MECHANICAL TECHNICAL ASSIGNMENT 3

Mechanical System Existing Conditions Evaluation

The Regional Learning Alliance at Cranberry Woods

850 Cranberry Woods Drive. Cranberry Township, PA 16066

PREPARED FOR: Dr. William Bahnfleth, Ph.D, PE
The Department of Architectural Engineering
The Pennsylvania State University

PREPARED BY: Caitlin L. Hanzel
Mechanical Option

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EXECUTIVE SUMMARY

The Regional Learning Alliance Conference and Learning Center is a 76,000 ft^2, two-story, mixed use, educational facility located in Cranberry Township, PA. The building is used primarily as office and conference space during the day and transforms into an educational facility during the evening and weekends. The environmentally friendly building was designed to meet a LEED Silver rating, as well as ASHRAE Standard 90.1, which sets forth minimum regulations for the design of energy efficient buildings. A complete LEED analysis and breakdown of the version 2.2 checklist are included in APPENDIX B.

The purpose of this report is to analyze the existing conditions of the complete heating, ventilating and air conditioning systems that were installed in The Regional Learning Alliance Center. Each system is analyzed, including the main air handling system, which consists of fan-coil units used in conjunction with a dedicated outdoor air unit. The hot water system (which is supplied by two gas fired boilers), chilled water system (ran by one 75-ton, water-cooled chiller) and sequence of controls are also explained in detail. The building's control logic sequence is provided by stand-alone application specific controllers (ASC) through a direct digital control (DDC) hardware.

After careful consideration, the mechanical design team chose to install the fan-coil unit system because of its overall efficiency and "green" characteristics. Since individual units would be located in each zone, it would be possible of having some of the zones heating while others were cooling. This idea was extremely important in the design of such a versatile space. In addition, the amount of duct work would be reduced since the room air would simple be recirculated back into the local fan-coil unit. While the initial installation cost of $2,026,932 ($24.40/ ft^2) was higher than other options explored, the owner hoped that the building's sustainable features would help lower the operating costs and payback period. According to the facility's general manager, a total of $162,304 is allotted to the building's annual utility expenses.

The Trane TRACE model that was produced for Technical Assignment 2 provided recommendations for adequate heating and cooling loads for the space. The result of the comparison to the actual design showed that both air handling units exceeded these computer generated recommendations. In addition, Section Six of ASHRAE Standard 62.1 was referenced in order to figure out the minimum amount of outdoor air required for each space. The calculations reflected the ASHRAE requirement of 20,221 CFM of outdoor air. The main air handling unit (AHU-1) unit can provide up to 22,500 CFM, demonstrating compliance with the standard.

While theoretical advantages of the fan-coil unit system include good zone control, enhanced acoustical performance and easy maintenance, this has not proven to be the case at The Regional Learning Alliance. The relatively complex hydronic system has caused in-house maintainability to be a huge issue. Over a one year period, extending from June 2006 to July 2007, over $24,000 has been spent on repair costs for the current HVAC system. With a majority of the rooms being office, conference or learning spaces, the acoustical performances of the fan-coil units have also proven to be distracting and overall unacceptable. Losing less than 2% of the buildings rentable space to mechanical features, the layout of the HVAC system is extremely efficient.

DESIGN OBJECTIVES & REQUIREMENTS

As mentioned previously, the 76,000 ft2 building that serves as a professional conference facility by day and an educational alliance by night. Currently, there are 18 classrooms (each around 750 ft^2), two smaller seminar rooms, two computer labs, a technical classroom, a 1600 ft^2 meeting room, a conference/banquet room (which can be split into two separate 1600 ft^2 spaces) and an 800 ft^2 board room. Other amenities, which are available to both populations of users, include two, 2500 ft^2 office suites, a 2600 ft^2 wellness center and an 1800 ft^2 daycare center.

Due to the intense conference and educational use of the facility, the following factors had a significant impact on the mechanical design:

1.) Occupancy (and therefore *outside air ventilation requirements),* tended to be a major factor in the cooling and heating load calculations.

2.) Each space can be used at any given time, at any given intensity. Therefore, the dramatically *fluctuating loads* that occur during the facility's long operating hours needed to be accounted for when modeling schedules for the energy model.

3.) *Acoustical performance* of both the central HVAC equipment and terminal units.

4.) As a building composed of primarily educational, conference and office space, *indoor air* quality was also one of the most important design concerns. Air distribution, outside air quantities and humidity levels were taken into consideration.

5.) The owner, architects and design team were striving to create a LEED certified building. Therefore, *energy efficiency and environmental impacts* were analyzed thoroughly.

6.) Maintainability, reliability and ease of operation.

Due to these features, the design team knew that the HVAC system would need to respond to the changing load conditions that would occur in both the cooling and heating seasons. In addition, the system would have to be capable of simultaneously conditioning spaces whose requirements may drastically vary due to occupancy and internal loads. With these objectives in mind, Tower Engineering initially proposed the four following HVAC systems:

1.) Package direct expansion (DX) gas-fired rooftop units
2.) Central system variable air volume (VAV) air handling units
3.) Distributed fan coils with make-up air from a DOAS
4.) Water-source heat pumps

The installation cost of the systems ranged in value, with option one being the least expensive, and option four being the most. Also, fan coil unit and water-source heat pump systems tend to have a longer service life and provide a more "green" design than rooftop units and VAV systems. As the design phase continued, the owner's desire to create one of Western Pennsylvania's first LEED certified conference building became an imperative issue, therefore, creating a greater impact on the selection of the HVAC system.

Due to its cost, overall efficiency and "green" characteristics, the owner and design teams opted for option three; a distributed 4-pipe fan coil unit system with a variable air volume dedicated outdoor air unit. In a building devoted to office, learning and conference space, the thermal comfort of the tenants was extremely important. By choosing the fan coil unit system, Tower hoped the occupants would also have the advantage of better control by having the actual terminal units located in each thermal zone.

TABLE 1: ADVANTAGES & DISADVANTAGES OF FCU SYSTEMS

ADVANTAGES	DISADVANTAGES
Good zone control	High cost
Capable of immediate switching from cooling to heating modes	Relatively complex hydronic system components
Capable of having some zones heating while others cool	Fan coil units typically need to be in the space served
Simple pieces of equipment that are easy to maintain	
Almost all equipment can be indoors (besides heat rejection devices)	
Capable of sufficiently dealing with humidity issues	
Least likely to cause acoustical problems	
Integral Waterside "free-cooling" can lower energy consumption	
High energy efficiences available in both chiller and boiler	

The Table above summarizes the system's theoretical advantages and disadvantages that were taken into consideration during the schematic design phase. A further investigation of these theories, with specific relevance to The Regional Learning Alliance Center, will be discussed in the Mechanical System Critique, which begins on Page 20.

SITE CONDTIONS AND COSTS

The Regional Learning Alliance Conference and Learning Center is located in Cranberry Woods of Cranberry Township, Pennsylvania. As seen in the image to the right, the placement and configuration of the building (shown in blue) was intended to limit the impact of new development on the wooded site and natural wetlands (shown in green) surrounding the area. The resulting shape leaves two wings of the L-shaped building embracing these wetlands. Both of the wings are exposed to maximum day-lighting and natural views through the use of large curtain walls throughout the building. Where used, this architectural feature greatly impacted the cooling and heating loads.

Therefore, the system had to be designed to handle the diversity in loads that occurred from these large, glass exposures.

MECHANICAL DESIGN CONDITIONS

Cranberry Township is located about ten miles north of Pittsburgh, Pennsylvania. Being the closest city represented in both Carrier's HAP and Trane's TRACE programs, Pittsburgh weather data was used in the building's model and design. Table 2 provides this relevant design data, including summer and winter outdoor design conditions.

TABLE 2: OUTDOOR DESIGN CONDITIONS

location:	PITTSBURGH, PA
Latitude	40 Degrees
Longitude	80 Degrees
Elevation	1137 ft
Summer Design DB	86 F
Summer Coincident WB	71 F
Winter Design DB	5 F
Barometric Pressure	28.7 in Hg
CO2 Level	400 ppm

Designers at Tower Engineering used the same supply conditions (see Table 3) for all interior spaces. The temperatures, corresponding drift points and relative humidity were agreed upon and used during the initial energy modeling, as well as the energy model completed during Technical Assignment 2, *Building Plant and Energy Analysis Report.*

TABLE 3: INDOOR DESIGN CONDITIONS

Cooling Supply DB	75 F
Cooling Setback	85 F
Heating Supply DB	70 F
Heating Setback	60 F
Relative Humidity	60%

Along with the temperature conditions, internal loads for each individual zone needed to be inputted into TRACE before an energy analysis could be performed. As shown in Appendix C of Technical Assignment 2, a detailed load analysis was completed for each zone. These loads included all equipment, lighting, and occupants that would typically be present in the space. After inputting the data, an estimated heating and cooling load was calculated for the entire building. Table 4 compares this estimated load with the design loads that were assembled from the equipment schedule information. Ventilation and supply airflow rates were also evaluated.

TABLE 4: HEATING AND COOLING LOAD COMPARISONS

	COMPUTED	DESIGNED
AHU-1		
Cooling Load (ft2 / ton)	587	707
Heating Coil Load (kBTU)	1,647,220	1,386,000
Supply Air (CFM/ft2)	0.717	0.80
Ventilation Air (CFM/ft2)	0.0526	0.06
AHU-2		
Cooling Loads (ft2 / ton)	315	456
Heating Coil Load (kBTU)	222,500	224,000
Supply Air (CFM/ft2)	1.97	1.25
Ventilation Air (CFM/ft2)	0.258	0.31

The designed cooling loads for AHU-1 and AHU-2 exceeded Trane TRACE recommendations by 20% and 38%, respectively. The discrepancies in values are most likely due to TRACE input errors that occurred while trying to accurately model the atrium, clear story windows and curtain wall constructions. Moreover, the TRACE model that was used to compute Technical Assignment 2 values used default archived schedules. During the actual design phase, Tower Engineering created customized occupancy, lighting and equipment schedules that more accurately depicted the use of the facility. This, on top of the modeling errors, could have accounted for the differences between the computed and designed loads.

A further design criteria that was explored during Technical Report 1, was The Regional Learning Alliance's compliance with the ventilation requirements present in ASHRAE Standard 62.1-2007. The amount of outdoor air required per zone was calculated via Section Six of the standard. This value that needed to be provided depended highly on the following four factors:

1.) The number of occupants in the space

2.) The total area (in square feet) of the space

3.) The occupancy category (in terms of the people outdoor air rate, Rp)

4.) The occupancy category (in terms of the area outdoor air rate, Rz)

Table 5, which can be found on the next page, displays Standard 62 compliance for the building's primary fan coil unit system, which is served by AHU-1. ASHRAE standards required 20,221 CFM of outdoor air, while the actual design can provide up to 22,500 CFM.

TABLE 5: ASHRAE STANDARD 62.1 VENTILATION COMPARISONS

Computed OA from AHU-1	20,221 CFM
Designed OA from AHU-1	22,500 CFM

NOTE: *Technical Assignment 1 has the computed OA listed as 13,771 CFM, however the 6,450 CFM of exhaust make up air that needs to be provided was not included in this value. Therefore, the newly computed outdoor air value of 20,221 CFM is correct.*

The excess outdoor air that is cushioned in the design is most likely due to Tower Engineering's more stringent design criteria. Classroom and Discussion spaces were allotted 15 CFM/person as opposed to the 7.5 CFM/person used for the ASHRAE Standard 62.1 calculations. Office space regulations were also increased. With a majority of the building being composed of office, classroom and conference space, these differences may have attributed to the varying computed and designed outdoor air values.

MECHANICAL SYSTEM SUMMARY & CONTROL LOGIC

Tower Engineering designed a unique and complete heating, ventilation and air conditioning system for The Regional Learning Alliance. This section will describe each system in detail, with all equipment tables and their corresponding operating characteristics being found in APPENDIX A on Page 21. The building's automatic temperature control (ATC) system is manufactured by Kivic and consists of stand-alone application specific direct digital controllers. More information on specific sensor types will be found in the following sections.

AIR HANDLING SYSTEMS

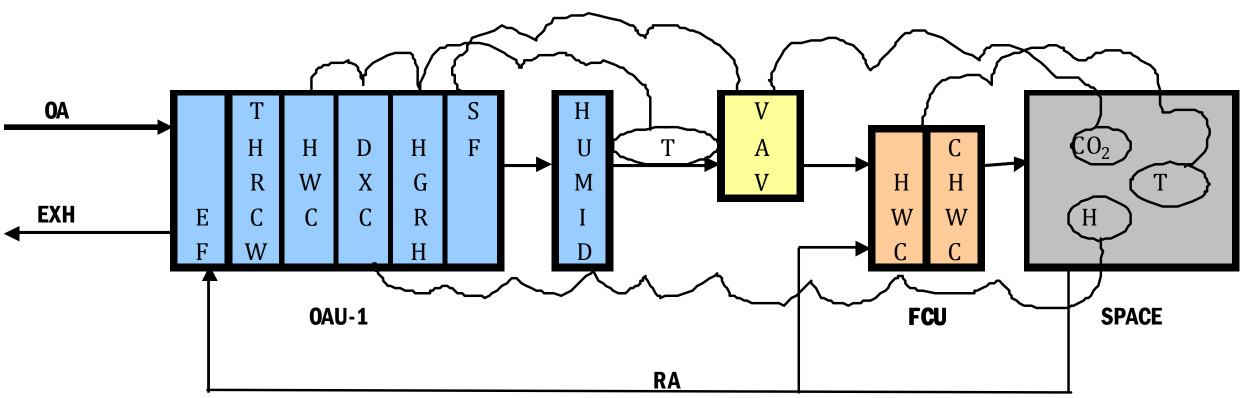
The Regional Learning Alliance ventilating system consists of two AAON air handling units, AHU-1 (which is located on the building's rooftop) and supplies outdoor air to the fan-coil units and AHU-2, which is strictly dedicated to the ventilation of the main lobby and atrium.

AHU-1 is a single variable-volume, demand-controlled air handling unit that provides complete air conditioning including heating, cooling, humidifying, dehumidifying and filtering of 100% outdoor air for the building's fan coil units and make-up air system. The ventilation air is supplied through terminal boxes to the fan coil units. The unit is controlled by a direct digital controller with electronic actuators and runs on an occupied/unoccupied schedule by the building's ATC.

CO_2 sensors in each space control the amount of outside air that is provided through the terminal box and into the fan-coil unit, according to demand. Where a fan-coil unit serves a single zone, the sensor is simply placed in that space, while units that serve a group of similar spaces still have one sensor, placed in the most logical area. A carbon dioxide sensor is also installed outside to measure the ambient carbon dioxide levels. When any space's sensor measures a CO_2 level more than 530 parts per million (ppm) above the outdoor CO_2 sensor, the variable air volume terminal box unit's damper opens to maximum position until the CO_2 levels drop below setpoint. Once the level has decreased below an acceptable concentration, the outside air damper returns to its previous position. The carbon dioxide sensor and transmitters used are infrared sensors, calibrated for 0-2000 ppm, with an accuracy of +/- 20 ppm plus 1.5% of reading and a +/- 1% repeatability.

As seen below, the variable air volume unit consists of an outdoor air damper, filter, total heat recovery wheel, hot pipe heat exchanger, flat plate heat exchanger, evaporatively-cooled DX cooling, reheat coil, humidifier, exhaust misting sprayer and supply and return fans with variable speed drives (VSD). Carbon Dioxide, temperature and humidity sensor control relationships are also shown and will be discussed later in the report.

FIGURE 1: AHU-1 SCHEMATIC



NOTE: *EF: exhaust fan, THRCW: total heat recovery wheel, HWC: hot water coil, DXC: DX Cooling, HGRH: hot gas reheat, SF: supply fan, HUMID: humidifier, CHWC: chilled water coil*

At start-up, the VSD operates at 10% (minimum position). When any terminal box damper is open to 100% and the associated CO_2 sensor value is greater than set point (indicating there is not enough outdoor air available to satisfy the space), the speed of the VSD is incrementally increased by 5%. The fans decrease in the same way when no dampers are fully open. Each drive converts 460V, 3-phase, 60 Hertz utility power to its adjustable voltage/frequency and is automatically controlled by a grounded electronic 4-20mA control signal.

A flat plate, sensible heat only heat recovery device is used to exchange heat between relief and outside air streams. There is no cross-contamination of the two airstreams. A spray system for the relief side of the device is also included to provide indirect evaporative cooling of the incoming airstream. A second sensible heat recovery device is used between the low temperature airstream (air leaving the chilled water coil and being supplied to the fan-coil units) and the high preconditioned, outside, high-temperature airstream. Again, no contact between the two streams ever occurs.

When outside conditions warrant, the unit starts in warm-up mode (heating mode only). When indexed to occupied mode, the supply fan shall run continuously, with the outside air damper being 100% open. When indexed to the unoccupied mode, the air handling unit stops, hot water coil valves open and the outdoor air damper closes. As seen in the chilled water schematic on Page 11, the chilled water coil valve is also locked out during this unoccupied mode. When any temperature in rooms with fan coils drops below night setback setpoint, the make-up air fan cycles on in heating mode only to maintain this setpoint. When running in the occupied mode, the unit falls under one of the three main operations summarized below:

OAT	SAT
45	70.0
50	68.3
55	66.7
60	65.0
65	63.3
70	61.7
75	60.0
80	58.3
85	56.7
90	55.0

1.) SUMMER OPERATION

a. Discharge air temperature after chilled water coil modulates 2-way chilled water valve to maintain 52 F (adjustable).
b. Discharge air temperature sensor modulates heat pipe reheat to maintain setpoint of 65 F (adjustable).
c. If the relative humidity in any space exceeds 60%, then the outdoor air is subcooled and reheated with hot gas to maintain setpoint
d. The outdoor air is preconditioned through the heat wheel and then cooled to the supply air temperature according to the schedule seen to the right.

2.) WINTER OPERATION

a. Discharge air temperature sensor modulates heating coil 2-way valve to maintain 65 F setpoint (adjustable). When the chiller is off, the set point is reset to 55 F.
b. Discharge air humidity sensor overrides humidifier valve to closed if humidity rises above setpoint of 80%.
c. Face and bypass dampers are positioned to divert flow around chilled water coil and heat pipes.
d. If the relative humidity in any space drops below 30%, then the humidifier injects steam to maintain setpoint.

3.) ECONOMIZER OPERATION

a. When the outside air temperature drops below 65 F, the heat wheel stops and outdoor air provides cooling for the zones. In return, the chiller is not designed to operate until the cooling load can not be met with this outside air.

FAN-COIL UNITS serve as the mixing place for the ventilation air supplied by AHU-1 and the return air that has been recirculated within each zone. Each four-pipe unit consists of two supply pipes and two return pipes, which allows either hot or cold water to enter the unit at any given time. Four-row coils are constructed of ½" copper tubes with aluminum fins, and are designed for a minimum 20 degree rise in chilled water temperature.

Each fan coil unit is controlled by an ATC DDC controller (that also controls the corresponding terminal box). Three-way diverting valves are provided at the coil inlet and outlet to channel the proper temperature water to satisfy the room temperature setpoint. During the occupied mode, the following operations occur:

1.) When space temperature drops below heating setpoint, the DDC control diverts the hot water supply to flow through the coils (modulating two-way control valve maintains heating setpoint). Valves are normally open to heat.

2.) If space temperature rises above cooling setpoint, DDC controls divert the chilled water supply to flow through the coils (a reverse-acting two-way control valve maintains cooling setpoint). When the chiller is in the unoccupied mode, the terminal box damper is opened for cooling when the fan coil's temperature sensor rises above setpoint.

During the unoccupied mode, each unit cycles on to maintain the reduced room temperature setpoint of 60 F.

TERMINAL BOXES are used in conjunction with each fan-coil unit to modulate the amount of outdoor air that is provided to each space. In the occupied mode, the box opens to minimum position, unless the CO_2 sensor measures level above the setpoint or the space humidity rises above a setpoint of 60%. In both cases, the damper will modulate to fully open. This also occurs when the chiller is off and the FCU temperature sensor rises above setpoint. In the unoccupied mode, each terminal box's damper will be fully closed. If the room temperature drops below the night setback setpoint, AHU-1's fan will cycle on to maintain this temperature.

AHU-2 is a single zone, constant volume AAON air handling unit located in the first floor Maintenance Garage. Equipped with both hot and chilled water coils, AHU-2 is dedicated to ventilating the building's immense lobby/atrium space with up to 10,000 CFM of supply air. The unit utilizes similar heat recovery devices as AHU-1, with the outdoor air intake being supplied from a 96" X 30" Greenheck louver located on the northeast side of the building. Control information for this unit is still being collected.

HOT WATER SYSTEM

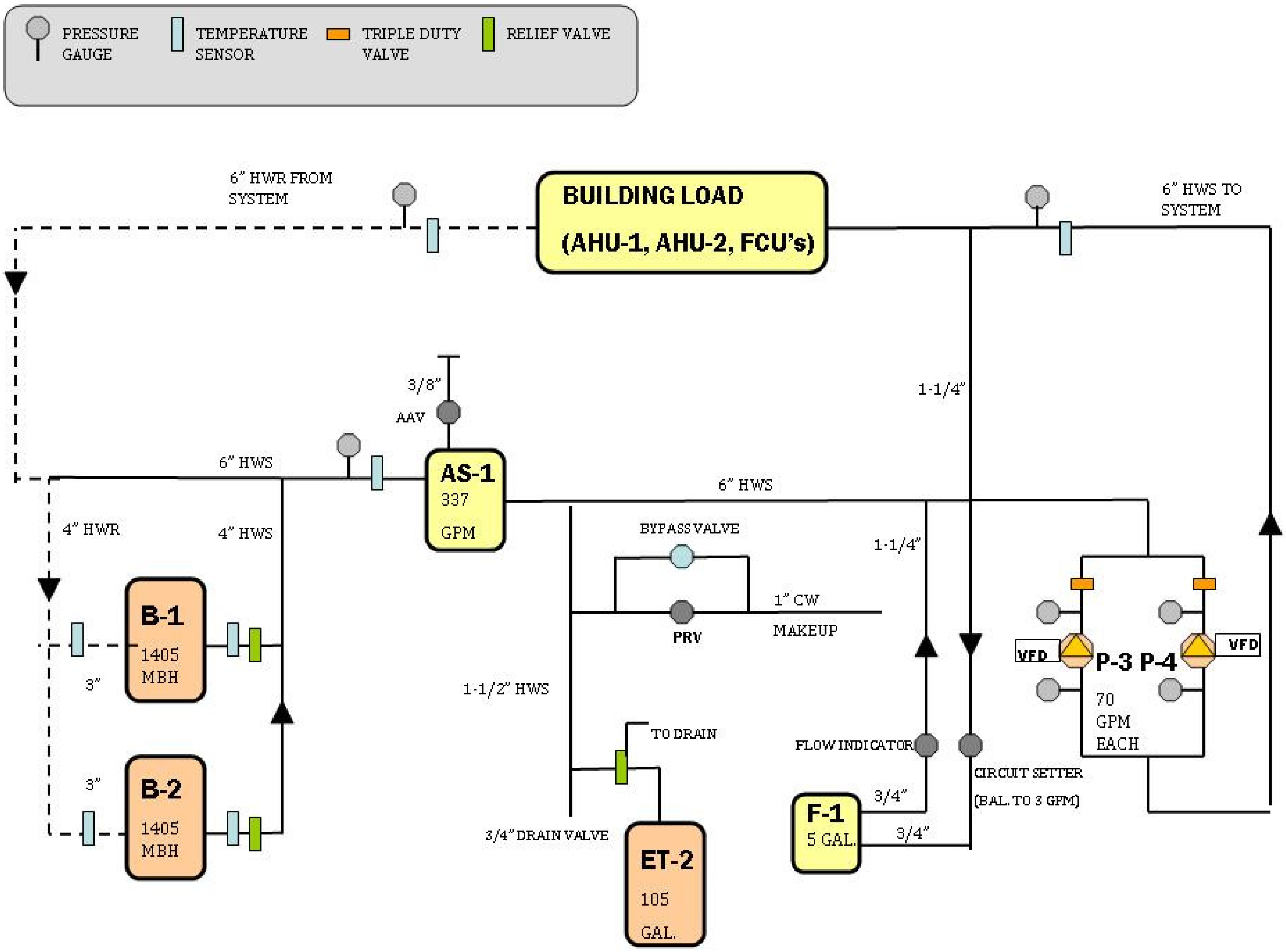
The Regional Learning Alliance hot water distribution system consists of two gas-fired boilers, which supply hot water to the entire building via two primary pumps and two secondary pumps. Each of the two high-efficiency, Lochinvar boilers are designed for a net output of 1402.5 MBH and are configured with a 150 PSI pressure relief valve and temperature sensor, as seen in Figure 2 on the following page.

The heating system is activated through the DDC panel when AHU-1 is indexed in the occupied mode. During this occupied cycle, the heating system is activated when the outside air temperature is below 55 F and the temperature differential between the hot water supply and hot water return is greater than 30 F. During the unoccupied cycle, the system is activated when the outdoor air temperature is less than 45 F. During this time, if the outdoor air temperature is above 55 F, the heating system is de-energized.

When system is activated, the DDC system starts the Bell & Gossett, base-mounted primary pump, P-3. If for any reason start up fails, the secondary pump, P-4, is activated. Both pumps are controlled by a variable speed drive that operates at 10% at start-up. The DDC system monitors the hot water piping system differential pressure (shown by pressure gauges in Figure 2). When the differential pressure falls below the setpoint, the pump speed is increased, and vice versa. The speed of the VSD is also increased by 5% anytime a room temperature sensor value is less than setpoint (when there is not enough heating available to satisfy the space).

The hot water provided by B-1 and B-2 serves only the HVAC loads, which include the air handler and fan coil unit's heating coils, as well as unit heaters. The domestic hot water system is served by four separate Bradford-White water heaters.

FIGURE 2: HOT WATER SYSTEM SCHEMATIC



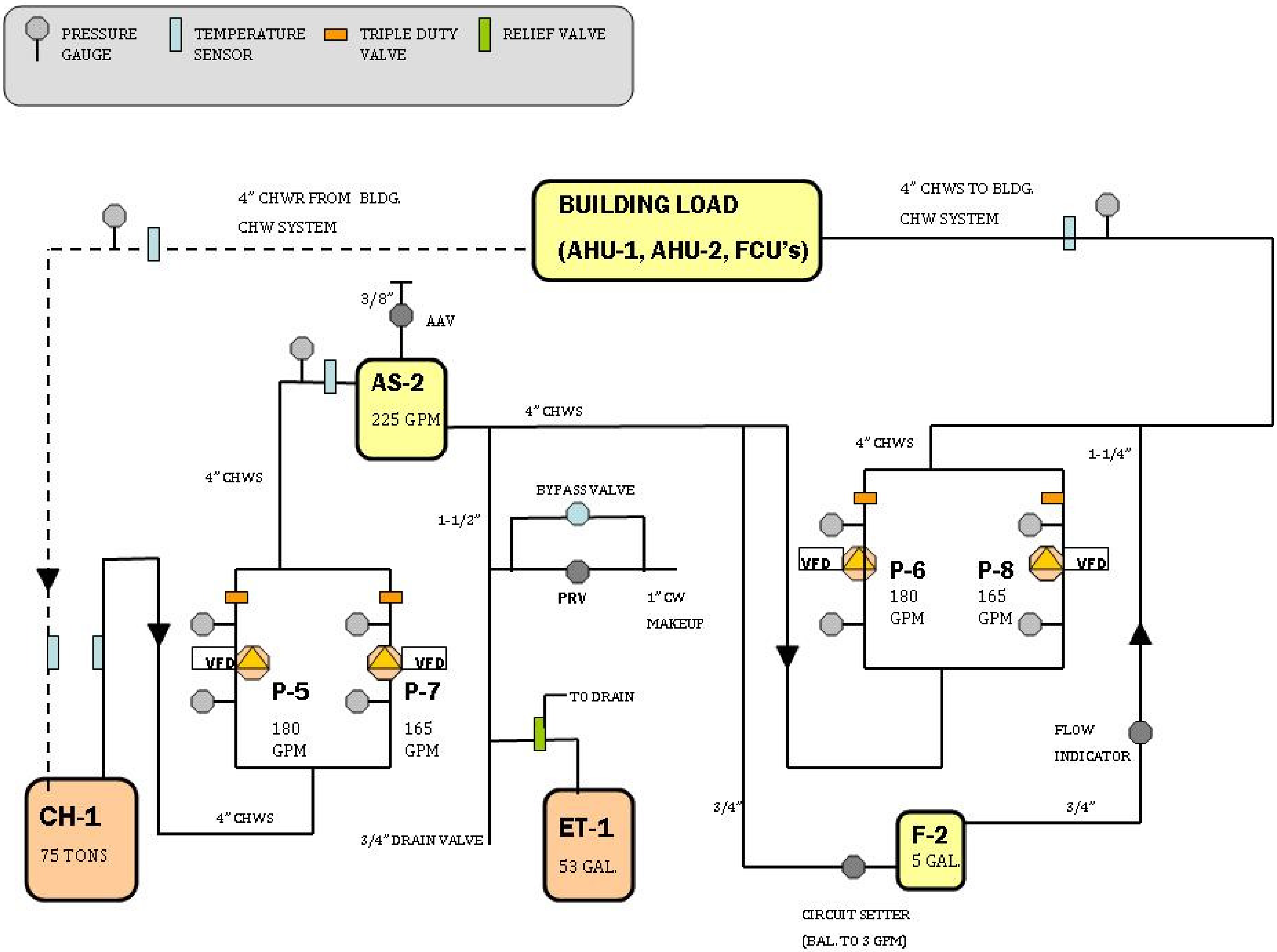
NOTE: *The 6" hot water line to the system is used to feed the heating coils in the fan-coil units, AHU-1 and AHU-2*

CHILLED WATER SYSTEM

The chilled water system is composed of one 75-ton, water-cooled chiller (with self-contained evaporative condenser and scroll compressor). The chiller runs off of environmentally friendly R-410A refrigerant, which added to the green design the owner was striving for. The primary AAON, inline pump (P-5) and secondary pump, (P-6), are used to circulate chilled water to the building's HVAC components. These components include the chilled water coils present in AHU-1, AHU-2 and each of the fifty fan-coil units. The building's chilled water system is driven by the primary pump P-7, and if needed, secondary pump, P-8.

Similar to the hot water system, each mechanical system pump is controlled by a variable speed drive (VSD), which starts up at 10% (minimum position) when the system is activated. When any temperature sensor value is greater than the setpoint (indicating not enough cooling to satisfy the space), the speed of the VSD incrementally increases by 5%. When all set points are satisfied, the speed is then decreased by 5%. Again, the DDC system monitors the chilled water piping system differential by measuring the pressure before and after the pumps. These gauges can be seen on the Chilled Water Piping Schematic below.

FIGURE 3: CHILLED WATER SYSTEM SCHEMATIC



NOTE: *The 4" chilled water line to the building system is also used to feed to cooling coils in both AHU-1 & AHU-2*

Flow switches energize the chiller to operate under its own factory controls. During the occupied cycle, the direct digital controller starts the chilled water system when the outside air temperature is above 50 F and the temperature differential between the chilled water return and the chilled water supply is greater than 20 F. The system is then de-energized during the unoccupied mode, when the outside air temperature drops below 47 F and the chiller has run for thirty minutes.

SENSOR INFORMATION

Throughout the system numerous sensors are used to send signals to the controllers and controlled device, which in return, modulate the control variable. The following information briefly explains the temperature sensors, humidity sensors and dew point sensors used in the Regional Learning Alliance mechanical system.

1.) Temperature Sensors (either of the RTD or thermistor type)
   a. Accuracy: +/- 0.5 F
   b. Operating Range: 35-115 F
   c. Set-back cooling
   d. Set back modes include independent heating, cooling, night setback heating and night setback cooling
   e. Room sensors are single point, while duct sensors are the averaging type, nickel element, evenly strung across the face area of the duct.
   f.
2.) Humidity Sensors (bulk polymer sensor element)
   a. Multiple signal and power output including 4-20ma, 0-10 vDC; loop and 24 V power.
   b. Relative Humidity sensors have +/- 2% accuracy from 5-95% RH.

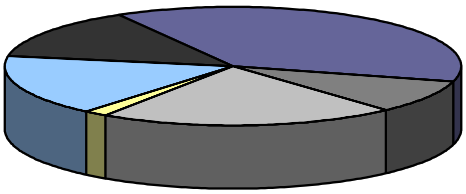
3.) Dew point Sensors
   a. Accuracy: +/- 1.8 F at 50% relative humidity.
   b. Signal output space: -40 F to 185 F

ANNUAL ENERGY CONSUMPTION ANALYSIS

After the mechanical system design was complete, Tower Engineering was able to use Carrier's Hourly Analysis Program (HAP) to computer-generate a building model which would project the annual energy consumption and operating costs of the project. Trane's TRACE 700 was used during Technical Assignment 2 to construct a similar model. The same ventilation rates, internal loads and envelope characteristics were modeled as accurately as possible. Fuel costs and equipment performance also needed to be entered into Trace and were referenced from Tower Engineering design documents and HAP output files. After a thorough analysis was complete, Trace estimated the building's annual energy consumption at 1,473,680 kWh. Figure 4 on the next page breaks down this energy consumption by building component.

FIGURE 4: ANNUAL ENERGY CONSUMPTION BREAKDOWN

Component	Percentage of Total Building Energy
heating	36.7
cooling	9.3
fans	21.4
pumps	1.5
lighting	17.1
receptacles	14.1



According to the TRACE model produced for Technical Assignment 2, the majority of the building's energy was spent on the heating and lighting, along with the powering of the system's fans. Table 6 lists the local energy sources and rates that were used during modeling. It should be noted that Tower's original energy analysis used flat electric and gas rates when calculating annual costs. Therefore, in order to get an equivalent estimated cost from the TRACE (refer to Table 7) the same rates were used.

TABLE 6: ENERGY SOURCES AND RATES

UTILITY/SERVICE	SUPPLIER	RATE USED FOR MODELING
Electric	Penn Power	$0.069/kWh
Natural Gas	Sprague Energy	$2.946/therm
Water	West View Water	(PER 1000 GALLONS) $3.36 for the first 45,000, $2.95 for the next 855,000, $2.40 for all over 900,000 gal.
Garbage and Recycling	Vogel Disposal	N/A

TABLE 7: ANNUAL OPERATING COSTS BY COMPONENT

Component	Percentage of Total Building Energy	Rough Estimated Cost/Year ($)
heating	36.7	43,656
cooling	9.3	11,065
fans	21.4	25,456
pumps	1.5	1,784
lighting	17.1	20,341
receptacles	14.1	16,773

As mentioned, HVAC designers at Tower Engineering also performed an energy analysis using Carrier's Hourly Analysis Program. Table 8 compares Tech Two's TRACE results with the results of this initial analysis.

TABLE 8: TRACE vs. HAP MODEL COMPARISON

Information Being Compared	HAP Value	TRACE Value	Percent Difference
Total Building Energy (kBTU/yr)	4,812,695	5,029,124	4.3
Total Source Energy (kBTU/yr)	12,197,073	11,447,279	6.1
Heating Coil Loads (kBTU)	2,029,091	1,869,723	8.5
PECENTAGE OF BUILDING ENERGY (%)			
Cooling	14.10	9.30	50
Heating	40.50	36.70	10
Pumps	3.25	1.50	20
Air System Fans	14.80	21.40	40
Lights	19.22	17.10	10
Electric Equipment	8.10	14.10	70
OPERATING COSTS ($/yr)			
Electric	58,073	63,873	10.0
Natural Gas	57,614	55,082	4.6
Totals	115,687	118,955	2.8

The majority of the TRACE values taken from Technical Assignment 2 came relatively close (within 10%) to those estimated by Tower Engineering. Noticeable differences arise in the percentage of building energy allotted to cooling, fan powering and electric equipment. Discrepancies between the cooling and electric equipment values most likely occurred due to modeling errors or inconsistencies. The two-story atrium curtain wall and clear story windows proved to be difficult elements to accurately represent. Also, miscellaneous equipment was inputted into TRACE on a W/ft^2 basis, which could have caused for the overcompensation in load since discrete values were inputted during HAP modeling.

BUILDING OVERVIEW

MECHANICAL SYSTEM INITIAL COST

Tower's thorough energy analysis not only projected the annual energy consumption and costs for the proposed system, but included a comparison of this energy efficient system to a more general, base building. The numbers spoke for themselves and the fan-coil unit system was installed at The Regional Learning Alliance Center. Other components installed included AHU-2, along with various electric unit heaters and cabinet unit heaters that were used to heat vestibules, stairwells and spaces with similar conditions. The initial mechanical construction costs were provided by Justin Griffith, the General Manager and owner representative at The Regional Learning Alliance Center. It should be noted that the figure provided in Table 9 for "plumbing and ductwork" includes piping and materials that were used for general plumbing installations as well. It was estimated that roughly half this value was used to pipe the mechanical systems.

TABLE 9: MECHANICAL SYSTEM INITIAL COST

Component	Initial Cost ($)
HVAC total (without plumbing & ductwork)	1,684,320
Plumbing and ductwork	342,612
GRAND TOTAL:	**$2,026,932**

With a total floor area of 76,000 ft^2, the initial cost of the Regional Learning Alliance's mechanical system, per square foot, is **$24.40.**

OPERATING HISTORY

After a valiant attempt, meter data and/or utility bills were unable to be obtained for the existing building. However, the general manager of the facility was able to provide overall water, gas and electric costs for June 30, 2006 to July 1, 2007. As shown in Table 10, electricity was the largest annual expense for the facility at $126,681, which is almost two times more than what was predicted in Technical Assignment 2. The TRACE cost estimate made for natural gas consumption at $55,082, was much closer to the actual annual spending of $30,766.

TABLE 10: ANNUAL OPERATING COSTS

Component	Annual Cost ($)
Water	4,857
Gas	30,766
Electric	126,681
GRAND TOTAL:	**$162,304**

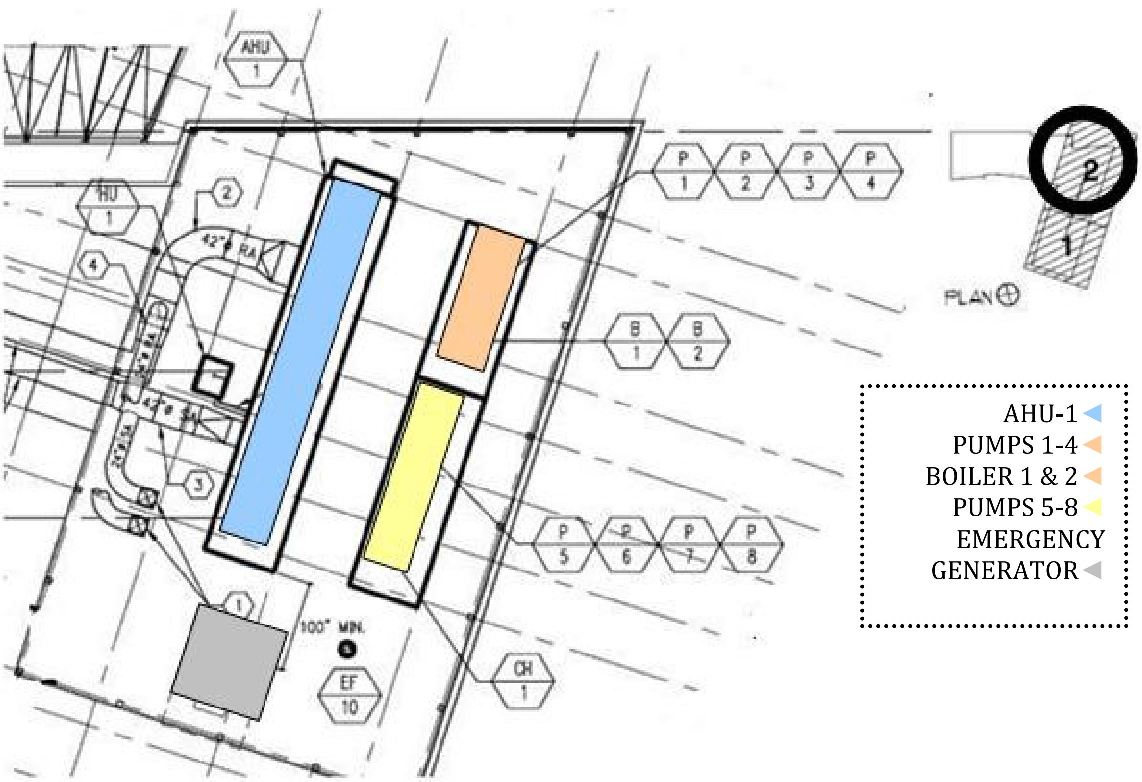
Griffith also provided information regarding annual HVAC expenses. These included a yearly controls contract at $3680 a year, chemicals ($4800), and preventative maintenance and repairs ($33,118). This added an additional $41,598 to the annual operating costs of the system. Since it is impossible to know how much of the electric was allotted to mechanical system components, an overall operating cost of the system is unable to be obtained.

BREAKDOWN OF LOST RENTABLE SPACE

While the initial installation cost of the fan coil unit system was higher than other suggested options, it proved beneficial in other areas. Since smaller fan coil units (which are either floor mounted or ceiling suspended) serve each zone, the large footprint that is often associated with corresponding air handling units is minimized. Therefore, the system essentially reduced the size/need of the mechanical room.

When calculating the lost rentable space, mechanical rooms, shafts and any other areas strictly designated to serve the HVAC system were taken into consideration. Although the initial design called for the 3525 ft^2, sub-grade mechanical room, the majority of the mechanical equipment (including the dedicated outdoor air unit, boilers, chiller and pumps) ended up in an enclosed area on the facility's rooftop, in the northeast corner (see Figure 5). The constant volume air handling unit serving the main lobby and atrium (AHU-2), resides inside the 278 ft^2, first floor Maintenance Garage (refer to Figure 6 on Page 17).

FIGURE 5: ROOFTOP MECHANICAL EQUIPMENT LAYOUT



In addition to the space lost in the Maintenance Garage, various mechanical shafts throughout the building (most prominently the 72 ft^2 shaft highlighted in Figure 7, on Page 17) needed to be accounted for.

Although the design documents were ambiguous when specifying the mounting locations of the FCU's, the schedules designated each unit as Trane's horizontal blower coil type. According to the manufacturer's design literature, horizontal units can be floor mounted but are typically ceiling suspended. Therefore, they were not included in the lost rentable space calculations.

FIGURE 6: FIRST FLOOR MECHANICAL EQUIPMENT SPACE

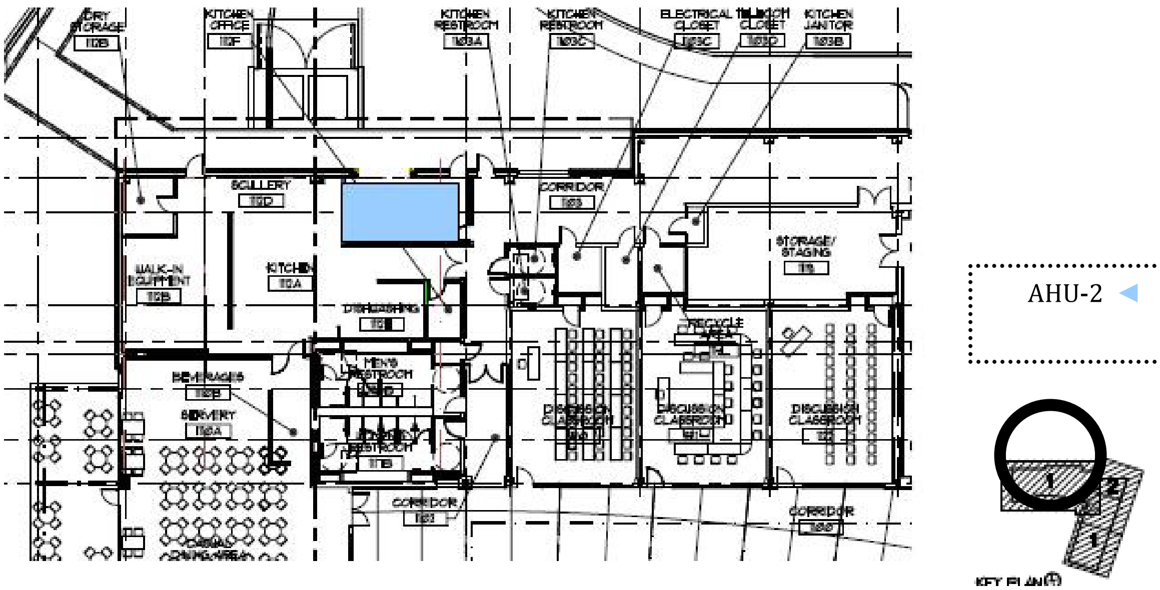
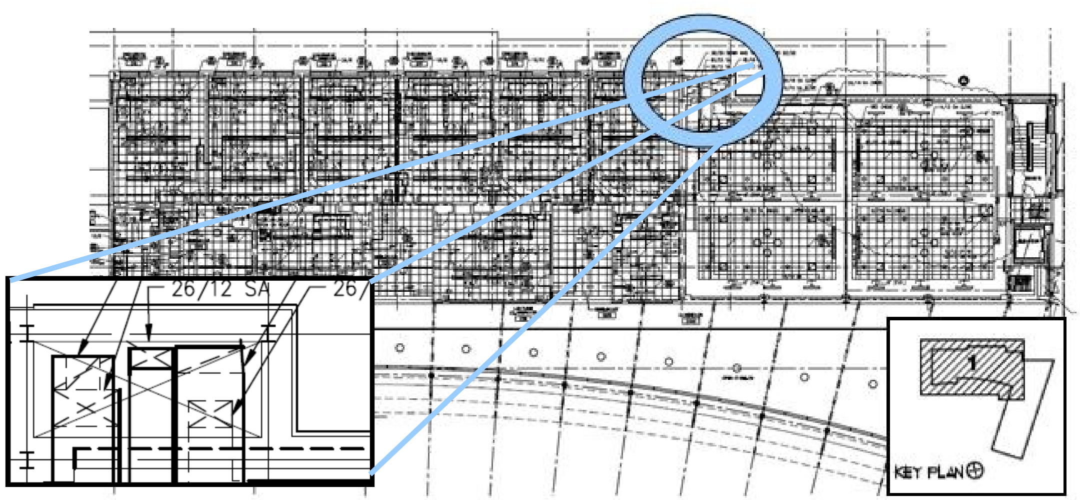
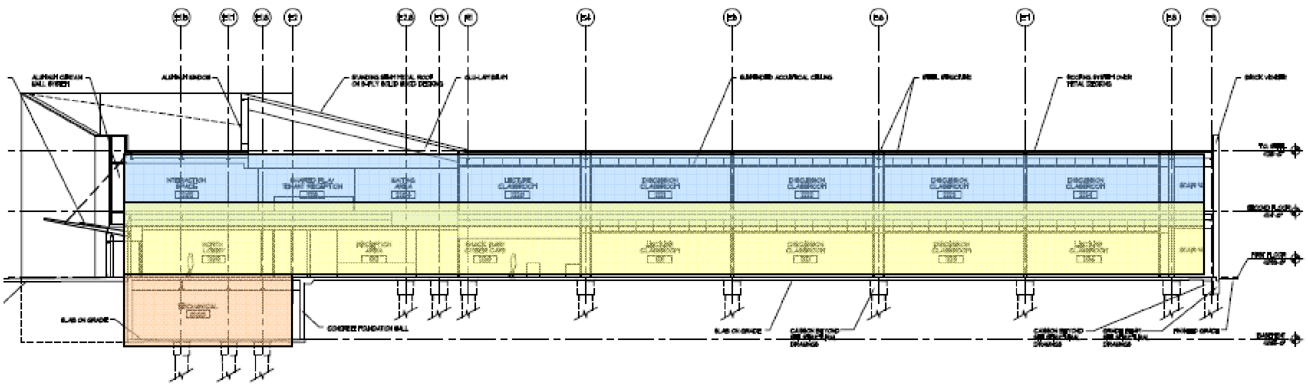


FIGURE 7: BUILDING'S MAIN MECHANICAL SHAFT



After examining each floor's layout, it was found that **less than 2%** of the building's rentable space was lost due to accommodations that were made for the mechanical system. A detailed, floor-by-floor breakdown of these values can be found in Table 11.

TABLE 11: LOST RENTABLE SPACE BY FLOOR



FLOOR	TOTAL FLOOR AREA (sf)	MECHANICAL ROOM AREA (sf)	SHAFT AREA (sf)	TOTAL LOST AREA (sf)	PERCENT LOST
Basement	4577	3525	n/a	3525	77%
First	40431	278	91.69	297.7	1%
Second	30485	0	78.7	78.7	< 1%

Although less than 2% of the building's occupied spaces were lost to the mechanical system, the initial design *and* construction of the building included the 4577 ft^2 basement. 3525 of this 4577 ft^2 (over 77%) was supposed to accommodate the mechanical equipment that ended up on the building's rooftop. These changes were made later in design, and were apparently attributed to "value engineering". Currently, the basement/mechanical room houses only the domestic hot water system. This unfinished, sub-grade area was not considered "rentable space" and therefore not integrated into the overall calculation. The use of this space is being considered for future redesign.

LEED ANALYSIS

U.S. GREEN BUILDING COUNCIL
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Leadership in Energy and Environmental Design (LEED) was developed in hopes to encourage building design and construction practices to decrease energy consumption and reduce the impact of buildings on the environment. Throughout the construction of The Regional Learning Alliance, the project team, including the construction managers, architects and design firms, worked hard to accomplish an official LEED Silver Rating from the United States Green Building Council (USGBC).

The environmentally friendly design began with the configuration and placement of the building on site, which was intended to limit the impact of new development on the wooded area and natural wetlands. The project team implemented a construction waste management plan early, which made sure that over 90% of construction materials were recycled, diverting waste from the areas landfills. Xeriscaope-type landscaping was designed to preserve rainwater and eliminate the need for an irrigation system. In order to reduce water usage even further, ultra low-flow toilets and waterless urinals were implemented in the plumbing design by Tower Engineering. The architects chose to use a white, EnergyStar compliant roof to help avoid the heat-island effect which often occurs with darker colored choices.

The two L-shaped wings that embrace the site's wetlands expose the occupants to natural views and maximum day lighting. All site lighting is shielded to avoid light pollution.

As mentioned earlier in this report, the mechanical and electrical systems were chosen for their energy efficient performance and their ability to exceed requirements set forth by ASHRAE Standard 90.1. All fire-suppression and refrigeration systems use non-HCFC and non-Halon refrigerants in attempts to avoid ozone depletion. Carbon dioxide monitoring was included in the mechanical design and construction, while a separate indoor air quality management team has been incorporated to help maintain an acceptable indoor environment for the building's tenants. In addition, the building owner entered into a yearly agreement to purchase green power from Energy Solutions.

Recycled steel and concrete, along with low maintenance exterior materials such as brick masonry, kynar-coated metal panels and frames and aluminum finishes were used to create the building's structure and envelope. Low-emitting materials were used for paints, adhesives, sealants, carpet and composite wood. The majority of the materials were purchased locally, and found within a 500 mile radius of the site.

The project's team main objective was to measure actual building performance and operating costs in order to determine the estimated payback period of the sustainable design. Tower Engineering's HAP analysis was performed for both a typical, base building *and* the actual designed building, which incorporated the following sustainable features:

1. Increased wall and roof insulation
2. Daylight dimming controls in classrooms, office and dining areas
3. Outdoor shading devices for daylight control and solar heat gain reduction
4. Variable-volume, demand-controlled ventilation unit with enthalpy heat recovery wheel and evaporative cooling
5. CO2 override in each classroom
6. High efficiency water chiller
7. Significant water usage reduction
8. High efficiency boilers and and domestic hot waters
9. Variable speed pumps and two-way valves

According to Tower Engineering's Energy and Analysis Report (which can be found in APPENDIX B), the designed building should consume almost 40% less energy than the budget, "base" building, which was also modeled in HAP without any of the sustainable features.

A full LEED Analysis (updated to meet Version 2.2 requirements) can be found in APPENDIX C of this report. The current design accumulated 34 points and a LEED Silver rating.

MECHANICAL SYSTEMS CRITIQUE

Theoretically, the mechanical system implemented at The Regional Learning Alliance Center can be seen as an efficient system. By installing a fan-coils served by a dedicated outdoor air unit, the building is capable of having some zones heating while others are cooling. In addition, if needed, each zone is able to immediately switching from cooling to heating modes. This is an extremely important, and effective feature of the system since a majority of the spaces in the facility are occupied at different densities, and used for different purposes throughout the day. In addition, the system was able to integrate a waterside "free-cooling" component by installing the economizer in the dedicated outdoor air rooftop unit (AHU-1). As mentioned on Page 8, when the outside air temperature drops below 65 F, the heat wheel stops in the unit stops and the outdoor air alone provides cooling for the zones. Therefore, the chiller was not designed to operate until the cooling load is not met with this outside air. By integrating such a feature, energy consumption was reduced. The dedicated outdoor air system, with demand controlled ventilation through the carbon dioxide sensors was a good choice to accumulate LEED points for the project.

While the system is valuable energy wise, the general manager has expressed numerous operating concerns, mostly importantly the in-house maintainability of the system. With its relatively complex hydronic system components (not to mention complicated ducting layouts), the owner/management team has been forced to hire a full-time maintenance manager to address daily issues that tend to arise with the system. Issues include indoor air quality (mostly temperature and humidity), controls and acoustical performance of the fan-coil units. Being in the space, you will notice that in large open areas, such as the main lobbies and atriums, it can get rather drafty. Temperatures recorded from one end of the atrium to the other have varied by up to ten degrees. The supply air distribution and control sequencing of AHU-2 will need to be analyzed and potentially altered to fix this problem. A variable volume air handling unit with more sophisticated controls might serve as a better option for the ventilation of the lobby/atrium. Problems also tend to arise where a number of rooms have been grouped into one thermal zone and are served by a single fan-coil unit. Either the thermostat control or design is proven inefficient, with the temperatures between the spaces varying from 5-8 F. It is possible that *too many* spaces (such in the office groupings on the second floor) were placed under the operation of one fan-coil unit.

Although it is beneficial to have the fan-coil units indoors (for maintenance and control purposes), the acoustical performance of the units have been undesirable. Vibrations and rattling of lighting fixtures have even been reported. This could be due to a number of factors, including the under sizing of individual units. With a majority of the rooms devoted to office, conference and learning space, these loud and distracting units are simply unacceptable for the occupants and tenants. This primary concern will be of upmost importance in any potential redesign considerations.

APPENDIX A – EQUIPMENT CHARACTERISTICS

BOILERS

BOILER	MAUNFACTURER	NET INPUT (MBH)	NET OUTPUT (MBH)	RELIEF VALVE (PSI)	FLOW RATE (GPM)
B-1	Lochinvar	1500	1402.5	150	70
B-2	Lochinvar	1500	1402.5	150	70

CHILLERS

CHILLER	MAUNFACTURER	CAPACITY (tons)	REFRIG. TYPE	GPM	EWT (F)	LWT (F)	MAX PD (ft w.g.)
CH-1 (with scroll compressor)	AAON LL-075	75	R-410A	180	52	42	7

PUMPS

PUMP	PRIMARY/ SECONDARY	TYPE	GPM	TOTAL HEAD (ft)	MOTOR HP	MOTOR RPM
P-3	Primary (building hw)	Bell & Gossett, Base Mounted	305	70	10.0	1750
P-4	Secondary	Bell & Gossett, Base Mounted	305	70	10.0	1750
P-5	Primary (chiller)	AAON, In-line	180	66	2.0	1750
P-6	Secondary	AAON, In-line	180	66	2.0	1750
P-7	Primary (building chw)	AAON, In-line	165	66	7.5	1750
P-8	Secondary	AAON, In-line	165	66	7.5	1750

NOTE: Pumps 1 & 2 serve the domesic hot water system

AIR SEPERATORS

AIR SEPERATOR	SERVING	CAPACTIY (GPM)	MAX. PRESSURE DROP (FT HEAD)	MANUFACTURER	MODEL
AS-1	Hot Water	337	10	Bell & Gossett	R-6
AS-2	Chilled Water	225	7	Bell & Gossett	R-4

EXPANSION TANKS

EXPANSION TANK	SERVING	ACCPTANCE (GALLONS)	WORKING PRESSURE (PSI)	SIZE (IN) DIA. x HEIGHT	MANUFACTURER	MODEL
ET-1	Chilled Water	53	125	24"x38"	Bell & Gossett	B-200
ET-2	Hot Water	105	125	24"x67"	Bell & Gossett	B-400

APPENDIX A – EQUIPMENT CHARACTERISTICS cont'd

AIR HANDLING UNITS

Ventilation (AHU-1):	AAON RL-075
Total Supply CFM	22,500
System Type	Variable Air Volume
SUPPLY FAN	
External static pressure	1.5 in w.g.
Motor	40 HP
EXHAUST FAN	
Total static pressure	1.75 in w.g.
Motor	15 HP
DX COIL	
Total MBH	867
Sensible MBH	707
EER	12.5
A.P.D.	0.85 in w.g.
HOT WATER COIL	
Capacity (MBH)	1386
Water Flow	150 GPM
W.P.D	8 ft head
A.P.D.	0.78 in w.g.

Lobby/Atrium (AHU-2):	AAON-Size 18
Total Supply CFM	10,000
System Type	Constant Air Volume
SUPPLY FAN	
External static pressure	1.0 in w.g.
Motor	1.0 HP
CHILLED WATER COIL	
Total MBH	237
Sensible MBH	221
Water Flow	25 GPM
HOT WATER COIL	
Capacity (MBH)	224
Water Flow	28

EXHAUST FANS

EXHAUST FANS	TYPE	TOTAL AIRFLOW (cfm)	E.S.P. (in w.g.)	MOTOR RPM	MOTOR HP	CONTROL
EF-1	CRE-D	1275	0.5	1027	1/4	Time Clock
EF-2	CRE-D	475	0.375	1285	0.08	Time Clock
EF-3	CRE-B	2250	0.625	1057	0.50	Time Clock
EF-4	CRE-B	600	0.8	1476	0.33	Interlock w/ Dishwasher
EF-5	KHE-B	6250	3.3	1317	7.50	Interlock w/ hood
EF-6	KHE-B	1820	2.25	1637	2.00	Interlock w/ hood
EF-7	CRE-D	950	0.375	1427	0.25	Time Clock
EF-8	IL-D	700	0.425	1082	350 W	Continuous
EF-9	SW-D	200	0.25	1422	0.03	Wall Switch
EF-10	CRE-D	100	0.25	1321	0.03	Thermostat
EF-11	CRE-D	100	0.25	1321	0.03	Thermostat
EF-12	IL-D	300	0.375	1000	140 W	Thermostat
EF-13	SW-PD	1000	0.15	1550	0.13	Thermostat

NOTE: All exhaust fans are GREENHECK models

APPENDIX A – EQUIPMENT CHARACTERISTICS cont'd

UNIT HEATERS

UNIT HEATERS	AREA SERVED	TOTAL AIRFLOW (CFM)	EAT (F)	LAT (F)	EWT (F)	LWT (F)	CAPACITY (MBH)	WATER FLOW (GPM)	W.P.D. (FT HEAD)	FAN HP
CUH-1	Stairs #1	512	60	93.7	120	100	18.7	2.4	7.0	1/15
CUH-2	Stairs #3	242	60	108.7	120	100	12.8	1.6	4.1	1/12
CUH-3	1200A Vestibule	262	60	93.8	120	100	9.7	1.2	6.9	1/25
CUH-4	Stairs #2	242	60	108.7	120	100	12.8	1.6	4.1	1/12
CUH-5	1210 N. Vestibule	623	60	100.4	120	100	27.8	13.6	5.5	1/8
CUH-6	1214 E.Vestibule	623	60	100.4	120	100	27.8	3.6	5.5	1/8
CUH-7	Kitchen 112A	512	60	93.7	120	100	18.7	2.4	7.0	1/15
CUH-8	Dry Storage 112B	242	60	108.7	120	100	12.8	1.6	4.1	1/12
UH-1	Maintenance Garage	1100	60	75	120	100	17.1	4.2	0.4	1/8
UH-2	Basement	600	60	77	120	100	14.2	3.5	0.4	1/20
UH-3	Basement	600	60	77	120	100	14.2	3.5	0.4	1/20

FAN-COIL UNITS

FAN COIL UNIT (4-Pipe)	TOTAL AIRFLOW (cfm)	SUPPLY FAN T. S.P. (in w.g.)	SUPPLY FAN MOTOR HP	WATER FLOW (GPM)	CHILLED WATER COIL LAT (F)	TOTAL MBH	W.P.D. (ft head)	HOT WATER COIL CAPACITY (MBH)	W.P.D. (ft head)
FCU-1	2750	0.84	0.5	4.25	61.7	24.8	0.13	29.7	0.18
FCU-2	710	1.01	0.5	1.25	59.3	8.4	0.51	7.7	0.45
FCU-3	500	0.49	0.5	4.00	55.0	12.8	3.00	5.4	2.65
FCU-4	640	0.67	0.5	0.55	63.0	4.9	0.13	6.9	0.11
FCU-5	840	0.57	0.5	2.00	56.0	14.6	1.58	9.1	1.40
FCU-6	415	0.82	0.5	2.75	55.0	10.4	4.00	4.5	3.50
FCU-7	2750	0.84	1	4.25	61.7	24.8	0.13	29.7	0.18
FCU-8	2750	0.84	1	4.00	62.0	24.8	0.11	29.7	0.16
FCU-9	1095	0.8	0.5	5.50	55.0	25.1	3.00	11.8	2.61
FCU-10	1450	1.02	0.5	4.50	55.0	28.6	6.50	15.7	5.75
FCU-11	NOT	USED	IN	FINAL	DESIGN				
FCU-12	1075	0.77	0.5	4.50	55.0	24.6	6.50	11.6	5.50
FCU-13	1085	0.74	0.5	3.25	55.0	21.1	4.00	11.7	3.50
FCU-14	750	0.52	0.5	2.00	55.0	12.3	1.61	8.1	1.42
FCU-15	750	0.52	0.5	2.00	55.0	12.3	1.61	8.1	1.42
FCU-16	750	0.52	0.5	2.00	55.0	12.3	1.61	8.1	1.42
FCU-17	1920	0.59	0.5	5.00	57.0	33.5	0.88	10.4	0.78
FCU-18	1920	0.59	0.5	5.00	57.0	35.8	0.88	10.4	0.78
FCU-19	985	0.6	0.5	6.75	55.0	18.8	1.50	10.6	1.50
FCU-20	989	0.6	0.5	6.75	55.0	21.1	1.50	10.7	1.50
FCU-21	840	0.57	0.5	2.50	55.0	14.6	2.00	9.1	2.00
FCU-22	720	0.78	0.5	2.75	55.0	12.0	2.00	7.8	1.75
FCU-23	840	0.57	0.5	2.50	55.0	14.6	2.00	9.1	2.00
FCU-24	725	0.78	0.5	2.50	55.0	12.1	2.00	7.8	2.00
FCU-25	435	0.77	0.5	1.50	55.0	7.2	1.50	4.7	1.30
FCU-26	580	0.63	0.5	2.00	55.0	11.1	1.25	6.3	1.00
FCU-27	520	0.47	0.5	3.00	55.0	9.8	1.75	5.6	1.50
FCU-28	440	0.78	0.5	1.50	55.0	7.5	1.50	4.8	1.30

APPENDIX A – EQUIPMENT CHARACTERISTICS cont'd

FCU-29	720	0.78	0.5	2.50	55.0	12.7	1.75	7.8	1.50
FCU-30	680	0.73	0.5	2.50	55.0	12.2	1.75	7.3	1.50
FCU-31	685	0.74	0.5	2.50	55.0	11.8	1.75	7.4	1.50
FCU-32	1170	0.56	0.5	3.75	57.0	20.6	1.00	12.6	0.75
FCU-33	700	0.77	0.5	2.75	55.0	14.4	2.00	7.6	1.80
FCU-34	1310	0.62	0.5	5.50	55.0	26.2	1.50	14.1	1.25
FCU-35	250	0.56	0.5	1.00	55.0	4.9	0.74	2.7	0.60
FCU-36	605	0.65	0.5	1.75	57.0	10.7	0.90	6.5	0.80
FCU-37	725	0.78	0.5	2.50	55.0	12.3	1.70	7.8	1.50
FCU-38	500	0.45	0.5	2.75	55.0	8.5	1.50	5.4	1.25
FCU-39	685	0.74	0.5	2.50	55.0	11.2	1.75	7.4	1.50
FCU-40	715	0.77	0.5	2.50	55.0	12.6	1.75	7.7	1.50
FCU-41	860	0.58	0.5	2.50	55.0	14.1	2.25	9.3	1.80
FCU-42	565	0.61	0.5	2.00	55.0	9.7	1.10	6.1	1.00
FCU-43	565	0.61	0.5	2.00	55.0	16.2	1.10	6.1	1.00
FCU-44	865	0.58	0.5	1.75	58.0	14.9	1.25	9.3	1.10
FCU-45	1275	0.62	0.5	5.25	55.0	25.3	1.25	13.8	1.10
FCU-46	1505	0.58	0.5	4.00	57.0	25.7	1.00	16.3	1.00
FCU-47	865	0.58	0.5	1.75	58.0	14.9	1.25	9.3	1.10
FCU-48	865	0.58	0.5	1.75	58.0	14.9	1.25	9.3	1.10
FCU-49	1240	0.59	0.5	5.00	55.0	23.1	1.50	13.4	1.25
FCU-50	640	0.67	0.5	0.55	63.0	4.9	0.13	6.9	0.11

NOTE: All units are of the TRANE type, with the chilled water coils having an EAT=70 F, EWT=44f and LWT=60F while the hot water coils have an EWT=120 F , LWT= 100 F, EAT=70 F and LAT= 80 F.

TERMINAL (VAV) BOXES

TERMINAL BOX	PRIMARY FLOW (min cfm)	PRIMARY FLOW (max cfm)	INLET SIZE
TB-1	825	2750	16
TB-2	215	710	9
TB-3	0	50	4
TB-4	195	640	8
TB-5	160	525	8
TB-6	0	60	4
TB-7	825	2750	16
TB-8	825	2750	16
TB-9	90	300	6
TB-10	340	1125	12
TB-11	NOT	USED	
TB-12	90	300	6
TB-13	165	545	8
TB-14	160	525	8
TB-15	160	525	8

APPENDIX A – EQUIPMENT CHARACTERISTICS cont'd

TB-16	160	525	8
TB-17	180	600	8
TB-18	100	450	7
TB-19	145	960	10
TB-20	NOT	USED	
TB-21	190	630	9
TB-22	135	440	7
TB-23	150	550	8
TB-24	150	550	8
TB-25	130	435	7
TB-26	150	550	8
TB-27	150	550	8
TB-28	135	440	7
TB-29	150	550	8
TB-30	150	550	8
TB-31	140	455	8
TB-32	90	300	6
TB-33	NOT	USED	
TB-34	90	300	6
TB-35	0	40	4
TB-36	0	90	4
TB-37	200	665	9
TB-38	110	370	7
TB-39	150	495	8
TB-40	130	435	7
TB-41	220	720	9
TB-42	120	380	7
TB-43	0	120	4
TB-44	0	160	4
TB-45	120	400	7
TB-46	175	580	8
TB-47	0	160	4
TB-48	0	160	4
TB-49	180	600	8
TB-50	195	640	8
TB-51	0	60	4

APPENDIX B – BASE vs. DESIGNED BUILDING ENERGY ANALYSIS

Energy Cost Budget (ECB) Compliance

Regional Learning Alliance

Energy Summary by End Use

End Use	Energy Type	Proposed Bldg		Budget Building		Proposed/Budget Energy (%)	
		Energy (10^3 BTU)	Peak (10^3 BTU/hr)	Energy (10^3 BTU)	Peak (10^3 BTU/hr)		
Lighting - conditioned	E	925,414	199	1,082,303	226	0.86	85.50%
Lighting - task	E						
Space heating (1)	E						
Space heating (2)	G	1,949,762	1,330	4,157,251	3,020	0.47	46.90%
Space cooling	E	678,554	270	775,238	328	0.88	87.53%
Pumps	E	156,718	43	388,766	84	0.40	40.31%
Heat rejection	E						
Fans - interior ventilation	E	713,981	153	767,108	162	0.93	93.07%
Fans - interior exhaust							
Fans - parking garage							
Service water heating DHW	G	308,845	800	574,695		0.54	53.74%
Office equipment	E	388,266	84	395,665	83	0.98	98.13%
Elevators & escalators							
Refrigeration (food, etc.)							
Cooking (commercial)							
Misc. equipment							
Total Building Consumption	E	2,862,933		3,409,080		0.84	83.98%
	G	2,258,607		4,731,946		0.48	47.73%
	Total	5,121,540		8,141,026		0.63	62.91%

Energy and Cost Summary by Fuel Type

		Proposed Building (DEC)		Budget Building (ECB)		Proposed/Budget (DEC/ECB)	
		Energy (10^3 Btu)	Cost ($)	Energy (10^3 Btu)	Cost ($)	Energy (%)	Cost (%)
Electricity		2,862,933	$50,221.00	3,409,080	$61,212.01	83.98%	82.04%
Natural Gas		2,258,607	$66,713.00	4,731,946	$139,437.00	47.73%	47.84%
Other fossil fuel							
District steam							
Total Nonsolar		5,121,540	$116,934.00	8,141,026	$200,649.01	62.91%	58.28%
Solar or site recovered							
Total including Solar		5,121,540	$116,934.00	8,141,026	$200,649.01	62.91%	58.28%

These results use assumptions for showing compliance during a typical year; actual energy costs may be substantially different.

Percent Savings = (ECB $ - DEC $) / ECB $ = 41.72%

APPENDIX C – LEED CHECKLIST

LEED for New Construction v2.2
Registered Project Checklist

Project Name:
Project Address:

Yes	?	No			
3	1	10	**Sustainable Sites**		**14** Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
		1	Credit 1	**Site Selection**	1
		1	Credit 2	**Development Density & Community Connectivity**	1
		1	Credit 3	**Brownfield Redevelopment**	1
		1	Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		1	Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel-Efficient Vehicles	1
		1	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1	**Site Development,** Protect or Restore Habitat	1
		1	Credit 5.2	**Site Development,** Maximize Open Space	1
		1	Credit 6.1	**Stormwater Design,** Quantity Control	1
1			Credit 6.2	**Stormwater Design,** Quality Control	1
		1	Credit 7.1	**Heat Island Effect,** Non-Roof	1
1			Credit 7.2	**Heat Island Effect,** Roof	1
	1		Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4		1	**Water Efficiency**		**5** Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
1			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
9		4	**Energy & Atmosphere**		**17** Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required

***Note for EAc1**: All LEED for New Construction projects registered after June 26th, 2007 are required to achieve at least two (2) points under EAc1.

Yes	?	No				
7		2	Credit 1		**Optimize Energy Performance**	1 to 10
					10.5% New Buildings or 3.5% Existing Building Renovations	1
					14% New Buildings or 7% Existing Building Renovations	2
					17.5% New Buildings or 10.5% Existing Building Renovations	3
					21% New Buildings or 14% Existing Building Renovations	4
					24.5% New Buildings or 17.5% Existing Building Renovations	5
					28% New Buildings or 21% Existing Building Renovations	6
				7	31.5% New Buildings or 24.5% Existing Building Renovations	7
					35% New Buildings or 28% Existing Building Renovations	8
					38.5% New Buildings or 31.5% Existing Building Renovations	9
					42% New Buildings or 35% Existing Building Renovations	10
			Credit 2		**On-Site Renewable Energy**	1 to 3
					2.5% Renewable Energy	1
					7.5% Renewable Energy	2
					12.5% Renewable Energy	3
		1	Credit 3		**Enhanced Commissioning**	1
1			Credit 4		**Enhanced Refrigerant Management**	1
		1	Credit 5		**Measurement & Verification**	1
1			Credit 6		**Green Power**	1

APPENDIX C – LEED CHECKLIST cont'd

continued...

Yes	?	No			
6	1	6		**Materials & Resources**	13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
		1	Credit 3.1	**Materials Reuse**, 5%	1
		1	Credit 3.2	**Materials Reuse**,10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
	1		Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regior	1
1			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regior	1
		1	Credit 6	**Rapidly Renewable Materials**	1
1			Credit 7	**Certified Wood**	1

Yes	?	No			
8	2	5		**Indoor Environmental Quality**	15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
		1	Credit 1	**Outdoor Air Delivery Monitoring**	1
1			Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
		1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
	1		Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
	1		Credit 6.1	**Controllability of Systems**, Lighting	1
		1	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort**, Design	1
1			Credit 7.2	**Thermal Comfort**, Verification	1
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
4		1		**Innovation & Design Process**	5 Points
1			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
1			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
1			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
		1	Credit 1.4	**Innovation in Design**: Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
34	4	27	**Project Totals** (pre-certification estimates)	69 Points

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

REFERENCES & WORKS CITED

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Tower Engineering. 2007. Mechanical Documents. Tower Engineering. Pittsburgh, PA. 2004.

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