable buildings ever built. As a way to measure this, the owner required that the design achieve three nationally recognized green standards (all focused around sustainability):

1. the ILBI (International Living Building Institute)Living Building Challenge
2. LEED Platinum
3. SITES Certification for landscapes

To ensure that all were met, Phipps hired Evolve, LLC to perform and coordinate the LEED Certification process. In total, there were ten different companies, summarized in Table 20, involved in CSL achieving LEED Platinum. The specific involvement of each party is noted in the right column of the LEED Analysis in Table 21 on the next page. Additional costs associated with hiring these consultants were not captured in the Initial Costs Section 8.1 because the amount to which each will be reimbursed for their services is undisclosed. Yet, it can be inferred that these services that were needed to ensure green certification are an added cost above traditionally designed buildings.

Table 20 LEED Analysis Team [with Mechanical System Focus]

COMPANY / RESPONSIBLE PARTIES			ROLE
1	evolve Environment:Architecture	eEA	LEED Certification Consultants
2	7 Group	7G	Energy, Daylight and Materials Consultants
3	Carnegie Mellon University - Center for Building Performance and Diagnostics, Advanced Infrastructure Systems	CMU	Advanced Measurement & Verification
4	Civil & Environmental Consultants, Inc.	CEC	Civil Engineering
5	CJL Engineering	CJL	MEP Engineering
6	Design Alliance Architects	DAA	Architecture
7	Energy Independent Solutions	EIS	Photovoltaic Array
8	H.F. Lenz	HFL	Commissioning
9	Pitchford Diversified	PFD	Enhanced Commissioning
10	Turner Construction	TC	General Contractor

LEED criteria directly affected by the mechanical design include:

1. Energy and Atmosphere
2. Indoor Environmental Quality

Both of these criteria are further analyzed with respect to the Center for Sustainable Landscapes in Table 21. The LEED Analysis shows how the designers and engineers executed each prerequisite and credit in order to achieve every point within Energy & Atmosphere (17/17) as well as Indoor Environmental Quality (15/15).

Table 21 LEED Analysis

CREDIT	DESCRIPTION	PTS	EXECUTION	Responsible Party
Energy & Atmosphere		**17/17**		
EA Prerequisite 1	Fundamental Commissioning of the Building Energy Systems	Rqd	Commissioning plan draft and construction document review of energy systems were completed by HFL & Pitchford. Coordination between the two is managed by Evolve.	HFL PFD
EA Prerequisite 2	Minimum Energy Performance	Rqd	ASHRAE Standard 90.1-2004 (Sections 5.5, 6.5, 7.5, and 9.5) is met as outlined in Technical Report 1. The MEP Engineer, CJL Engineering performed an initial and final energy model. CSL's yearly energy use is projected to be greater than the minimum 10% energy improvement from the baseline building as outlined by ASHRAE Standard 90.1.	CJL
EA Prerequisite 3	Fundamental Refrigerant Management	Rqd	CJL Engineering ensured that the mechanical system for does not use any CFC-based refrigerants.	CJL
EA Credit 1.1-1.5	Optimize Energy Performance	10	The simulated energy model in Section 7.3 shows that CSL will perform on average 75% better than typical buildings of its size, function, and location (beyond the required 10.5-42% reduction range).	7G
EA Credit 2.1-2.3	On-Site Renewable Energy 2.5 / 7.5 / 12.5 % reduction	3	Solar photovoltaics were added to an adjacent facilities building & special events hall roof surfaces at a near-southern orientation. Vertical Axis Wind Turbines were also added on site to contribute to the net zero approach of offsetting 100% of the annual energy consumption.	CSL EIS
EA Credit 3	Enhanced Commissioning	1	Throughout construction document phase & through completion, work scope for enhanced commissioning was broken down into two third party commissioning agents: H.F Lenz &Pitchford.	HFL PFD
EA Credit 4	Enhanced Refrigerant Management	1	Documented analysis of HVAC equipment shows a LCGWP (Lifecycle Direct Global Warming Potential) lower than 100, which meets the maximum threshold for refrigerant impact in order to achieve this LEED credit.	CJL
EA Credit 5	Measurement & Verification	1	Product data and wiring diagrams for sensors and data collection systemused to provide continuous metering of building energy-consumption performance is shown in Section 6.2. Carnegie Mellon University also partnered with CSL in order to provide future advanced measurement & verification for research purposes.	CJL CMU
EA Credit 6	Green Power	1	Greater than the required 35% of electricity is received from renewable sources including generation from on-site photovoltaics as well as a wind mill. eEA will determine equivalency for on-site renewables .	CJL EIS eEA
Indoor Environmental Quality		**15/15**		
EQ Prerequisite 1	Minimum IAQ Performance	Rqd	The project has been designed to meet the minimum requirements of ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, using the discussed Ventilation Rate Procedure in Technical Report 1.	CJL
EQ Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Rqd	Smoking is prohibited inside the building. Anydesignated smoking areas are at least 25 feet away from any building openings.	eEA
EQ Credit 1	Outdoor Air Delivery Monitoring	1	There is a permanent CO_2 monitoring system with lights cuing occupants that outside conditions are favorable for opening windows.	CJL
EQ Credit 2	Increased Ventilation	1	As previously mentioned in Section 5.3 of this report, the rooftop air handling unit contains the capacity for 12,400 cfm of primary air, and 2843 cfm of outdoor air, which exceeds the requirements set forth by ASHRAE Standard 62.1	CJL
EQ Credit 3.1	Construction IAQ Management Plan: During Construction	1	An Indoor Air Quality plan is documented within the specification and summarized in Section 5.3. In addition, filters with a minimum rating of MERV 8 were used during construction to maintain air quality as well.	TC
EQ Credit 3.2	Construction IAQ	1	Phipps has required Turner Construction to schedule & implement a building	TC

	Management Plan: Before Occupancy		and duct flush-out prior to occupancy.	
EQ Credit 4.1	Low-Emitting Materials: Adhesives & Sealants	1	Product data for adhesives and sealants used inside the weatherproofingsystem indicate complying VOC content.	TC
EQ Credit 4.2	Low-Emitting Materials: Paints & Coatings	1	Product data for paints and coatings used inside the weatherproofingsystem indicate complying VOC content.	TC
EQ Credit 4.3	Low-Emitting Materials: Carpet Systems	1	Product data for carpet systems complying with testing and productrequirements of Carpet and Rug Institutes Green Label Plus program for carpet andGreen Label program for cushion and pad.	TC
EQ Credit 4.4	Low-Emitting Materials: Composite Wood &Agrifiber Products	1	Product data for products containing composite wood or agrifiberproducts or wood glues indicate that they do not contain urea-formaldehyde resin.	TC
EQ Credit 5	Indoor Chemical & Pollutant Source Control	1	Provided by Design Alliance Architects, entryway systems employed are of at least six feet in length in order toprevent dirt and particulates from entering the building. Also, Turner is to provide air filters of MERV 13 rating or higher.	DAA CJL TC eEA
EQ Credit 6.1	Controllability of Systems, Lighting	1	Individual lighting controls for at least 90% of the occupants was installed. An advanced lighting network control system discussed in section 6.3 will use Lutron'sEcosytem. In addition, occupancy sensors turn off lights in unoccupied rooms.	CJL
EQ Credit 6.2	Controllability of Systems, Thermal Comfort	1	Each multi-occupant space, including offices and classrooms, is provided with its own individual space controls. Additional HVAC controls are to be controlled by an Argus Control system.	CJL
EQ Credit 7.1	Thermal Comfort, Design	1	The rooftop air handling unitdistributes 55° F supply air and the desiccant dehumidification system allows for a higher comfortable indoor temperature setpoint of 78° F. The building envelope and HVAC design also meets ASHRAE Standard 55.	CJL
EQ Credit 7.2	Thermal Comfort: Verification	1	eEA is to administer a comfort survey assuring adequate assessment of building thermal comfort during post completion.	eEA
EQ Credit 8.1	Daylight & Views: Distribution Quality to 75-90% of Spaces	1	For the windows on the exterior of the building, there is at least a 2% daylighting factor in only 18% of regularly occupied spaces. In addition, ceiling cloud surface & interior finish color schemes provide high reflectance values.This along with light shelves maximize the depth of daylight penetration into the space.	DAA eEA
EQ Credit 8.2	Daylight & Views: Views for Seated Spaces	1	Of the total regularly occupied area, 100% of seated spaces have access to views (exceeding the 90% requirement).	DAA eEA
Total Energy & Atmosphere, Indoor Environmental Quality		**32 earned** / 32 available points for the mechanical systems		
Total Overall		**55 earned** / 69 available points for this site		

Overall CSL is predicted to achieve 55 likely earned + 8 maybe = **63 total points** in play. All points are "likely" until submitting to LEED Online (LOL). Evolve LEED Consultants considered this point cushion sufficient to maintain Certification Goal of Platinum. Appendix A1 shows the full LEED Scorecard created by Evolve, LLC. For reference, LEED Certification Levels and points associated with each are shown in Table 22. Note that LEED Certification is ultimately a determination of the USGBC, but it is clear through this LEED analysis that CSL's design is well on its way to achieving LEED Platinum.

Table 22 LEED Certifications & Points	
LEED Certified	26-32 points
LEED Silver	33-38 points
LEED Gold	39-51 points
LEED Platinum	52+ points

10.0 Evaluation

As a response to the requirements of the building program, the mechanical systems of the Center for Sustainable Landscapes exceed standards in nearly every category, yet maintaining such new and complex systems may cause future issues. The evaluation for the Center for Sustainable Landscapes was conducted using seven categories and grades A through F.

Space: A

CSL mechanical systems including the 1st floor mechanical room, electrical room, rooftop energy recovery unit, and vertical duct shafts account for 835 SF of the 24,350 SF building, which equates to 3.5% of lost usable architectural space. Typically, the mechanical system space ranges from 8 to 15% of the total floor area. Thus, CSL mechanical systems were extremely space efficient.

Comfort: B

The geothermal system in conjunction with the rooftop energy recovery unit provides heating, cooling, ventilation, and dehumidification. Operable windows give occupants added control of their comfort. Increased daylighting within the space makes the open office a comfortable space to work. Yet, the minimally conditioned atrium with its roof being 100% glazing and its supplemental radiant floor systems potentially being cut due to end of project budget costs, has a small potential for comfort concerns.

Health & Indoor Air Quality: A

With its high performance envelope which creates a tight building with little infiltration, indoor air quality in CSL was an initial potential concern. But, the designers added five different air quality systems that are expected to combat unhealthy air. With an energy recovery ventilator with a 100% outdoor air mode, CO_2 occupancy sensors, exhaust fans, natural ventilation with operable windows, and ultraviolet duct lights, indoor air quality in CSL should not be a concern.

Controls & Maintainability: D

The sequence of operations for the selected mechanical systems is extremely detailed and intricate. Systems are highly dependent upon each other and are even more dependent on the overarching Building Management System (BMS), WebCTRL by Automatic Logic. This BMS is to take in over 236 hardware and software points (some of which consists of continuous metering) from 5 different product manufacturers and make all of the information understandable and manageable to the facility manager and building owner. If each BMS point represents a potential maintainability issue, that equates to 236 potential controls problems. Due to these high risks and poor user interfaces of controls software, maintainability is likely to be very difficult.

Energy: A
CSL strives to exceed net-zero by generating more electricity than it uses with photovoltaic panels and an on-site wind turbine. Using Trane TRACE 700, it 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.

Costs: B
The mechanical system initial cost is $714,000 (approximately 3.6% of the total budget), and annual operating costs is $14,216. Typically, the mechanical system cost ranges from 15 to 20% of the total estimated construction budget. Thus, CSL's initial cost appears to be much lower than traditional designs at face value, yet could be misleading. In order to achieve LEED Platinum, Phipps hired 10 consultants (which increased initial services costs yet was not able to be captured in the up-front costs amount). Additionally, since the controls manufacturer and supplier was through a separate contract, the hundreds of intended building sensors are also excluded from the initial costs. Nevertheless, the mechanical system first cost and annual operating costs break down to $29.32 and $0.68 per square foot respectively. Both the system first cost and annual energy costs are below the building industry. New, progressive designs are not cheap, thus CSL has higher up-front yet lower costs throughout its life.

Sustainability: A
With a team of over 10 companies committed to achieving LEED Platinum, CSL is expected to earn 55 of the 69 available points for its Pittsburgh site. Well above the 52 points LEED Platinum threshold, it is highly likely that CSL will be awarded the highest rating given by the USGBC upon construction.

Opportunities for Improvement
After evaluating the Center for Sustainable Landscapes, its mechanical design is found to be extremely well rounded. Four of the selected seven categories received a perfect rating (including: space, health / indoor air quality, energy, and sustainability). Two categories received a near perfect rating (comfort and costs), while controls and maintainability fell short of an otherwise near flawless design. To investigate the maintainability as an opportunity of improvement, several potential changes may:

- improve & simplify energy model & metering accessibility
- streamline the controls coordination
- decrease time in operations education

The controls and maintainability of the existing mechanical system may benefit from a redesign. Future reports will address redesign ideas.

11.0 Appendix

[A1] LEED Scorecard

Phipps Center for Sustainable Landscapes
LEED DOCUMENTATION AND ACTION PLAN
LEED NC 2.2
Project Goal: LEED Platinum Certification
Date: September 9, 2011

evolve environment :: architecture

Action Items in Bold Red

Credit	Phas	Description	AVAILABLE Points	LIKELY Points	MAYBE Points	UNLIKELY Points	Responsible Party	Credit Status	Credit Status (Credit Status Symbols Key Below)
Sustainable Sites									
Prerequisite	C	Constuction Activity Pollution Prevention	Rqd.	Rqd.			**CEC / Turner**	CEC document in LOL & Turner implement ESCP.	✚
SS Credit 1	D	Site Selection	1	1			eEA	Complete	✓
SS Credit 2	D	Development Density & Community Connectivity	1	1			eEA	Complete	✓
SS Credit 3	D	Brownfield Development	1		1		eEA	Complete	✓
SS Credit 4.1	D	Alternative Transportation: Public Access	1		1		eEA	Complete	✓
SS Credit 4.2	D	Alternative Transportation: Bicycle Friendly	1	1			eEA	Complete	✓
SS Credit 4.3	D	Alternative Transportation: Low Emitting & Fuel-Efficient Vehicles	1	1			**eEA / TDA**	TDA Confirm number & location of spaces. (31 parking spaces provided: 5%=2 LEFE vehicle spaces located nearest entry)	!
SS Credit 4.4	D	Alternative Transportation: Parking Capacity	1		1		**eEA / TDA**	TDA to confirm number & location. (TDA provide Zoning Ordinance parking reqmt and demonstrate number of spaces meet minimum reqmt. (31 parking spaces*5%=2 carpool/vanpool spaces located near entry)	!
SS Credit 5.1	D	Site Development, Protect or Restore Habitat	1		1		**TDA / Andropogon**	TDA adjust calc (to include revised green roof calc for view window at HVAC) and reissue LEED documentation drawing.	!
SS Credit 5.2	D	Site Development, Maximize Open Space	1	1			**TDA**	TDA adjust calc (to include revised green roof calc for view window at HVAC) and reissue LEED documentation drawing.	!
SS Credit 6.1	D	Stormwater Design, Quantity Control	1	1			**CEC**	Confirm that stormwater calc is for current LEED site boundary; adjust calc to LEED site if necessary. Upload documentation to LOL.	!
SS Credit 6.2	D	Stormwater Design, Quality Control	1	1			**CEC**	Document in LOL.	✚
SS Credit 7.1	D	Heat Island Effect, Non-Roof Surfaces	1			1	N/A	Credit not attempted.	X
SS Credit 7.2	D	Heat Island Effect, Roof Surfaces	1			1	**TDA**	TDA adjust calc (to include revised green roof calc for view window at HVAC) and reissue LEED documentation drawing.	!
SS Credit 8	D	Light Pollution Reduction	1	1			**CJL / CEC?**	Confirm design complies: provide site photometric that demonstrates light spill compliance given current LEED site boundary / confirm automatic building lighting shutoff after hours.	!
		Subtotal - Sustainable Sites	**14**	**8**	**4**	**2**			
Water Efficiency									
WE Credit 1.1-1.2	D	Water Efficient Landscaping, 50% Reduction, 100% Reduction	2	2			**Andropogon**	Document in LOL.	✚
WE Credit 2	D	Innovative Wastewater Technologies	1	1			**CEC**	Document in LOL.	✚
WE Credit 3.1-3.2	D	Water Use Reduction, 20% Reduction/30% Reduction	2	2			**CJL**	CJL clarify storm water quantity calc from Tropical Forest roof and storage capacity will supply water for 100% of toilet & urinal use given anticipated storm intensity and frequency.	✚
		Subtotal Water Efficiency	**5**	**5**	**0**	**0**			
Energy and Atmosphere									
EA Prerequisite 1	C	Fundamental Commissioning of the Building Energy Systems	Rqd.	Rqd.			**HFL / Pitchford**	Confirm OPR/BOD review, commissioning plan draft & CD review are all complete. Confirm point of contact and chain of command for HFL Pitchford shared responsibility for Cx.	*
EA Prerequisite 2	D	Minimum Energy Performance	Rqd.	Rqd.			**CJL**	Defer until final energy model can be completed.	*

Action Items in Bold Red

Credit	Phas	Description	AVAILABLE Points	LIKELY Points	MAYBE Points	UNLIKELY Points	Responsible Party	Credit Status	Credit Status (Credit Status Symbols Key Below)
EA Prerequisite 3	D	Fundamental Refrigerant Management	Rqd.	Rqd.			CJL	LOL documentation appears complete; CJL to confirm.	+
EA Credit 1.1-1.5	D	Optimize Energy Performance, 10.5%-42% Reduction	10	10			7 Group	Defer until final energy model can be completed.	*
EA Credit 2.1-2.3	D	On-Site Renewable Energy, 2.5%/7.5%/12.5% Reduction	3	3			CJL / EIS	Defer until energy model complete. Document in LOL.	*
EA Credit 3	C	Enhanced Commissioning	1	1			HFL / Pitchford	Assure work scope breakdown between HFL & Pitchford is clear (see EAp1).	*
EA Credit 4	D	Enhanced Refrigerant Management	1	1			CJL	CJL to complete calc in LOL template.	+
EA Credit 5	D	Measurement and Verification	1	1			CJL / CMU	CJL provide proposed M&V plan and confirm metering is included in CD's.	+
EA Credit 6	C	Green Power	1	1			CJL / EIS / Phipps / eEA	Defer until energy model is complete. eEA to determine equivalency for onsite renewables. Document in LOL.	*
		Total Energy and Atmosphere	17	17	0	0			
Materials and Resources									
MR Prerequisite 1	D	Storage and Collection of Recyclables	Rqd.	Rqd.			eEA / Phipps	Complete	✓
MR Credit 1.1	C	Building Reuse, Maintain 75% of Walls, Floor & Roof	1			1	N/A	Credit not attempted.	X
MR Credit 1.2	C	Building Reuse, Maintain 95% of the Existing Walls, Floor & Roof	1			1	N/A	Credit not attempted.	X
MR Credit 1.3	C	Building Reuse, Maintain 50% of Interior Non-Structural Elements	1			1	N/A	Credit not attempted.	X
MR Credit 2.1-2.2	C	Construction Waste Management, Divert 50% or 75% from Disposal	2	2			Turner	Implement & document waste management plan.	*
MR Credit 3.1-3.2	C	Materials Reuse, Specify 5% - 10%	2		2		Turner / TDA	Continue effort to maximize material reuse. Document value of reused items.	*
MR Credit4.1-4.2	C	Recycled Content, 10% or 20% (post-consumer + 1/2 pre-consumer)	2	1	1		Turner	Continue effort to maximize recycled material use. Document value of recycled materials.	*
MR Credit 5.1-5.2	C	Regional Materials, 10% or 20% Extracted, Processed & Manufactured Regionally	2	2			Turner	Continue effort to maximize regional material use. Document value of regional materials. (LBC requirements likely to help.)	*
MR Credit 6	C	Rapidly Renewable Materials	1			1	N/A	Credit not attempted.	X
MR Credit 7	C	Certified Wood	1	1			Turner	Continue effort to use 100% certified wood per LBC. Document value of certified wood and develop action plan. (100% FSC will result in an ID credit)	*
		Total Materials and Resources	13	6	3	4			
Indoor Environmental Quality (IEQ)									
EQ Prerequisite 1	D	Minimum IAQ Performance	Rqd.	Rqd.			CJL	Document in LOL.	+
EQ Prerequisite 2	D	Environmental Tobacco Smoke Control	Rqd.	Rqd.			eEA / Phipps	Complete	✓
EQ Credit 1	D	Outdoor Air Delivery Monitoring	1	1			CJL	Document in LOL.	+
EQ Credit 2	D	Increased Ventilation	1		1		CJL	CJL to determine if this is desirable / achievable?	!
EQ Credit 3.1	C	Construction IAQ Management Plan, During Construction	1	1			Turner	Implement & document IAQ plan.	*
EQ Credit 3.2	C	Construction IAQ Management Plan, Before Occupancy	1	1			Turner	Coordinate testing with LBC testing. Schedule and implement flushout only if Phipps requests..	*
EQ Credit 4.1	C	Low Emitting Materials, Adhesives and Sealants	1	1			Turner	Document use of VOC complying materials..	*
EQ Credit 4.2	C	Low Emitting Materials, Paints & Coatings	1	1			Turner	Document use of VOC complying materials..	*
EQ Credit 4.3	C	Low Emitting Materials, Carpet Systems	1	1			Turner	Document use of complying carpet systems.	*
EQ Credit 4.4	C	Low Emitting Materials, Composite Wood & Agrifiber Products	1	1			Turner	Document use of composite wood and agrifiber products containing no added no urea-formaldehyde.	*

Action Items in Bold Red

Credit	Phase	Description	AVAILABLE Points	LIKELY Points	MAYBE Points	UNLIKELY Points	Responsible Party	Credit Status	Credit Status (Credit Status Symbols Key Below)
EQ Credit 5	C	Indoor Chemical and Pollutant Source Control	1	1			TDA / CJL / Turner / eEA	CJL confirm complying ventilation for janitor's closets. Turner provice MERV 13 filter documentation. TDA to provide plans showing walk off mats at entries. eEA document in LOL.	*
EQ Credit 6.1	D	Controlability of Systems, Lighting	1	1			CJL	Docunent in LOL.	+
EQ Credit 6.2	D	Controlability of Systems, Thermal Comfort	1	1			CJL	Confirm controls in open office area. Document in LOL.	+
EQ Credit 7.1	D	Thermal Comfort, Design	1	1			CJL	Docunent in LOL.	+
EQ Credit 7.2	D	Thermal Comfort, Verification	1	1			eEA	Complete	✓
EQ Credit 8.1	D	Daylight and Views, Distribution Quality to 75%/90% of Spaces	1	1			TDA / eEA	Docunent in LOL.	+
EQ Credit 8.2	D	Daylight and Views, Views for Seated Spaces	1	1			TDA / eEA	Docunent in LOL.	+
		Total Indoor Environmental Quality	15	14	1	0			
Innovation in Design									
ID Credit 1.1	D	Innovaton in Design	1	1			CJL / EIS	EP onsite renewable energy. Defer until final energy model is completed. Document in LOL.	*
ID Credit 1.2	D	Innovaton in Design	1	1			CJL	EP reuse or infiltrate 100% of waste water. Document in LOL.	+
ID Credit 1.3	D	Innovaton in Design	1	1			CEC	EP manage all storm water on site. Document in LOL.	+
ID Credit 1.4	D	Innovaton in Design	1	1			eEA / Phipps	SITES pilot participation. Complete	✓
ID Credit 2	D	LEED Accredited Professional	1	1			eEA	Complete	✓
		Total Innovation in Design	5	5	0	0			
		Total Points	69	55	8	6			

LEED Certified	26 - 32 Points	LEED Status: 55 Likely + 8 Maybe = 63 Total Points in Play Point cushion sufficient to maintain Certification Goal of Platinum.
LEED Silver	33 - 38 Points	
LEED Gold	39 - 51 Points	
LEED Platinum	52 + Points	

Notes:

1. D indicates Design Phase LEED Online documentation required ASAP. Goal for LEED Design Phase Certification Submission is October 15, 2011.

2. Possible other ID Credits include : Non-toxic material use, non-chemical water treatment, carbon offset for construction, EP construction waste management / over 95%, EP certified wood / over 95% - continue tracking performance of these credits.

3. Staff FTE 77 weekdays /34 weekends; Transient Visitors 50 weekdays / 200 weekends; Average Transient Visitors 100/day; Parking Spaces 31

CREDIT STATUS KEY	
Documentation Complete	✓
Documentation Required	!
Upload LOL Documentation	+
Defer Until Later	*
Credit Not Attempted	X

This LEED credit evaluation represents the project team's best determination of the likelihood of attaining the evaluated credits. LEED Certification is a determination of the USGBC and can not be assured by evolveEA or the project team.

[A2] 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 Heat-ing	Cool-ing	Venti-lation	Water Heat-ing	Light-ing	Cook-ing	Refrig-eration	Office Equip-ment	Com-puters	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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