Technical Assignment 2

Building and Plant Energy Analysis Report

The Milton Hershey School New Supply Center
Hershey, Pennsylvania

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1.0 EXECUTIVE SUMMARY

The Milton Hershey School New Supply Center is a single story, 110,000 square foot building located on the Milton Hershey School Campus. Located in Hershey, Pennsylvania, the building's envelope, mechanical systems, lighting systems, and electrical systems must meet the requirements listed in ASHRAE Standard 90.1 – 2004 (ASHRAE 2004) for its climate zone in order to qualify as a energy efficient "green" building. Analysis of the supply center's building materials, equipment efficiencies, and lighting power densities results in the majority of the categories complying with the standard. Table 1 summarizes the results.

Table 1 ASHRAE Standard 90.1 – 2004 Compliance Check

	Building Envelope			HVAC Systems & Equipment				Lighting	Motors
	Wall Insulation	Roof Insulation	Glass U-Value	Chiller COP	Boilers Efficiency	Cooling Towers	Pipe Insulation	Lighting	Motor Efficiency
Result	Complies	Complies	Complies	Complies	Complies	Complies	Does not Comply	Complies except Restrooms	Does not Comply

While the supply center appears energy efficient from the Standard 90.1 analysis, the LEED-NC Green Building Rating System indicates that the project, though currently under construction, has 24 points secured. Accumulating at least two more LEED points will successfully reach the project goal of LEED Certification (26-32 points).

Since the supply center is a single story building and all 14 air handling units are located on raised mechanical mezzanine rooms, no lost rentable space occurs due to the air side mechanical system. The boiler and chiller plant, located on the main floor, consumes 4% of the usable floor area. The entire mechanical systems first cost is approximately $6,000,000 or $54.54/ft^2.

Carrier's Hourly Analysis Program (HAP) performs design load calculations on the supply center. The program then calculates the annual energy consumption and the cost to operate the building. The building simulation program reports that the design air flows for each AHU are very similar to the values stated on the design documents. HAP also calculates that the total annual cost to operate the HVAC systems in the supply center is $145,485. The HVAC operating cost consumes 59.4% of the energy expenses for the entire building.

2.0 LEED-NC CERTIFICATON

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System is a method developed by the US Green Building Council (USGBC) used to help professionals improve the quality of buildings and their impact on the environment (LEED 2005). The USGBC's rating system, LEED-NC Version 2.2, is a point system used with the intent to make a positive impact on public health and the environment as well as reducing operating costs for the building and potentially increasing occupant productivity (LEED 2005). Overall, LEED-NC helps to create a sustainable community.

The Milton Hershey School New Supply Center is currently under construction, and LEED-NC for new construction is used to determine the certification level for the building. There are four levels of certification:

- LEED Certified (26 – 32 points)
- Silver (33 – 38 points)
- Gold (39 – 51 points)
- Platinum (52 – 69 points)

The design of the New Supply Center is intended to achieve LEED Certification by receiving points in all six major categories.

Table 2 LEED-NC Certification Checklist Summary

	Sustainable Sites	Water Efficiency	Energy and Atmosphere	Materials and Resources	Indoor Environmental Quality	LEED Innovation Credits	TOTAL
Secure Points	2	3	4	2	12	1	**24**
Possible Points	9	2	2	4	0	0	**17**
TOTAL	**11**	**5**	**6**	**6**	**12**	**1**	**41**

Table 2 illustrates that the original design has 24 points secured making the building just two points shy of achieving its goal of LEED Certified. However, there are also 17 possible points to obtain which can result in 41 total LEED points. Since the original intent for the supply center is LEED Certified, spending the extra money to reach gold status with 40 points is unreasonable. However, accumulating at least two more points is very realistic.

A possible point not yet secured is the use of non-HCFC refrigerants in the mechanical equipment. This will aid in the point total reaching the range of the project goal of 26 – 32.

Additional cost is added to the project when achieving some of the LEED points. The Sustainable Sites category requires an additional cost for using a white EPDM roof. Also, the Energy and Atmosphere category gives up to 10 points for optimizing energy performance. To receive points in this section, the building design must show a percentage improvement in the proposed building performance rating compared to the baseline rating outlined in ASHRAE Standard 90.1 (LEED 2005). Points in this section are rewarded by making use of variable frequency drives (VFD) on all major hydronic pumps, using ultra efficient (93% and above) boilers and hot water heaters, the use of air to air heat recovery on the air handling units, and by having lighting controls to utilize day-lighting capabilities. Everything listed in this category adds to the cost of the building, however. Appendix A includes the LEED-NC Version 2.2 project checklist, provided by H.F. Lenz Company, with detailed breakdowns of the points earned.

3.0 BUILDING ENVELOPE COMPLIANCE WITH ASHRAE STANDARD 90.1

ASHRAE Standard 90.1-2004 provides minimum requirements for the design of energy efficient buildings (ASHRAE 2004). Section 5 of Standard 90.1 (ASHRAE 2004) specifies requirements for an energy efficient building envelope and is used as the basis for the calculations.

Standard 90.1 (ASHRAE 2004) provides two methods for checking building envelope compliance, the Prescriptive Building Envelope Option and the Building Envelope Trade-Off Option. According to the standard, in order to use the Prescriptive Building Envelope Option the total vertical fenestration must not exceed 50% of the gross wall area (ASHRAE 2004). Also, the total skylight area can not surpass 5% of the total roof area. The supply center, however, contains vertical clear story windows not horizontal skylights. Therefore, the clearstory windows' areas are accounted for in the vertical fenestration calculation. Incase either of the two stipulations are not satisfied, the Building Envelope Trade-Off Option is used for determining envelope compliance.

Table 3 Percent Vertical Fenestration Breakdown

Total Glass Area (ft²)	Total Wall Area (ft²)	% Total Vertical Fenestration
2600	30,500	8.5%

Table 3 shows that the total glass area for the supply center is less than 50% of the total wall area verifying the use of the Prescriptive Building Envelope Option for the Standard 90.1 (ASHRAE 2004) compliance check.

The Milton Hershey School New Supply Center, located in Hershey, Pennsylvania, falls under the climate zone 5A according to Table B-1 in Appendix B of the Standard (ASHRAE 2004). Table 5.5-5 in the Standard (ASHRAE 2004) is used to determine building envelope compliance and breaks down into three sections; residential, nonresidential, and semi-heated. The supply center falls under the nonresidential section. The portions of Table 5.5-5 (ASHRAE 2004) examined are as follows:

- Roofs, Walls, and Floors
  - Compliance based on the assembly maximum U-value or insulation minimum R-value.

- Vertical Glazing % of Wall
  - Compliance based on the assembly maximum U-value for both fixed and operable windows.
  - Compliance based on the assembly maximum solar heat gain coefficient (SHGC) for either case of the glass facing the north or all directions.

Construction documents provided by H.F. Lenz Company and the architectural specification provided by Spillman Farmer Architects indicate the R-values used for wall and roof insulation. The two design documents also provide the U-value for the windows as well as the solar heat gain coefficient which are both used in checking for fenestration compliance with Standard 90.1 (ASHRAE 2004). Tables 4 and 5 compare the requirements for building envelope compliance dictated by Standard 90.1 (ASHRAE 2004) to what is actually designed. As the tables indicate, the New Supply Center complies with ASHRAE Standard 90.1 (ASHRAE 2004) for an energy efficient building envelope.

Table 4 Building Envelope Compliance Summary

	Roof (Insulation Entirely Above Deck) Insulation Min R-value		Walls (Metal Building) Insulation Min R-Value		Floors (Slab on Grade) Unheated
Required (ASHRAE 2004)	R-15 Continuous Insulation		R-13		N/A
Installed	3” Thick	R-18.5 Continuous Insulation	6” Thick	R-19	N/A
Compliance	**Complies**		**Complies**		**Complies**

Table 5 Fenestration Compliance Summary

% Vertical Glazing 0-10%	Assembly Max U-Value (Fixed Windows)	Assembly Max SHGC (All Orientations)	Comments
Required (ASHRAE 2004)	0.57	0.49	Windows are double pane (1/4" thick glass each) insulating float glass with Low-e coating
Installed	0.35	0.40	
Compliance	Complies	Complies	

4.0 HVAC SYSTEMS COMPLIANCE WITH ASHRAE STANDARD 90.1

Section 6 of Standard 90.1 (ASHRAE 2004) indicates efficiency requirements for mechanical equipment and systems serving heating, ventilating, and air conditioning needs for new buildings. These efficiency standards are based on results found by testing major HVAC equipment at specific operating conditions. Since the supply center's floor area is greater than 25,000 square feet, the Simplified Approach Method is not valid for use. Therefore, the Mandatory Provisions portion of section 6 describes the method used for the compliance check. Table 6.8.1A-J found in the standard (ASHRAE 2004) lists the test performed, the operating conditions, and the resulting efficiency for each piece of equipment and is used for the compliance check.

The Milton Hershey School New Supply Center contains two water cooled centrifugal chillers each having a capacity of 270 tons. Compliance with Standard 90.1 (ASHRAE 2004) requires the chillers to meet the efficiency standards listed in table 6.8.1I. The supply center also contains three fire tube boilers powered by natural gas. These boilers are part of a 40 psig medium pressure steam system. The boilers must meet the standard efficiencies found in table 6.8.1F for compliance. Finally, the two cooling towers included in the chilled water system of the supply center must achieve an efficiency rating greater than or equal to that found in Table 6.8.1G of the standard. Table 6 illustrates the results of the HVAC systems compliance check with ASHRAE Standard 90.1 (ASHRAE 2004).

The major HVAC equipment for the supply center all comply with ASHRAE Standard 90.1 (ASHRAE 2004) as seen in table 6. Calculations that are required to evaluate the HVAC system's performances are found in Appendix B.

Table 6 HVAC Equipment Performance Compliance Summary

	270 Ton Centrifugal Chillers		200 BHP Fire Tube Boilers	Induced Draft Cooling Tower	
	LCWT: 45˚F	ECDWT: 85˚F	Size Category: >2,500,000 Btu/hr	EWT: 95˚F	LWT: 85˚F
	Condenser Flow: 3 gpm/ton		Steam System	Fan Motor HP: 25 hp Water GPM: 1380 gpm	
	COP	NPLV	Minimum Efficiency	Performance	
Required (ASHRAE 2004)	5.09	5.32	80% Combustion Efficiency	≥ 20 gpm/hp	
Installed	5.6	8.9	82%	55.2 gpm/hp	
Compliance	**Complies**		**Complies**	**Complies**	

NOTE: All "installed" values were taken from HVAC construction documents provided by H.F. Lenz Company.

Table 7 Additional HVAC Equipment Compliance Summary

	Cooling Capacity for which economizer is required	Min. Duct Insulation R-Value	Min. Pipe Insulation Thickness
Required (ASHRAE 2004)	Climate zone 5a: ≥ 135,000 BTU/h	None – Indirectly Conditioned Space	Varies See Appendix B
Installed	All AHU's Include Air Side Economizers	Not Required	Varies See Appendix B
Compliance	**Complies**	**Complies**	**Does Not Comply**

Additional HVAC equipment performance compliance checks that are set fourth by Standard 90.1 (ASHRAE 2004) are listed in table 7. A spread sheet table with all pipe sizes and their corresponding insulation thicknesses is found in Appendix B. These insulation thicknesses are compared to what is required by Standard 90.1 (ASHRAE 2004) in the appendix, however, table 7 summarizes that the piping insulation used in the supply center does not comply with the standard. The results found in this section indicate that the HVAC systems found in the New Supply Center all comply with ASHRAE Standard 90.1 (ASHRAE 2004) except pipe insulation.

SERVICE WATER HEATING

Section 7 of Standard 90.1 (ASHRAE 2004) specifies performance requirements for water heating equipment. The format for using this section is similar to the HVAC portion of the standard. Table 7.8 in Standard 90.1 (ASHRAE 2004) indicates performance standards that the equipment in the supply center must meet in order to comply. These values were determined from test procedures at specified operating conditions.

The fire tube boilers that are used for HVAC heating also produce hot water for domestic use. According to table 7.8 (ASHRAE 2004), the boilers must have an efficiency of 80%. The calculations performed in this section of the report and are summarized in table 6 indicate that the boilers are 82% efficient proving that the New Supply Center complies with ASHRAE Standard 90.1 (ASHRAE 2004) for service water heating.

5.0 POWER & LIGHTING COMPLIANCE WITH ASHRAE STANDARD 90.1

POWER

Section 8 of Standard 90.1 (ASHRAE 2004) sets fourth compliance paths for power distribution systems in new buildings. The mandatory provisions required for compliance to the standard deal with voltage drop and are as follows.

- Feeder conductors are sized for a maximum voltage drop of 2% at design load.
- Branch circuit conductors shall be sized for a maximum voltage drop of 3% at design load.

The Milton Hershey New Supply Center's electrical systems were designed to meet these voltage drop requirements and therefore comply with ASHRAE Standard 90.1 (ASHRAE 2004).

LIGHTING

Standard 90.1 section 9 (ASHRAE 2004) provides two methods for calculating lighting power allowances for buildings. The Building Area Method and the Space-by-Space Method both use standard lighting power density values based on space occupancy use. The Building Area Method is a more simplified approach where the interior lighting wattage for each occupancy use is summed and divided by the total square footage of the space. This value is then compared to the requirements listed in Table 9.5.1 of the standard (ASHRAE 2004). If the actual value is less than that scheduled in Table 9.5.1, then the building complies with Standard 90.1 (ASHRAE 2004). The Space-by-Space Method is similar in the calculation of a space's lighting power density, but more flexibility is allotted by using this method. This method allows for comparison of each individual space's (instead of looking at a particular occupancy type as a whole) lighting power densities to that listed in Table 9.6.1 of the standard (ASHRAE 2004).

The Building Area Method was used for calculating lighting power densities and checking for compliance. As Table 8 illustrates, all areas of the building comply with Standard 90.1 (ASHRAE 2004) except for the restroom areas.

Table 8 Lighting Power Allowance Summary

Space	Floor Area	Lighting Fixture	Quantity	Watts/ Fixture	Total Watts	Std. 90.1 Max. Watts/ft^2	Allowed Watts	Compliance
Kitchen Prep Area	12,800	Ceiling Recessed Fluorescent	140	64	8,960	1.2	15,360	Complies
Offices	4,923	Ceiling Recessed Fluorescent	75	64	4,800	1.1	5,415	Complies
Conference	1,502	Ceiling Recessed Fluorescent	16	64	1,024	1.3	1,953	Complies
Clothing/ Retail	7,564	Ceiling Recessed Fluorescent	138	64	8,832	1.5	11,346	Complies
Restrooms	886	Ceiling Recessed Fluorescent	14	64	896	0.9	798	Does Not Comply
Corridor	7,956	Ceiling Recessed Fluorescent /Pendant	54	24 W Recessed 32 W Pendant	1,576	0.5	3,978	Complies
Active Storage	19,089	Ceiling Pendant Fluorescent	80	64	5,120	0.8	15,270	Complies
Inactive Storage	22,202	Ceiling Pendant Fluorescent	100	64	6,400	0.3	6,660	Complies
Mail Room	1,351	Ceiling Recessed Fluorescent	25	32	800	1.2	1,621	Complies

MOTOR EFFICIENCIES

Section 10 of Standard 90.1 (ASHRAE 2004) provides a table of minimum efficiencies that motors must exceed to comply with the standard. Fan motor data is given in the design documents provided by H.F. Lenz Company, and the fan motor efficiencies are calculated to check for compliance. Appendix B includes spreadsheet tables used to calculate the efficiencies and compares the values to the requirements listed in the standard. The results show that all of the air handling unit's fan motors do not comply with Standard 90.1.

6.0 LOST RENTABLE SPACE AND MECHANICAL SYSTEMS FIRST COST

The Milton Hershey School New Supply Center is a single story building with a footprint floor area of 112,000 square feet. The total usable floor area when all interior wall thicknesses are subtracted is approximately 110,000 square feet. The supply center also contains 4 elevated mechanical mezzanine rooms that house the air handling units for the supply center.

Since the air handling units are located above the main floor, there is no lost rentable space due to their presence. All of the supply air for ventilation and thermal comfort is distributed to the spaces from ceiling diffusers. Since the supply center is a single story building with the AHU's located above the main floor, no vertical duct shafts are needed. Therefore, the air side portion of the buildings mechanical systems do not occupy any potential rentable space.

The north side of the main floor of the supply center includes the building's chiller and boiler plant. The boiler plant consumes approximately 4,700 square feet or about 4% of the total building area. The boiler and chiller plant is the only portion of the mechanical space that intrudes on the supply centers rentable space. Figure 1 illustrates the mechanical systems locations in the supply center and shows how only the boiler and chiller plant consume usable floor area.

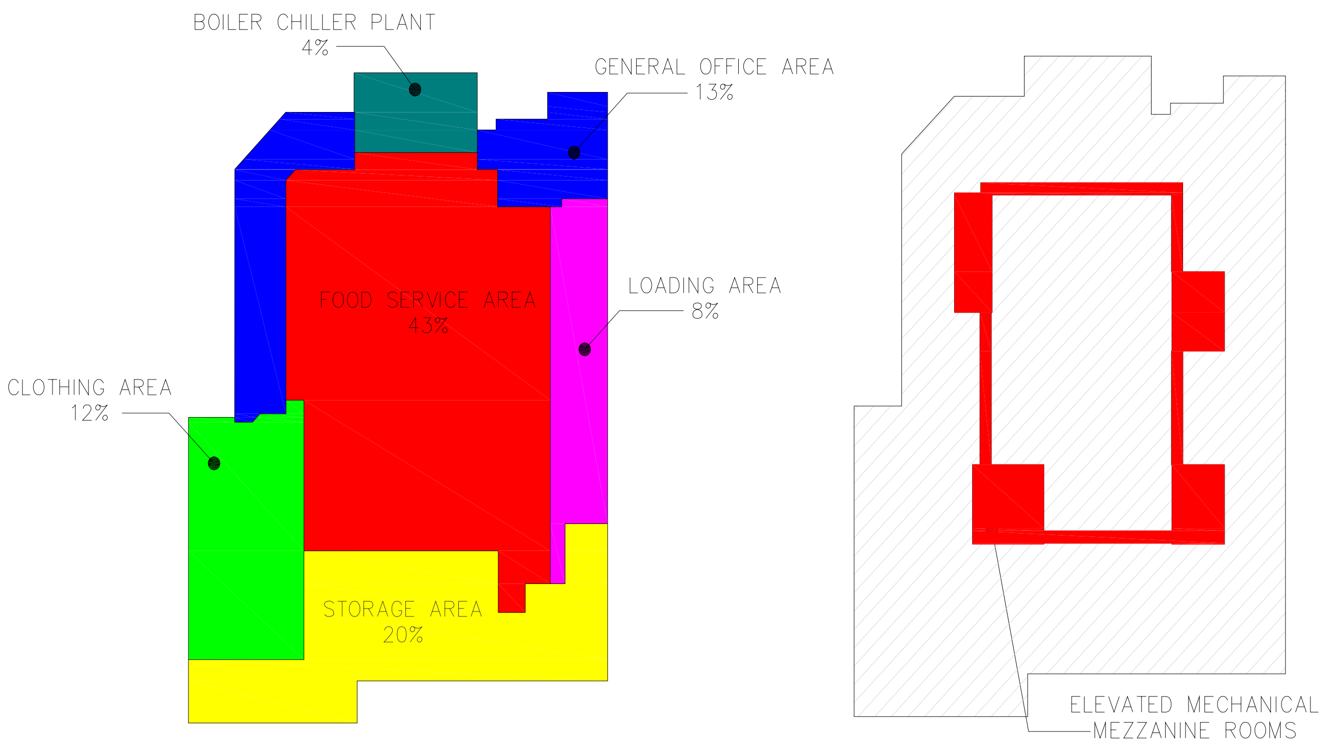

Figure 1 Space relationship area breakdown

HVAC INITAIL COST

The Milton Hershey School New Supply Center's major mechanical equipment consists of 14 air handling units, two 270 ton centrifugal water cooled chillers, two brine chillers supplying chilled water to walk-in coolers, three gas fired fire tube boilers, and two cooling towers. Additionally, the mechanical systems include variable frequency drives on most pumps and fans, three heat exchangers for energy recovery and water side free cooling, and a total energy recovery wheel. This additional equipment all contributes to saving energy, but add to the initial cost.

The mechanical systems first cost for the supply center is an estimated value provided by H.F. Lenz Company. The Milton Hershey School requests to keep the actual bid numbers private, consequently, they are not used for this report. Table 9 gives a breakdown of the mechanical systems first cost.

Table 9 Mechanical Systems Initial Cost Breakdown

HVAC Systems Initial Cost	$6,000,000
HVAC Systems Initial Cost/Ft^2	$54.54 / Ft^2

7.0 DESIGN LOAD ESTIMATION

In order to estimate design loads, annual energy consumption, and operating cost of the Milton Hershey School New Supply Center, Carrier's Hourly Analysis Program (HAP) is used as the building energy simulation program. Input data including OA ventilation rates, lights and equipment loads on a W/sq-ft basis, and design occupancy were all taken from design documents that are supplied by H.F. Lenz Company. The building envelope characteristics (wall materials and glass) that are stated in the ASHRAE Standard 90.1 analysis are also used in the energy model.

The ASHRAE Handbook of Fundamentals (ASHRAE 2005) lists the design outdoor conditions that are used for energy model. According to the handbook the design temperatures for Harrisburg, PA is 92.8˚F DBT and 73.7˚F WBT. The handbook also shows the design temperatures of 8.3˚F DBT and 6.7˚F WBT for heating calculations. These values are imported into HAP and a yearly analysis is conducted. The analysis simulates thermal loads on the building due to outdoor conditions as well as internal loads.

Appendix C shows detailed inputs from HAP's calculations on the supply center. The following tables highlight key summaries on the comparisons between the design loads found on construction documents and the computed loads.

Table 10 indicates that the computed cooling loads are similar to the design cooling loads. In all but one AHU, the computed load estimates are higher than the design loads which also justifies why the computed chilled water flow rates are slightly higher than the design values. Table 11 compares the computed supply air quantities to the design values, and the results show they are similar.

Table 10 cooling Load Comparison

System	Design Load (ft^2/ton)	Computed Load (ft^2/ton)	Design CW Flow (gpm)	Computed CW Flow (gpm)
AHU-1	67.8	56.1	240.8	253
AHU-2	53.6	40.7	240.8	275.5
AHU-3	378	374.6	57.8	59.91
AHU-4	301	279.0	70.4	74.06
AHU-6	180.7	129	145.3	175.8
AHU-7	389.5	312.4	50.1	47.3
AHU-8	56.2	44.9	79.8	86
AHU-9	516	458.2	38.0	41.2
AHU-10	326	250	40.7	49.3
AHU-11	252	218.9	28.1	38.1
AHU-12	451	381.8	65.8	75.6
AHU-13	325.5	348.2	66.2	51.5
AHU-14	314	313.1	39.1	37.2

Note: AHU-5 does not include a cooling coil - Delivers 100% outdoor air year round

Table 11 Supply Air and Outdoor Air cfm/ft^2 Comparison

System	Design Supply Air (cfm/ft^2)	Computed Supply Air (cfm/ft^2)	Ventilation Supply (cfm/ft^2)
AHU-1	3.72	3.72	3.72
AHU-2	4.71	4.71	4.71
AHU-3	0.97	0.96	0.34
AHU-4	1.26	1.25	0.65
AHU-5	1.83	1.81	1.80
AHU-6	1.43	1.43	1.43
AHU-7	0.81	0.80	0.49
AHU-8	4.60	4.60	4.60
AHU-9	0.76	0.75	0.13
AHU-10	1.46	1.45	0.22
AHU-11	1.77	1.75	0.30
AHU-12	0.94	0.93	0.11
AHU-13	1.00	0.99	0.40
AHU-14	1.34	1.33	0.16

Note: AHUs 1, 2, 6, and 8 all have equal values for all three categories because the units are 100% outdoor air. Since ventilation rates used in the simulation were exact values used in the design documents, the computed values are the same as the design values.

When performing an energy simulation, heat generation for various equipment and people is needed. Another important factor in energy modeling is defining load source schedules for people, lighting, and electrical equipment. The tables found in Appendix C indicate the load sources used in the HAP analysis. Also located in Appendix C are load schedules for lights, occupancy density, and electrical equipment broken down by the space's function.

8.0 ANNUAL ENERGY CONSUMPTION AND OPERATING COST

The Hourly Analysis Program is also used to estimate the annual energy consumption for the supply center. Using the same data as in the cooling and heating loads simulation, specifying the mechanical equipment (AHUs, chillers, boilers, cooling towers, pumps, and fans) actually used in the design of the supply center allows for the calculation of annual energy consumption. Performance characteristics, such as efficiencies and COPs, of the major equipment are taken from the design documents supplied by H.F. Lenz Company. Summaries of these characteristics are found in Appendix D.

The last pieces of information needed to perform a cost estimate are electric utility rates and the cost of natural gas. Meter data or utility bills are not obtainable since the supply center is currently under construction. Therefore, the electricity rates and natural gas cost used in the simulation are from the energy analysis performed by the design engineer (H.F. Lenz Company).

Table 12 Fuel Cost

	Off peak	Demand Charge
Electric Rates	$0.06 / kWh	$8.60 / kWh
Natural Gas Rates	$1.35 / therm	

All air flow rates used in the analysis are taken from the design documents. The load analysis already calculated the design flow rates for each space and that the air handling units supply. Table 11, shown in the last section, indicates that the calculated values and the actual design values are very similar. Therefore, these flow rates are used in the simulation. HAP automatically calculates the design water flow rates for cooling and heating coils, and they are shown in table 10. Do to this restriction, the actual water flow rates used are calculated, not imputed.

The following figure illustrates the results from the energy simulation. Detailed cost and energy consumption values are found in Appendix D.

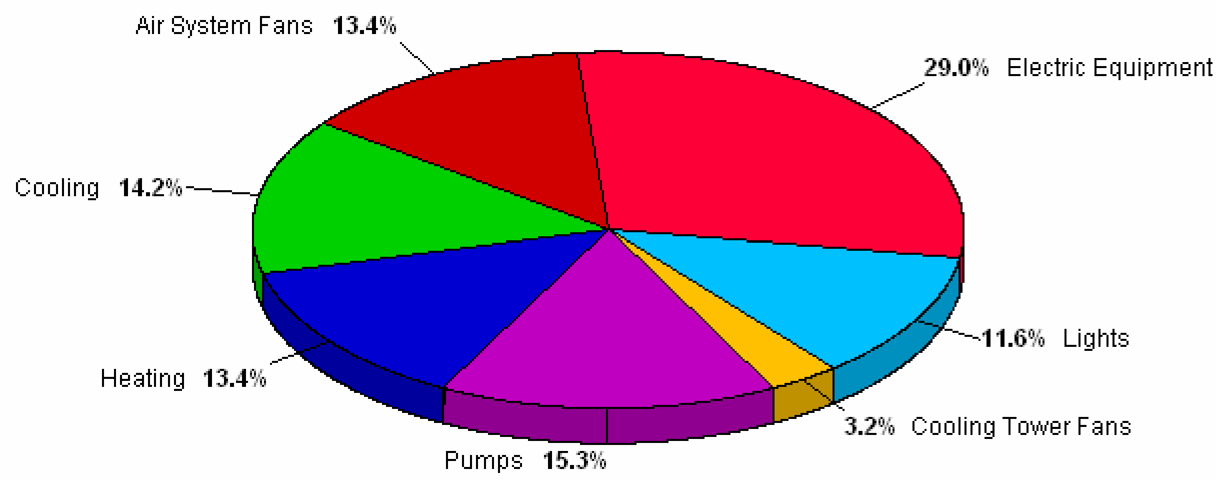

Figure 2 Annual component cost summary

Figure 2 shows what percentage of the total energy cost each major component consumes. Detailed cost data for each piece of equipment is found in Appendix D. Also included in the appendix are monthly cost and energy consumption data. As the pie chart indicates, HVAC equipment represents 59.4% of the total energy cost. The tables shown below compare the annual cost and energy consumption of HVAC equipment to non HVAC equipment.

Table 13 Annual Energy Cost Breakdown

Component	Annual Cost ($/yr)	Annual Cost/ft^2 ($/ft^2 yr)	% of Total Energy Cost
HVAC Component			
Electric	113,037	1.281	46.2 %
Natural Gas	32,420	0.368	13.2 %
HVAC Subtotal	145,458	1.649	59.4 %
Non HVAC Component			
Electric	99,387	1.127	40.6 %
Natural Gas	0	0	0
Non HVAC Subtotal	99,397	1.127	40.6 %
TOTAL	244,855	2.775	100 %

Table 14 Annual Energy Consumption Breakdown

Component	Annual Energy Consumption
HVAC Component	
Electric (kWh)	1,238,947
Natural Gas (therms)	23,969
Non HVAC Component	
Electric (kWh)	1,067,486
Natural Gas (therms)	0
TOTAL	
Electric (kWh)	2,306,433
Natural Gas (therms)	23,969

Aside from energy consumption, it is also important to recognize the amount emissions generated from operating the building. HAP also performs an annual emissions calculation for the production of CO_2, SO_x, and NO_x. Table 15 illustrates the estimated annual emissions produced for operating the supply center.

Table 15 Annual Emissions Report

Emission	Amount Produced
CO_2	280,437 lb
SO_x	652 kg
NO_x	2,253 kg

The building design engineer, H.F. Lenz Company, also performed an energy analysis on the supply center. H.F. Lenz Company used Trane's Trace 700 building energy simulation software to perform the analysis. Table 16 compares the HAP calculated values to the Trace results.

Table 16 Annual Energy Cost Comparison

Component	HAP Annual Cost Result ($/yr)	TRACE Annual Cost Result ($/yr)
HVAC Component		
Electric	113,037	60,309
Natural Gas	32,420	28,940
HVAC Subtotal	145,458	89,249
Non HVAC Component		
Electric	99,387	55,520
Natural Gas	0	0
Non HVAC Subtotal	99,397	55,520
TOTAL	244,855	144,769

Table 16 illustrates some major differences in the HAP model compared to the Trace analysis. H.F. Lenz Company did state, however, that the design of the chiller and boiler plant is not yet completed. The design engineer also mentioned that the building simulation the company performed is not accurate due to the changes. After further analysis, the Trace simulation is outdated compared to the HAP calculation. The HAP simulation uses actual design values for all major equipment as stated on construction documents. The Trace analysis uses more generic values since it was performed early on in the design process. The Trace analysis uses 100% efficiencies on the boilers, for example, which drastically affects the results.

The electric cost of operating the supply center, as calculated by the design engineer, is 42% of the cost that the HAP analysis reports. Upon further review, the fan and pump efficiencies used in the two calculations differ from one another. Also, the chiller input compressor power also differs in the two processes.

As stated above, actual supply air and ventilation air quantities are used in the simulation. Since the Trace model is a design model, not analysis model, the air flows quantities are not the final value specified on construction documents. The schedule sheet on the design documents indicate the total connected supply air flow rate for each AHU and the total ventilation air quantity each AHU is to intake. The Trace model uses the values that are calculated in order to meet thermal loads without any safety factors. The design engineer adjusts the air flow to each space from what the Trace outputs recommend. This final value becomes what is actually scheduled and used in the HAP analysis. Therefore, the HAP analysis uses larger volumes of air to calculate loads than the Trace design model. These differences between the two energy simulations justifies why the HAP analysis expects more cost to operate the supply center.

9.0 REFERENCES

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APPENDIX A – LEED NC 2.2 PROJECT CHECKLIST

Information on this checklist is provided by H.F. Lenz Company and Spillman Farmer Architects.

YES	?	No			
2	9	2	**Sustainable Sites**		Possible **14** Points
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
				Provide ESC Plan per EPA-833-R-92-001, Chapter 3	
	?		Credit 1	**Site Selection**	1
				No prime farmland, 5 feet above above 100 year flood plain, etc	
		N	Credit 2	**Development Density**	1
				Not Obtainable	
		N	Credit 3	**Brownfield Redevelopment**	1
				Not Obtainable	
	?		Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
				1/4 mile of two public or campus bus lines	
Y			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
				Provide secure bicycle storage with shower facilities (within 200 yds of bldg)	
	?		Credit 4.3	**Alternative Transportation**, Alternative Fuel	1
				Provide electric vehicle outlets	
	?		Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling	1
				Provide preferred parking spots for carpools and limit parking to minimum	
	?		Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
				Limit Site Disturbance to 40 feet beyond building, 5 feet beyond roads and utilities	
	?		Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
				Exceed open space zoning requirement by 25%	
	?		Credit 6.1	**Stormwater Management**, Rate or Quantity	1
				Design no net increase in storm water runoff	
	?		Credit 6.2	**Stormwater Management**, Treatment	1
				Provide complying treatment systems	
	?		Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
				Provide shade or light colored pavement on 30% of non-roof impervious site	
Y			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
				Provide compliant roofing	
	?		Credit 8	**Light Pollution Reduction**	1
				Provide compliant lighting	

3	2	0	**Water Efficiency**		Possible **5** Points
Y			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
				Reduce use of potable water for irrigation by 50%	
Y			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
				No potable water use for irrigation	
	?		Credit 2	**Innovative Wastewater Technologies**	1
				Reduce provided potable water for bldg. sewage conveyance by a min. of 50%	
Y			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
				Meet energy Act of 1992 (Fixture performance requirements)	
	?		Credit 3.2	**Water Use Reduction**, 30% Reduction	1
				Meet energy Act of 1992 (Fixture performance requirements)	

4	2	3		**Energy & Atmosphere**	Possible 17 Points
Y			Prereq 1	**Fundamental Building Systems Commissioning**	Required
				‣ Need to hire commissioning agent	
Y			Prereq 2	**Minimum Energy Performance**	Required
				‣ Assure design exceeds ASHRAE/IESNA 90.1-1999	
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**	Required
				‣ No use of CFC-based refrigerants (no R-11, etc)	
Y			Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing	2
				‣ VFD's on all major hydronic pumps	
				‣ Extra insulation on walls and roof?	
				‣ Use of ultra-efficient (93%+) boilers and hot water heaters	
				‣ Use of air to air energy recovery	
				‣ Lighting controls (day lighting)	
		N	Credit 2.1	**Renewable Energy**, 5%	1
				‣ Not Obtainable	
		N	Credit 2.2	**Renewable Energy**, 10%	1
				‣ Not Obtainable	
		N	Credit 2.3	**Renewable Energy**, 20%	1
				‣ Not Obtainable	
Y			Credit 3	**Additional Commissioning**	1
				‣ Commissioning agent needed	
	?		Credit 4	**Ozone Depletion**	1
				‣ No HCFCs (no R-22, R-123, etc.)	
Y			Credit 5	**Measurement & Verification**	1
				‣ Develop a measurement and verification plan	
	?		Credit 6	**Green Power**	1
				‣ 50% of power purchased from renewable sources for a 2 year contract	

2	4	7	**Materials & Resources**			Possible **13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required	
				▸ Provide area for separation, collection, and storage of materials		
		N	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1	
				▸ Not Obtainable		
		N	Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1	
				▸ Not Obtainable		
		N	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1	
				▸ Not Obtainable		
	?		Credit 2.1	**Construction Waste Management**, Divert 50%	1	
				▸ Recycle 50% (by weight) of construction, demolition and land clearing waste		
	?		Credit 2.2	**Construction Waste Management**, Divert 75%	1	
				▸ Recycle 75% (by weight) of construction, demolition and land clearing waste		
		N	Credit 3.1	**Resource Reuse**, Specify 5%	1	
				▸ Not Obtainable		
		N	Credit 3.2	**Resource Reuse**, Specify 10%	1	
				▸ Not Obtainable		
	?		Credit 4.1	**Recycled Content**, Specify 5% (post-consumer + 1/2 post-industrial)	1	
				▸ Reference Federal Trade Commission document (Guides for the Use of Environmental Marketing Claims		
		N	Credit 4.2	**Recycled Content**, Specify 10% (post-consumer + 1/2 post-industrial)	1	
				▸ Use materials with recycled content		
Y			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1	
				▸ Manufactured regionally within a radius of 500 miles		
	?		Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1	
				▸ Manufactured regionally within a radius of 500 miles		
		N	Credit 6	**Rapidly Renewable Materials**	1	
				▸ 5% off the total value of all building materials and products used in project		
Y			Credit 7	**Certified Wood**	1	
				▸ 50% of wood based materials and products, certified in accordance with the Forest Stewardship council's Principles and Criteria for wood buildings components		

Yes	?	No				
12	0	3		**Indoor Environmental Quality**	Possible **15** Points	
Y			Prereq 1	**Minimum IAQ Performance**	Required	
				▸ Assure design complies with ASHRAE 62-1999 and approved Addenda		
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required	
				▸ Prohibit smoking in building		
Y			Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1	
				▸ Provide carbon dioxide monitoring		
		N	Credit 2	**Increase Ventilation Effectiveness**	1	
				▸ Not Obtainable		
Y			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1	
				▸ Develop and implement a complying IAQ Plan		
Y			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1	
				▸ Conduct a two week building flush out of HVAC systems prior to occupancy		
Y			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1	
				▸ Specify low-emitting adhesives and sealants complying with LEED standard		
Y			Credit 4.2	**Low-Emitting Materials**, Paints	1	
				▸ Specify low-emitting paints complying with LEED standard		
Y			Credit 4.3	**Low-Emitting Materials**, Carpet	1	
				▸ Specify low-emitting carpet and backing complying with LEED standard		
Y			Credit 4.4	**Low-Emitting Materials**, Composite Wood	1	
				▸ Specify composite wood products with no added urea-formaldehyde resins		
Y			Credit 5	**Indoor Chemical & Pollutant Source Control**	1	
				▸ Design prevents cross-contamination of occupied areas by chemical pollutants		
Y			Credit 6.1	**Controllability of Systems**, Perimeter	1	
				▸ Provide complying operable windows and lighting controls at perimeter		
		N	Credit 6.2	**Controllability of Systems**, Non-Perimeter	1	
				▸ Not Obtainable		
Y			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1	
				▸		
Y			Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1	
				▸		
Y			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1	
				▸ Provide minimum Daylight Factor of 2% in 75% of spaces used for visual tasks		
		N	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1	
				▸ Provide direct line of site to vision glazing from 90% of occupied areas		
1	5	0		**Innovation & Design Process**	Possible **5** Points	
	?		Credit 1.1	**Innovation in Design**	1	
				▸		
	?		Credit 1.2	**Innovation in Design**	1	
				▸		
	?		Credit 1.3	**Innovation in Design**	1	
				▸		
	?		Credit 1.4	**Innovation in Design**	1	
				▸		
	?		Alternate	**Innovation in Design**		
				▸		
				▸		
Y			Credit 2	**LEED™ Accredited Professional**	1	
				▸ Involve LEED certified professional		
24	22	15		**Project Totals**	**Possible -- Points**	

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

APPENDIX B – ASHRAE STANDARD 90.1 COMPLIANCE CALCULATIONS

Chiller COP Calculations

Chiller

$$COP = \frac{CoolingEffect}{EnergyInput}$$

Compressor

$$kW / Ton = 0.627$$

$$Input = 0.627(\frac{kW}{Ton}) \times 270(Ton)$$

$$Input = 169.3kW$$

Evaporator

$$CoolingEffect = 270ton$$

$$270ton = 949.5kW$$

$$COP = \frac{949.5kW}{169.3kW}$$

$$COP = 5.6$$

Boiler Efficiency Calculations

Gas CFH = 9165

Gross Output = 6695 MBH

$$Boiler\ Efficiency = \frac{6695MBH}{8165CFH}$$

Boiler Efficiency = 0.82 = 82%

Table B-1 Minimum Pipe Insulation Thickness

	Fluid Design Operating Temp Range (˚F)	Nominal Pipe (in.)					Compliance
		<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8	
STEAM AND HOT WATER PIPING							
Required	100-200	1	1.0	1.0	1.5	1.5	Complies
Installed		N/A	N/A	1 to 1-1/2	N/A	N/A	
Required	450	2.5	3.0	3.0	4.0	4.0	Does Not Comply
Installed		N/A	N/A	2 to 2-1/2	N/A	N/A	
CHILLED WATER PIPING							
Required	40-60	0.5	0.5	1.0	1.0	1.0	Complies
Installed		1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	
Required	<40	0.5	1.0	1.0	1.0	1.0	Complies
Installed		2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	

Table B-2 Minimum Fan Motor Efficiencies

AHU FAN	Input Hp	BHP	Efficiency %	rpm	Required	Complies
1 Supply	40	31.2	78	1115	93	NO
2 Supply	40	31.2	78	1115	93	NO
3 Supply	20	11.5	57.5	1846	91	NO
4 Supply	20	15	75	1122	90.2	NO
4 Return	10	6.3	63	700	89.5	NO
5 Supply	5	3	60	2362	87.5	NO
6 Supply	25	19.3	77.2	1123	91.7	NO
7 Supply	10	5.9	59	1769	89.5	NO
7 Return	3	1.2	40	562	87.5	NO
8 Supply	15	8.2	54.6	1438	90.2	NO
9 Supply	10	7.1	71	1890	89.5	NO
10 Supply	15	9.4	62.6	1510	90.2	NO
11 Supply	15	8.6	57.3	2006	90.2	NO
12 Supply	20	11.1	55.5	1127	90.2	NO
13 Supply	20	11.6	58	2231	90.2	NO
14 Supply	15	8.1	54	1977	91	NO

APPENDIX C – DESIGN LOAD ESTIMATION INPUTS AND RESULTS

The following tables illustrate the heat generation loads from electrical equipment and people. The loads are used in the HAP analysis.

Table C-1 Electrical Equipment Loads

Equipment	Heat Generation
Computer Server	500 W
Washer/Dryer	500 W
Dishwasher	2285 W
Office PC	250 W
Kitchen Equipment	122 kW

Table C-2 People Heat Generation

Occupancy Type	People Sensible Load (Btuh)	People Latent Load (Btuh)
General Office	250	200
Loading Dock	275	275
Storage	315	325
Retail Sales	250	200
Reception Area	245	155
Corridor	315	325
Dinning	275	275

The figures shown below are the exact schedules used in the energy model for lights, occupancy, and electrical equipment.

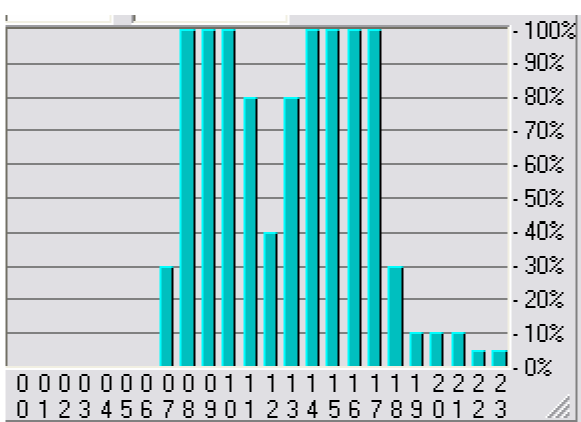

Figure C-1 General office occupancy schedule

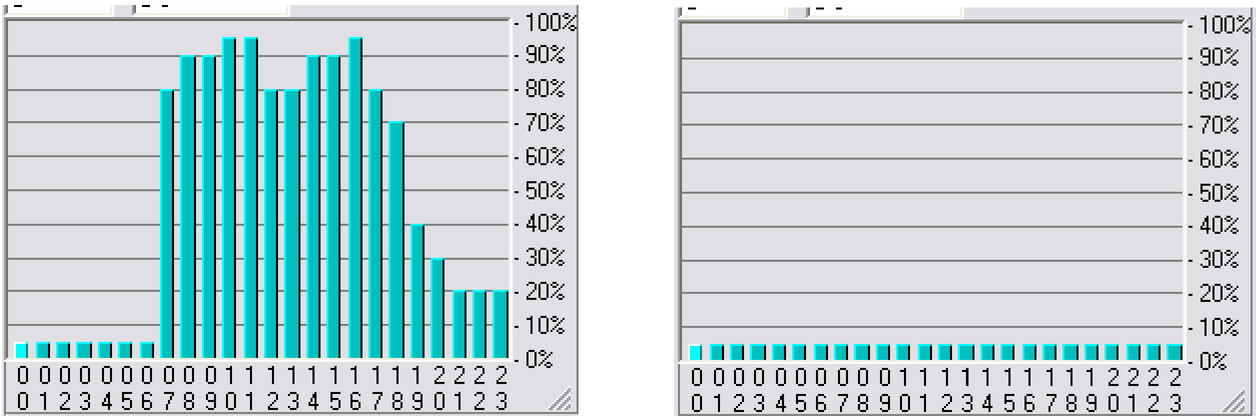

Figure C-2 Building lighting schedule

Figure C-2 shows the lighting schedule for the entire building. The figure on the left indicates the schedule for the design day, and every weekday (Monday-Friday). The figure on the right shows the lighting schedule for weekends and holidays.

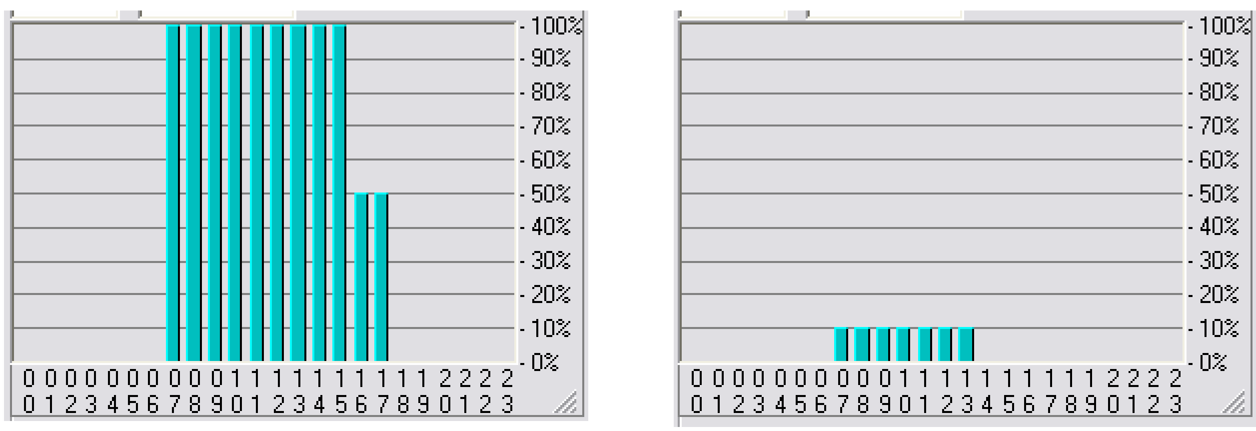

Figure C-3 Kitchen occupancy schedule

Figure C-3 shows the lighting, occupancy, and electrical equipment schedule for all kitchen area for the supply center. The schedule on the left is for every day during the months of September through May. The schedule on the right is for every day during the months of June through August.

APPENDIX D – ANNUAL ENERGY CONSUMPTION AND COST RESULTS

INPUTS

Boiler Full Load Data

Name	Boiler 1	
Gross Output	6695.0	MBH
Energy Input	8165.0	MBH
Overall Efficiency	82.0	%
Fuel or Energy Type	Natural Gas	
Boiler Accessories	11.20	kW
Hot Water Flow Rate	475.0	gpm

Part Load Model

- (•) Constant Efficiency
- ( ) Part Load Curve

Part Load Performance	
% Load	Efficiency (%)
100.0	82.0
90.0	82.0
80.0	82.0
70.0	82.0
60.0	82.0
50.0	82.0
40.0	82.0
30.0	82.0
20.0	82.0
10.0	82.0
0.0	82.0

Figure D-1 Boiler performance characteristics

Full Load LCHWT:	45.0	°F	Cooler Flow Rate:	648.0	gpm
Full Load ECWT:	85.0	°F	Cooler Pressure Drop:	19.8	ft wg
Full Load Capacity:	270.0	Tons	Condenser Flow Rate:	810.0	gpm
Full Load Power:	0.627	kW/Ton	Condenser Pressure Drop:	22.9	ft wg
Minimum ECWT Setpoint:	60.0	°F			
Minimum Load:	20.0	%			

Figure D-2 Chiller performance characteristics

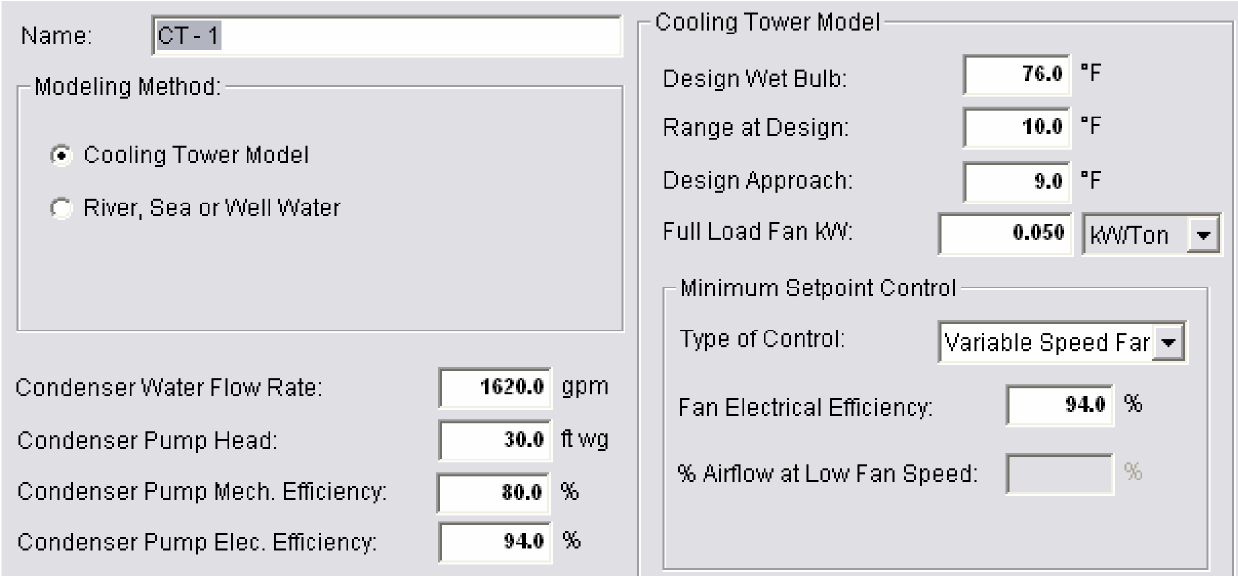

Figure D-3 Cooling tower performance characteristics

Figures D-1 to D-3 indicated the performance characteristics of the major mechanical equipment used in the HAP energy analysis. Also, all major fan and pump efficiencies are used and taken from the design documents provided by H.F. Lenz Company.

- Fan efficiencies range from 45% - 74%
- Primary loop chilled water pump efficiency is 85%
- Secondary loop chilled water pump efficiency is 77%

RESULTS

Table D-1 Component Annual Cost Breakdown

Component	Annual Cost ($/yr)	Annual Cost/ft² ($/ft² yr)	% of Total Energy Cost
HVAC Component			
Air System Fans	32,722	0.371	13.4 %
Cooling	34,875	0.395	14.2 %
Heating	32,725	0.371	13.4 %
Pumps	37,397	0.424	15.3 %
Cooling Tower Fans	7,742	0.088	3.2 %
HVAC Subtotal	145,460	1.649	59.4 %
Non HVAC Component			
Lights	28,507	0.323	11.6 %
Electrical Equipment	70,887	0.804	29.0 %
Non HVAC Subtotal	99,394	1.127	40.6 %
TOTAL	244,855	2.775	100 %

Table D-1 shows the annual energy cost to operate each component in the supply center. The table also breaks down the cost per square foot.

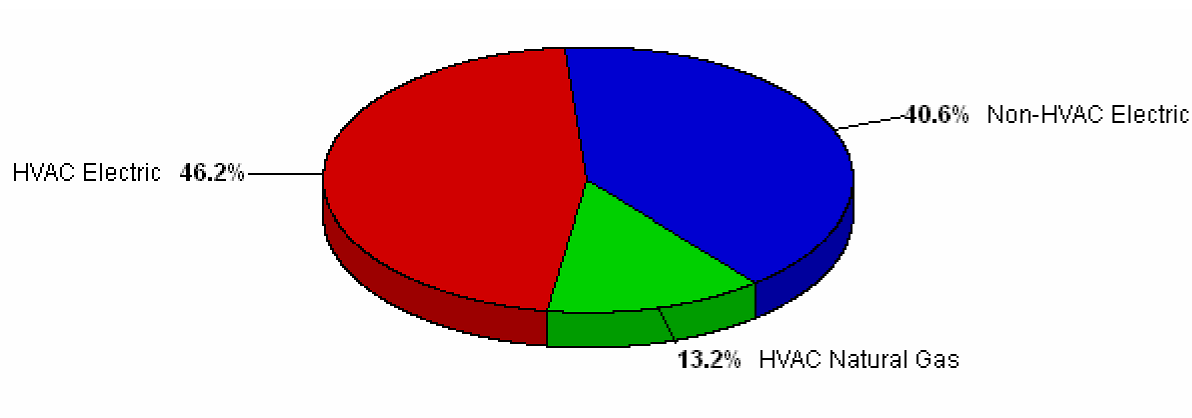

Figure D-4 Annual energy cost by fuel type

Figure D-5 and D-6 illustrate monthly cost to operate the supply center. D-5 is a breakdown according to each component where as D-6 breaks down the monthly cost by fuel type.

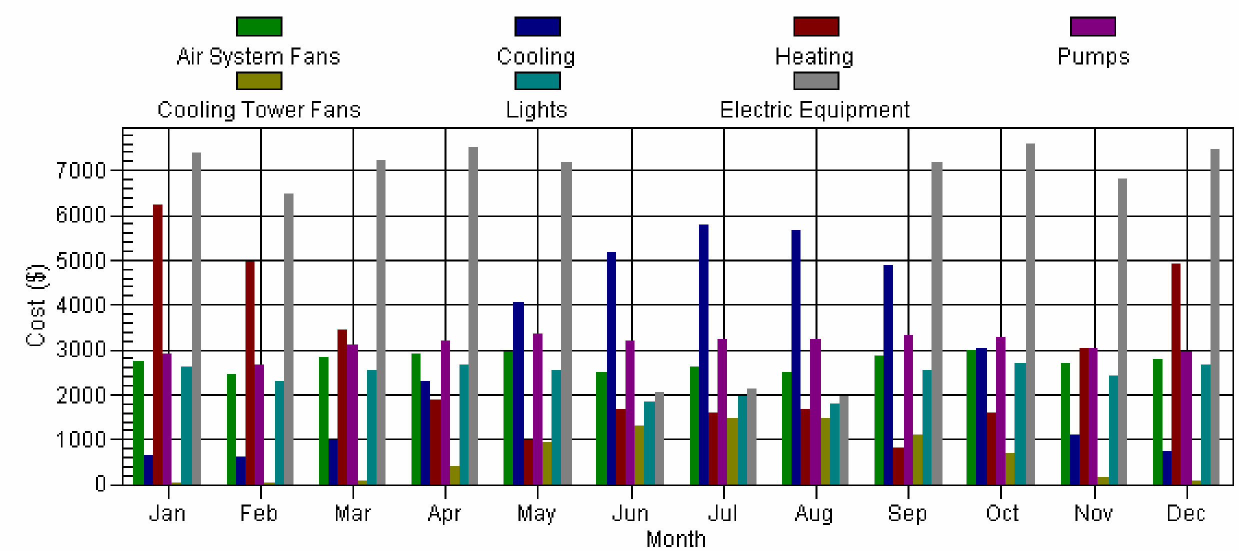

Figure D-5 Monthly cost breakdown by component

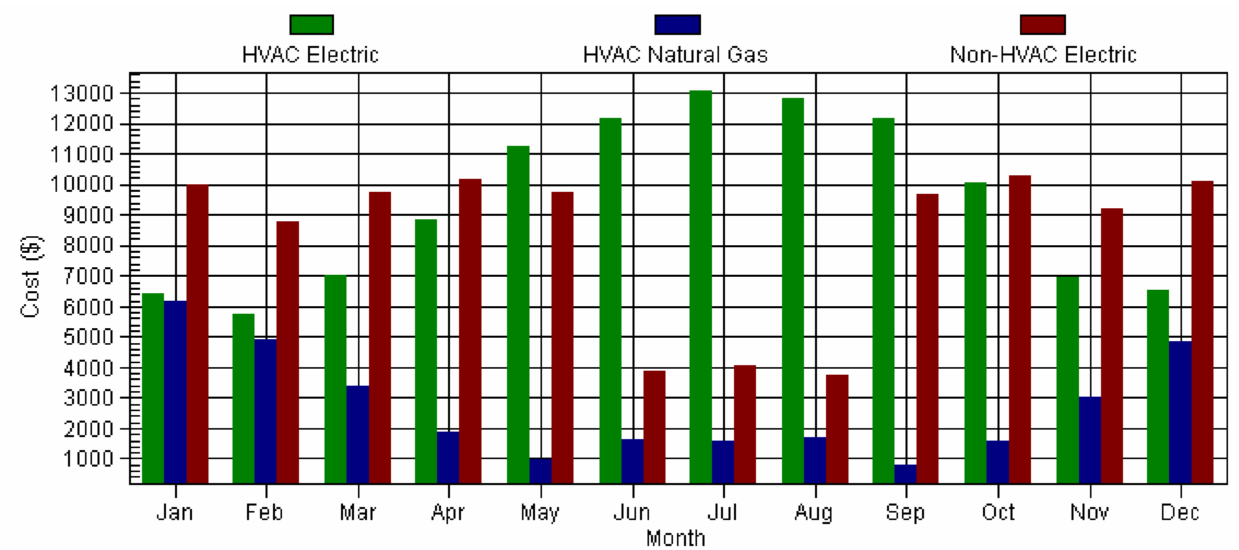

Figure D-6 Monthly cost breakdown by fuel type