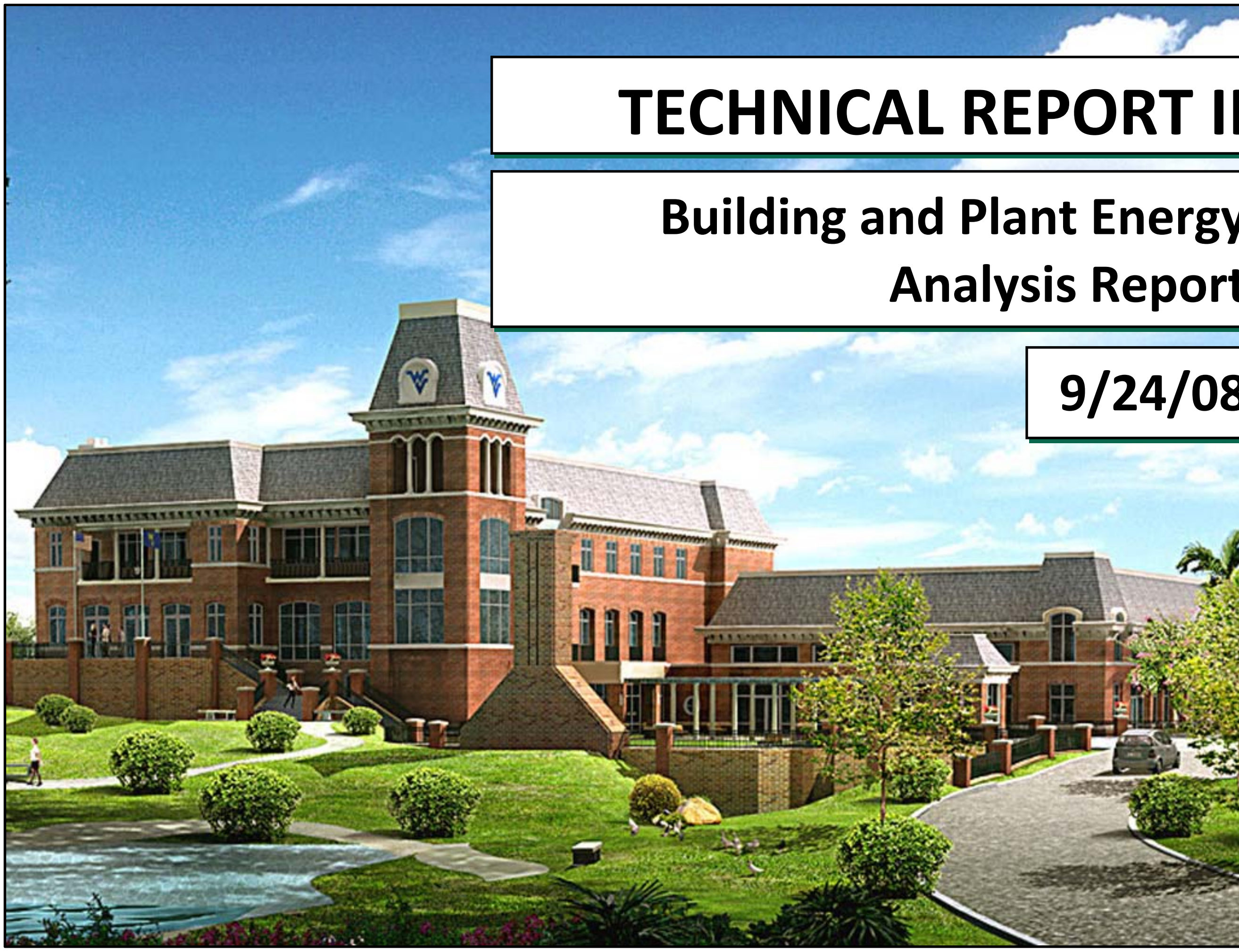

TECHNICAL REPORT II

Building and Plant Energy Analysis Report

9/24/08

WEST VIRGINIA UNIVERSITY ALUMNI CENTER

Morgantown, West Virginia

GREGORY SMITHMYER

PENN STATE UNIVERSITY

ARCHITECTURAL ENGINEERING

MECHANICAL OPTION

FACULTY ADVISOR:
Dr. Jelena Screbric

Table of Contents

1.0 Executive Summary

A design load estimation and energy consumption analysis were performed for the West Virginia University Alumni Center. Both the load estimation and energy analysis were performed using Trane Trace 700 software utilizing inputs based on information gathered from the design documents as well as suggestions and information provided by the design engineer.

Complete information on the design load estimation, including assumptions and inputs, is available in Section 3 of this report. The estimated design loads, as modeled, were comparative to the loads of the actual design equipment in most cases. There were discrepancies in all of the design heating loads and a few of the design cooling loads as summarized in Section 3.2 due mainly to the use of simplified occupancy schedules.

Assumptions and inputs for the energy consumption analysis are available in Section 4 of this report. The energy analysis seems to produce a reasonable output. The total annual energy use is 3,266 MMBH for a total annual energy cost of \$68,714 or \$1.48/ft^2. A majority of the energy consumption comes from electrical HVAC equipment and could greatly be reduced by using higher efficiency components or changing to a higher first cost, lower energy using HVAC System. Complete annual and monthly energy usage and cost results are available in Sections 4.3 and 4.4 of this report.

2.0 Mechanical System Overview

The 48,000 ft² West Virginia University Alumni Center is conditioned by 9 Air Handling Units that serve four distinct space types. As shown in Figure 1, AHU-1, AHU-2, AHU-3, and AHU-9 serve the lobbies, hallways, and office areas of the ground floor, first floor and second floor. These four AHU's provide conditioning through air-cooled direct expansion cooling and gas-furnace heating. AHU-1, AHU-2 and AHU-3 are variable volume AHU's and serve VAV boxes with electric reheat. AHU-9 is a single zone constant volume AHU.

Figure 1 also show AHU-4, AHU-5 and AHU-6 which each provide conditioning to 1/3 of the Banquet Hall while AHU-7 serves the two loggias surrounding the Banquet Hall. These four AHU's also operate with air-cooled direct expansion cooling and gas-furnace heating and they are all single zone constant volume systems with AHU-7 supplying 100% outdoor air.

AHU-8 is a make-up air unit that provides air directly to the kitchen exhaust hoods and is only equipped with gas-fired furnace heating designed to provide 100% outdoor air.

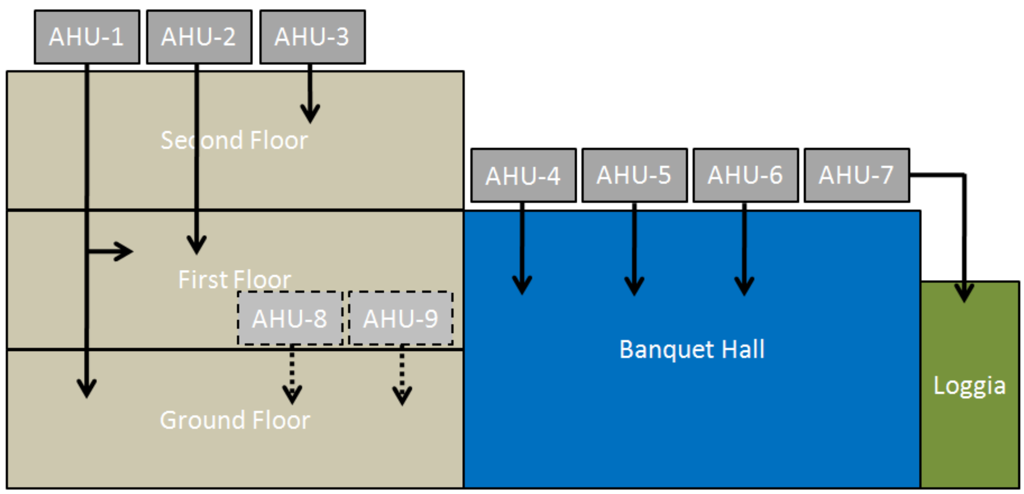

Figure 1 – AHU Distribution Schematic

3.0 Design Load Estimation

3.1 Assumptions

Trane Trace 700 was utilized to estimate the design heating and cooling loads for the Alumni Center. Information to construct the building model was gathered from design documents from both the architect and mechanical engineer. A summary of the basic assumptions used to create the building model are included below.

Outdoor Air Ventilation Rates

All ventilation rates are taken from the mechanical equipment schedules in the mechanical design documents.

Lights and Electrical Equipment Loads and Schedules

The lighting load and electrical equipment loads for the Alumni Center were input on a W/ft^2 basis. The lighting load was based on the calculation performed for Technical Report I using the Whole Building Method of ASHRAE Standard 90.1. Electrical equipment loads were also input on a W/ft^2 basis based on recommendations from the design engineer. Table 1 provides a summary of the lighting and electrical equipment loads used for the design load estimation.

Table 1 – Lighting and Equipment Loads

	Entire Building	Offices	Hallways	Restrooms	Banquet Hall	All Others
Load (W/sq ft)	1.0	1.5	0.5	0.5	0.75	1.5

The utilization schedules for the lighting and equipment loads are based on typical low-rise office buildings. The schedules show the percentage of maximum use at each hour of the day. Tables 2 and 3 summarize the utilization schedules for the equipment and lighting loads.

Table 2 – Equipment Load Schedule

	Equipment
12 am - 7 am	5.0
7 am - 8 am	80.0
8 am -10 am	90.0
10 am - 12 pm	95.0
12 pm - 2 pm	80.0
2 pm - 4 pm	90.0
4 pm - 5 pm	95.0
5 pm - 6 pm	80.0
6 pm - 7 pm	70.0
7 pm - 8 pm	60.0
8 pm - 9 pm	40.0
9 pm - 10 pm	30.0
10 pm - 12 am	20.0

Table 3 – Lighting Load Schedule

	Lights
12 am - 6 am	0.0
6 am - 7 am	10.0
7 am - 8 am	50.0
8 am - 5 pm	100.0
5 pm - 6 pm	50.0
6 pm -7 pm	10.0
7 pm - 12 am	0.0

Design Indoor and Outdoor Air Conditions

The design indoor air conditions were specified by the designer and the outdoor air conditions for the Alumni Center were obtained from the ASHRAE Handbook of Fundamentals 2005 and are noted in Table 3. Additionally, the heating and cooling supply temperatures were taken from the mechanical equipment schedules in the design documents.

Table 4 – Indoor and Outdoor Design Conditions

Summer Design Dry Bulb Temp	90°F
Summer Design Wet Bulb Temp	75°F
Winter Design Dry Bulb Temp	10°F
Indoor Cooling Dry Bulb Temp	75°F
Indoor Heating Dry Bulb Temp	70°F
Indoor Relative Humidity	50%

Occupancy Load and Schedule

The occupancy load is typically based on moderate office activity providing a sensible load of 250 BTU/hr and a latent load of 200 BTU/hr. Other occupancy loads are used based on the use of each space. The occupancy schedule is based on a typical low-rise office building as summarized in Table 5.

Table 5 – Occupancy Load Schedule

	People
12 am - 7 am	0.0
7 am - 8 am	30.0
8 am - 5 pm	100.0
5 pm -6 pm	30.0
6 pm -7 pm	1.0
7 pm - 12 am	0.0

Infiltration

As a newly constructed building the Alumni Center was assumed to have tight construction for the purpose of this design load estimation. With tight construction the infiltration rate was set at 0.3 air changes per hour.

Additional Design Load Assumptions

Additional assumptions including wall constructions and typical rooms are available in Appendix 1.

3.2 Results

Comparison of the results of the modeled building to the actual design shows some similarities and some differences. A summary of the results are in Table 6 below.

Table 6 – Modeled Results versus Designed System

	AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8	AHU-9
ft^2/ton-Modeled	272	220	414	127	127	127	129	N/A	90
ft^2/ton-Designed	306	182	563	127	127	127	142	N/A	75
CFM/ft^2-Modeled	1.01	1.16	0.74	1.25	1.25	1.25	1.39	N/A	3.43
CFM/ft^2-Designed	1.09	1.58	0.59	2.1	2.1	2.1	1.51	N/A	4.6
OA CFM/ft^2-Modeled	0.31	0.41	0.14	1.1	1.1	1.1	1.1	N/A	0.92
OA CFM/ft^2-Designed	0.27	0.55	0.15	1.1	1.1	1.1	1.51	N/A	0.92
Cooling Load-Modeled (Tons)	28.7	43	19.4	18.7	18.7	18.7	28.1	N/A	24.1
Cooling Load-Designed (Tons)	25.5	52	14.25	18.7	18.7	18.7	25.4	N/A	28.9
Heat Load-Modeled (MBh)	236	350	171	238	238	238	414.5	671	238
Heat Load-Designed (MBh)	270	780	270	390	390	390	780	750	540

There are a few small discrepancies in the modeled versus actual cooling tons. There are a few instances where the modeled cooling load is a few tons higher than the actual design. This may be due to the simplified schedule which put every space on a generic office schedule. Many of the conference rooms and offices will most likely not all be utilized at the same time period and therefore the cooling load was increased in the model.

There are also a few discrepancies in the modeled versus actual heating loads. The heating loads as calculated in the model are all lower than the actual design. Some of them are close enough that the difference can be as trivial as the implementation of a small safety factor. Others, however, show significant differences between the calculated load and the actual designed load. Again, this could be due to the simplified office schedule. Spaces such as the loggias, served by AHU-7, are assumed to have a large number of occupants throughout the day, which would greatly decrease the need for heating. However, that is most likely not the case as the loggia is only used sparingly through the day, which is difficult to model. AHU-2 probably also suffers from the simplified schedule since it conditions mostly conference rooms, which most likely are not all occupied at the same time. Reducing the number of occupants increases the need for heat because each occupant produces a significant amount of sensible and latent heat.

4.0 Annual Energy Consumption and Operating Costs

4.1 Energy Analysis by Design Engineer

The MEP design engineers at H.F. Lenz did not perform an energy analysis during the design of this building. An analysis was not performed because it was not a LEED building, it was not required by code, and the owner was not willing to spend the extra money for the service. The system was chosen based on the available budget, best practice and knowledge of the energy usage of various designs

4.2 Assumptions

Trane Trace 700 was utilized to estimate the annual energy consumption and operating for the Alumni Center. All assumptions made for the design load estimation in Section 3.1 of this report are also valid for the energy model. A summary of the additional basic assumptions used to create the building energy model are included below.

Equipment Efficiencies

All equipment was modeled with the efficiencies and EER's as specified in the design documents. A summary of this information is available in Technical Report I.

Supply and Return Fan Types and Energy Use

All supply and return fan types were taken from the equipment schedules on the design documents and their energy use is based on the Horsepower listed on the same schedule. Fan motor mechanical efficiency was assumed to be 75% for all fans.

Air-Cooled Condenser Fan Energy Use

Air-Cooled Condenser fan Horsepower information was obtained from the equipment schedules on the design documents. Fan motor mechanical efficiency was assumed to be 75% for all condenser fans.

Domestic Hot Water Demand

There are two gas-fired water heaters in the Alumni Center. One serves the normal domestic hot water loads of the restrooms while the other serves the hot water needs of the commercial kitchen. The energy use information for the water heaters was obtained from the plumbing design documents and they follow the schedules in Tables 7 and 8.

Table 7 – Domestic Hot Water Load Schedule

	Domestic Hot Water
12 am - 8 am	0.0
8 am - 10 am	55.0
10 am - 11 am	50.0
11 am - 12 pm	55.0
12 pm - 1 pm	90.0
1 pm - 2 pm	60.0
2 pm - 3 pm	80.0
3 pm - 4 pm	70.0
4 pm - 5 pm	75.0
5 pm - 7 pm	30.0
7 pm - 8 pm	50.0
8 pm - 9 pm	5.0
9 pm - 12 am	0.0

Table 8 – Kitchen Hot Water Load Schedule

	Kitchen Hot Water
12 am - 8 am	5.0
8 am - 11 am	70.0
11 am - 2 pm	60.0
2 pm - 5 pm	40.0
5 pm - 11 pm	80.0
11 pm - 12 pm	20.0

Electric Rates

The West Virginia University receives their electricity from a subsidiary of Allegheny Power. They are charged based on the General Service Rate Schedule D. The rate structure is comprised as follows:

Customer Charge: $0 per month
Demand Charge: $11.46 per kilowatt per month for the first 500 kilowatts and $10.25 per kilowatt per month above 500 kilowatts
Energy Charge: $0.02327 per kilowatt-hour

Natural Gas Rates

Natural gas is delivered to the site by Dominion Peoples. They are charged based on Rate CS-S for small commercial buildings. The rate structure is comprised as follows:

Customer Charge: $18.38 per month
First 5 MCF: $14.9672 per MCF
Next 5 MCF: $14.4283 per MCF
Next 20 MCF: $13.9821 per MCF
Over 30 MCF: $13.7310 per MCF

Sample Trane Trace Inputs

Sample inputs of the cooling and heating equipment can be found in Appendix 2.

4.3 Annual Energy Use and Cost Results

The West Virginia University Alumni Center, as modeled, consumes a total of 3,266 MMBH/year with 1,129 MMBH/year in natural gas usage and 2,137 MMBH/year in electricity usage. Figure 2 shows how the annual energy use is divided among the different energy consumers.

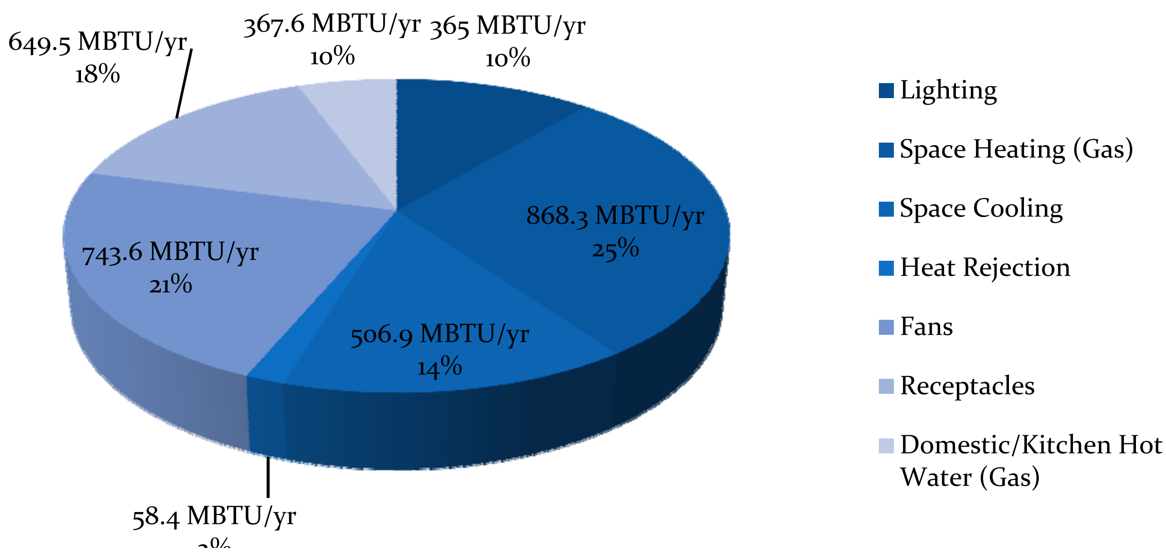

Figure 2 – Annual Energy Consumption by Category

Since the price of natural gas is less expensive than electricity per BTU of consumption it is also important to see how each energy consumer contributes to the entire annual energy cost. The fraction of energy *use* for space heating and hot water is higher than the fraction of energy *cost* for the same categories as shown in Figure 3.

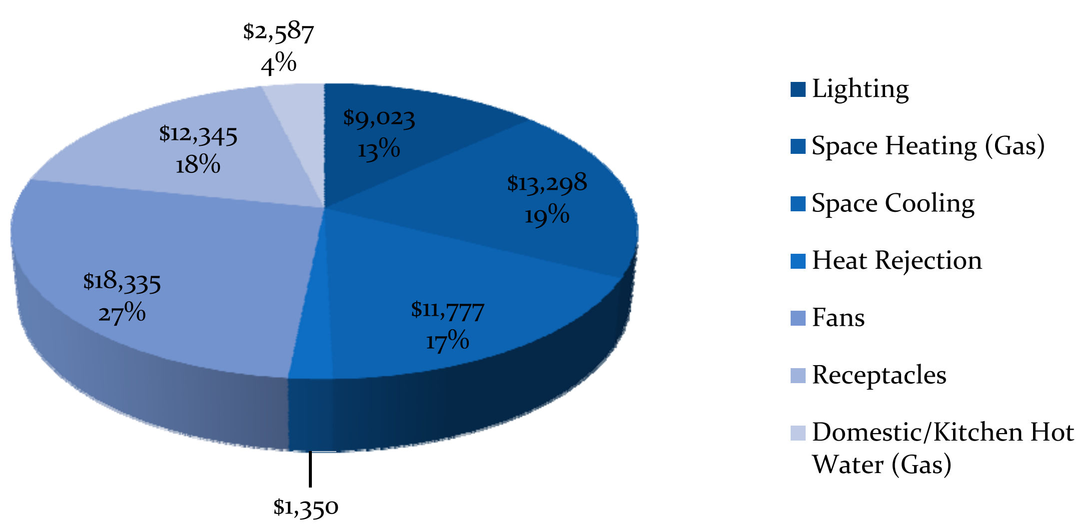

Figure 3 – Annual Energy Cost by Category

The total annual energy cost is $68,714 or about $1.43/ft² with an annual cooling cost of $0.245/ft². The overall energy cost per square foot value is comparable to the value in the ASHRAE Application Handbook-2003. The ASHRAE Application Handbook provides a cost of $1.51.ft² for the average office building. The values in the Application Handbook are based on data from 1995 and are therefore somewhat outdated. Even though the modeled annual energy cost is lower than the value from the Application Handbook, it does not mean that the Alumni Center uses less energy than the average office building. Energy standards have improved since 1995 and the Alumni Center most likely consumes more energy than the average office building constructed in more recent years.

An additional way to see how the Alumni Center's annual energy consumption compares to other buildings is to check its Energy Performance Rating according on EnergyStar's Target Finder website. The Alumni Center's Energy Performance Results are included in Appendix 3. The building achieved an Energy Performance Rating of 54, which indicates that it uses less energy than approximately 54% of buildings with similar characteristics. This means that the Alumni Center is only slightly better than average on an annual energy consumption basis.

4.4 Monthly Energy Use and Cost Results

It is also important to review the month by month energy usage and energy costs to help identify where energy cutting measures should be focused. Figure 4 shows the monthly combined usage of natural gas and electricity. From this figure it is obvious that electric consumption increases in the summer (air-conditioning usage) and that gas usage decreases in the summer (little heating needed). However, Figure 5 shows how energy costs change month by month.

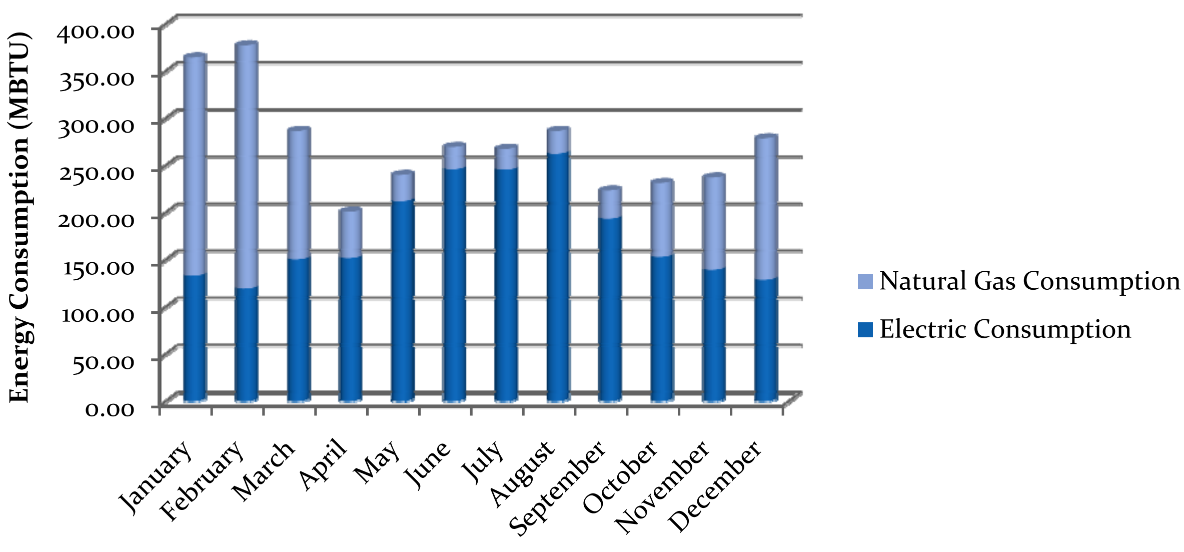

Figure 4 – Monthly Combined Natural Gas and Electric Consumption

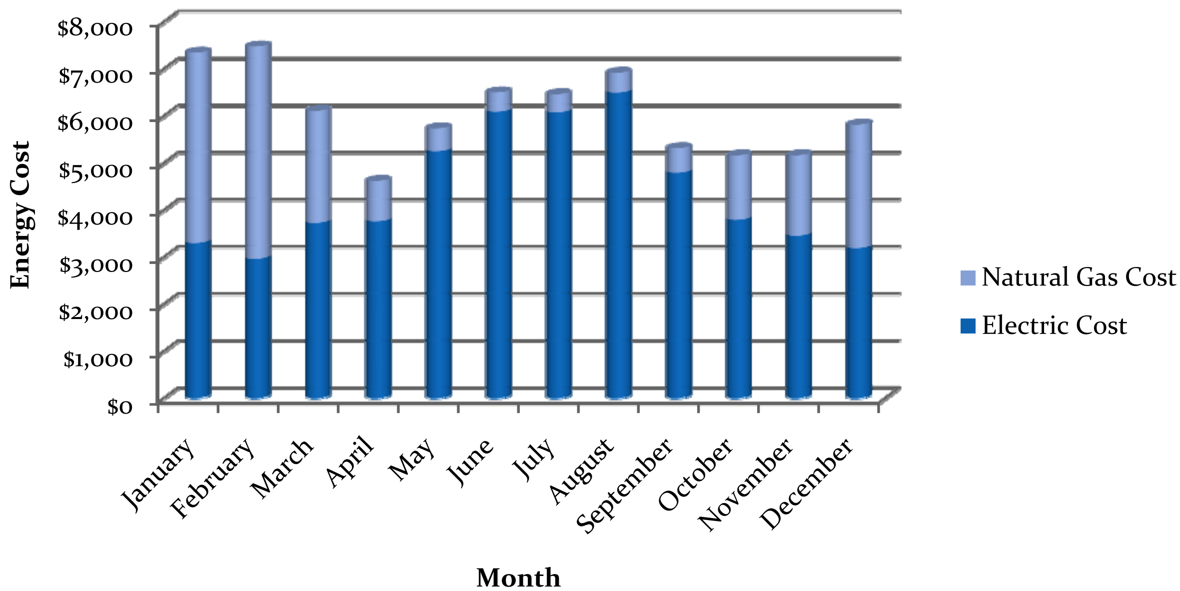

Figure 5 – Monthly Combined Natural Gas and Electric Cost

Figures 4 and 5 show that while in winter months electricity only accounts for 1/3 of the building's energy consumption it accounts for almost half of the overall energy bill. This means that electricity usage is the driving factor of the energy bill during every month of the year, and the focus should be on reducing electrical usage.

Since a majority of the electrical consumption comes from the HVAC systems the possibility is presented to achieve lower energy costs by improving equipment efficiencies or looking for different HVAC systems to utilize for the building to reduce energy costs. The design engineer estimated that during the value engineering phase of the project that utilizing electric reheats in all VAV boxes would add an additional $19,000 in energy cost per year over the use of a system that would be utilizing a central boiler and chiller system.

References

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H.F. Lenz Company. 2003-2008. Mechanical Construction Documents. H.F. Lenz Company, Johnstown, PA.

IKM Inc. 2007. Architectural Construction Documents. IKM Inc., Pittsburgh, PA.

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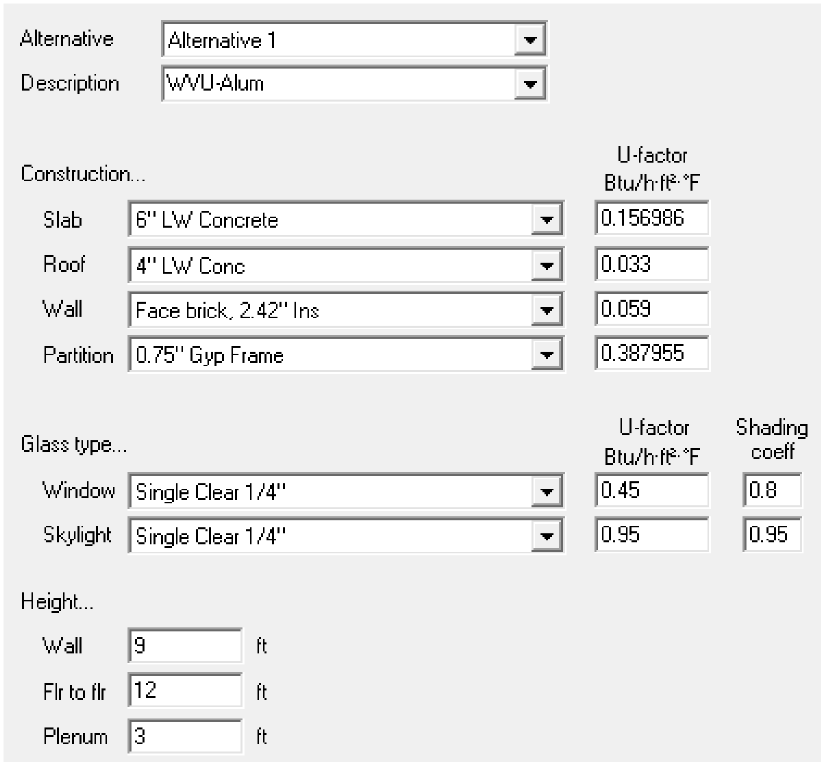
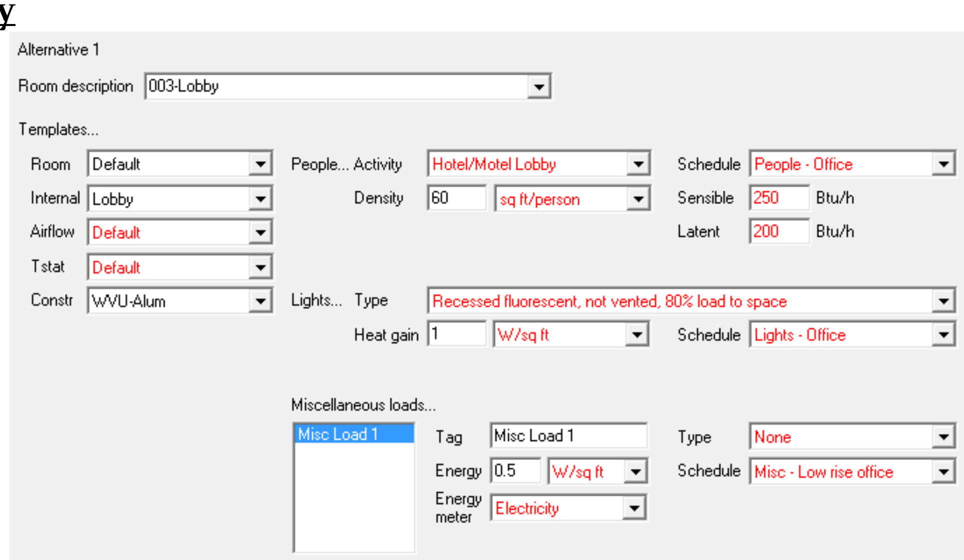
Appendix 1-Additional Design Load Assumptions

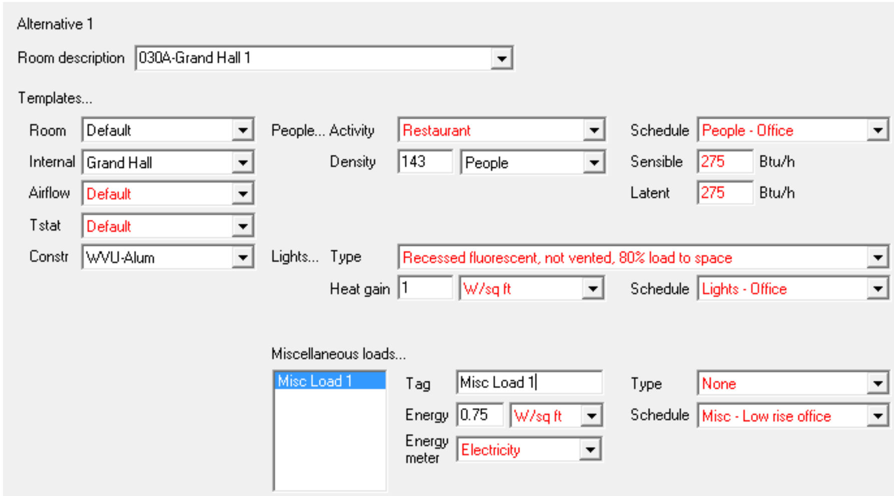
Typical Wall Construction



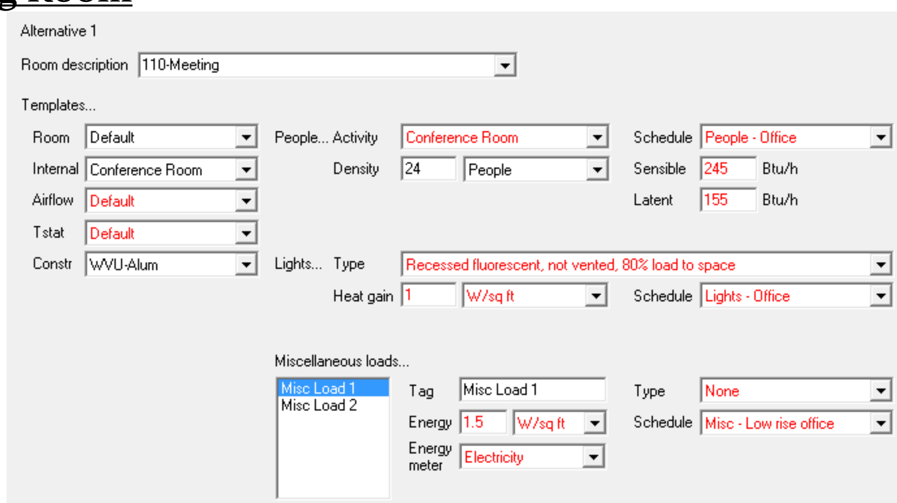
Typical Lobby



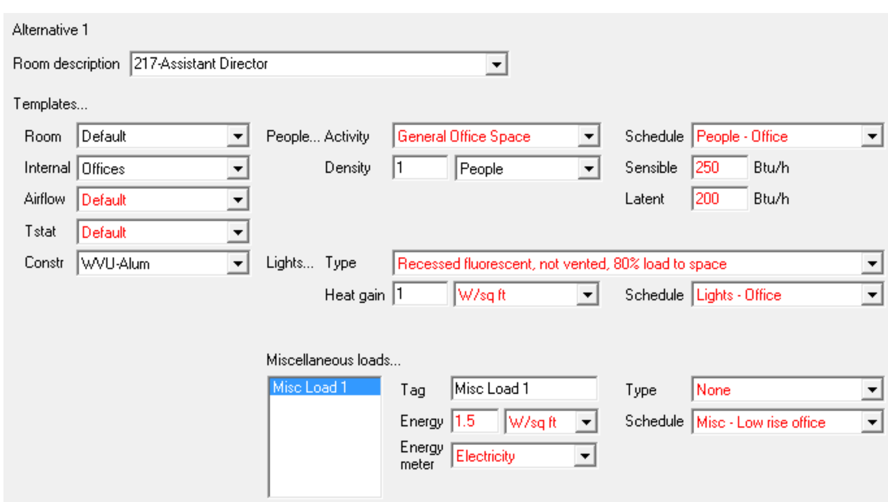
Typical Banquet Hall



Typical Meeting Room

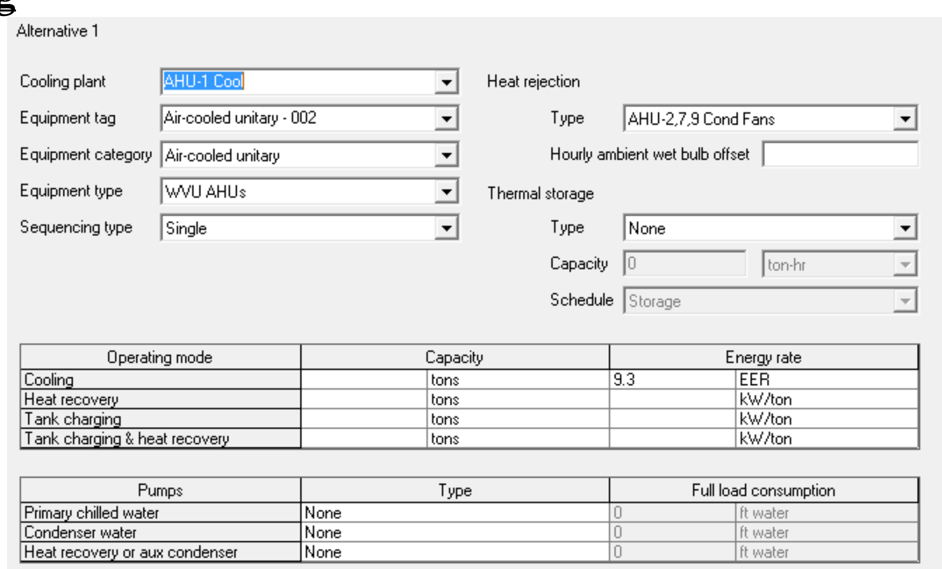


Typical Office



Appendix 2-Sample Equipment Inputs

AHU-1 Cooling



Alternative 1

Cooling plant: AHU-1 Cool
Equipment tag: Air-cooled unitary - 002
Equipment category: Air-cooled unitary
Equipment type: WVU AHUs
Sequencing type: Single

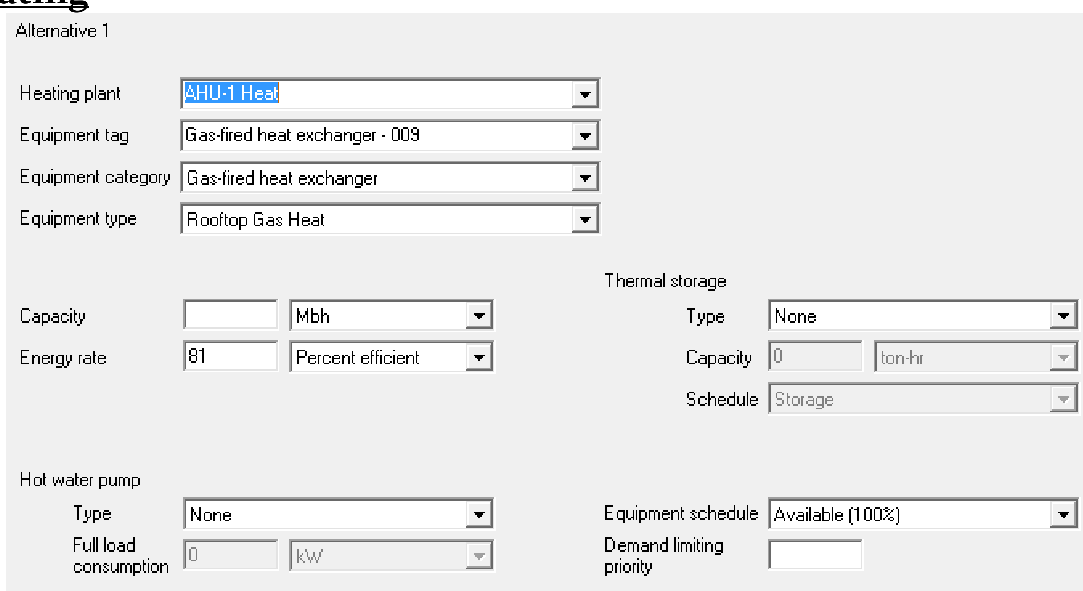
Heat rejection
Type: AHU-2,7,9 Cond Fans
Hourly ambient wet bulb offset:

Thermal storage
Type: None
Capacity: 0 ton-hr
Schedule: Storage

Operating mode	Capacity		Energy rate	
Cooling		tons	9.3	EER
Heat recovery		tons		kW/ton
Tank charging		tons		kW/ton
Tank charging & heat recovery		tons		kW/ton

Pumps	Type	Full load consumption	
Primary chilled water	None	0	ft water
Condenser water	None	0	ft water
Heat recovery or aux condenser	None	0	ft water

AHU-1 Heating



Alternative 1

Heating plant: AHU-1 Heat
Equipment tag: Gas-fired heat exchanger - 009
Equipment category: Gas-fired heat exchanger
Equipment type: Rooftop Gas Heat

Capacity: Mbh
Energy rate: 81 Percent efficient

Thermal storage
Type: None
Capacity: 0 ton-hr
Schedule: Storage

Hot water pump
Type: None
Full load consumption: 0 kW

Equipment schedule: Available (100%)
Demand limiting priority:

Appendix 3-EnergyStar Performance Rating

Target Energy Performance Results (estimated)			
Energy	**Design**	**Target**	**Top 10%**
Energy Performance Rating (1-100)	54	50	90
Energy Reduction (%)	5	0	45
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	173.3	182.7	101.3
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	68.0	71.7	39.7
Total Annual Source Energy (kBtu)	8,319,556.1	8,771,403.9	4,860,604.8
Total Annual Site Energy (kBtu)	3,265,699.4	3,443,064.5	1,907,947.2
Total Annual Energy Cost ($)	$ 72,172	$ 76,091	$ 42,165
Pollution Emissions			
CO2 Emissions (tons/year)	554.6	584.8	324.0
CO2 Emissions Reduction (%)	5%	0%	45%

Facility Information Edit

WVU Alumni Center
Morgantown, WV 26506
United States

Facility Characteristics	Edit
Space Type	**Gross Floor Area (Sq. Ft.)**
Office	48,000
Total Gross Floor Area	48,000

Estimated Design Energy			Edit
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity	kWh	626,348	$ 0.090/kWh
Natural Gas	therms	11,286	$ 1.400/therms

Source: Data adapted from DOE-EIA. See EPA Technical Description.