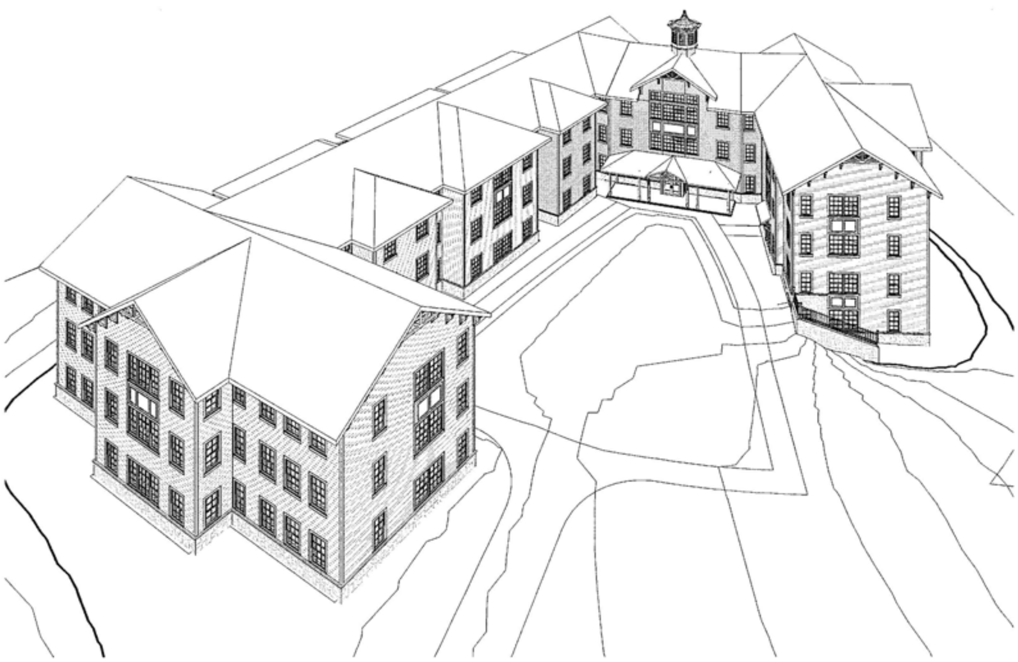
ASHRAE STANDARD 90.1-2004
BUILDING ENERGY ANALYSIS

MECHANICAL TECHNICAL REPORT #2



NEW STUDENT HOUSING BUILDING
AT
THE MOUNT ST. MARY'S UNIVERSITY
EMMITSBURG, MD

Prepared By: Erik Shearer
Mechanical Option
Faculty Advisor: Dr. Jelena Srebric
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EXECUTIVE SUMMARY

The purpose of this report is to perform a detailed energy analysis of the new student housing project soon to be built at the Mount St. Mary's University. Several methods of evaluation will be considered, such as a LEED-NC analysis, a detailed study for compliance with ASHRAE Standard 90.1-2004, analysis of mechanical systems first cost and lost rentable space due to mechanical systems, and building loads, energy usage, and cost estimates.

Although a LEED™ rating was not pursued by the university, the building was designed to be environmentally friendly and energy efficient. Energy recovery and the use of geothermal heat pumps contributed to 26 attainable LEED™ Credits, which would have allowed the building to be Certified.

ASHRAE Standard 90.1-2004 compliance was determined for building envelope, HVAC systems, service water heating, lighting, and motor efficiency. For all intents and purposes, the building was found to be fully compliant with the Standard, only fenestration posing a few questions. First cost of the mechanical systems was approximately $2.3 million or $41.66 per square foot, and they accounted for a mere 1.94% of the available building space.

Carrier's Hourly Analysis Program (HAP) was utilized to estimate building cooling and heating loads, as well as supply and ventilation air flow rates. The calculated results were found to be comparable to the design loads and flow rates. HAP was also used to evaluate building energy consumption and operating costs in order to describe the actual impact various building systems would have on overall energy usage. It was found that heating would account for 6.1% of overall annual costs, cooling would account for 13.2%, and lighting loads would account for 22.3%.

This report illustrates a comprehensive study of building energy usage, showing environmentally conscious techniques, building energy efficiencies, compliance to applicable energy requirements, and estimated actual consumption and costs. Based on the results of this study, when complete, this new student housing project will provide the Mount St. Mary's University with a well designed and energy efficient dormitory.

LEED™ ANALYSIS

Created by the U.S. Green Building Council (USGBC), the Leadership in Energy and Environmental Design (LEED™) rating system is considered to be the "nationally accepted benchmark for the design, construction, and operation of high performance green buildings." Utilization of the LEED™ system encourages an environmentally friendly approach to building design, while at the same time saving on building operating costs.

Four levels of LEED™ certification exist and are dependant upon the number of credits a building receives under six different categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design Process. Receiving between 26 and 32 credits allows a building to become Certified, 33 to 38 receive a Silver rating, 39 to 51 will receive Gold, and 52 to 69 receive Platinum.

Those involved with the new student housing project at the Mount St. Mary's University were very interested in creating an efficient building that would also demonstrate the University's commitment to environmentally conscious design practices. Because this housing project was entirely new construction, a preliminary study of compliance to LEED-NC Version 2.2 was undertaken. Although the university has chosen not to pursue a LEED™ classification, the building would, in fact, have received a minimum of 26 credits and been a candidate for basic certification. It could possibly have been designed to receive a Silver rating if the university had pushed for certain credits, such as Innovative Wastewater Technologies, Measurement and Verification, Outdoor Air Delivery Monitoring, and Controllability of Systems.

Credits that would have been achieved due to mechanical systems are largely from three of the six categories: Water Efficiency, Energy and Atmosphere, and Indoor Environmental Quality. Requirements for Water Use Reduction, Enhanced Refrigerant Management, and Thermal Comfort credits were all designed into the building mechanical systems, and of the ten possible Optimize Energy Performance credits, it was assumed that a minimum of three could have been attained by the geothermal heat pump system. The entire LEED-NC checklist as it was compiled in the initial preliminary analysis is available in Appendix A.

BUILDING ENVELOPE COMPLIANCE

ASHRAE Standard 90.1-2004 stipulates two separate approaches for determining building envelope compliance: the Prescriptive Building Envelope Option and the Building Envelope Trade-Off Option. The Prescriptive Building Envelope Option may be utilized if the following two criteria are met:

- The vertical fenestration area must not exceed 50% of the gross wall area.
- The skylight fenestration area must not exceed 5% of the gross roof area.

After calculating the percentages of the gross areas, it was determined that the vertical fenestration area is 17.1% of the gross wall area, and because the building has no skylights, the skylight percentage is 0%. Therefore, the Prescriptive Building Envelope Option was used to determine building envelope compliance.

Minimum R-Values for the insulation of various wall, roof, and door assemblies were taken from the design documents as follows:

- Roof: *Typical Wood-Framed Assembly* - R-30
- Walls: *Typical Wood-Framed 2x6 Assembly* - R-19
  Typical Stairwell Masonry - 2″ R-10
  Typical Basement Foundation Walls - 2″ R-10
- Floors: *Typical Slab-On-Grade* - 2″ R-10 extending 2′ horizontally and 2′ vertically on inside of foundation wall
- Doors: *Exterior, Hollow Metal* - R-8

Maximum U-Values and Solar Heat Gain Coefficients (SHGC) for fenestration compliance of both operable and fixed windows were taken from the design documents as follows:

- Maximum U-Value = 0.49
- Maximum SHGC = 0.49

Using Table B-1 of Appendix B of the Standard, it was determined that the climate zone for Emmitsburg, Maryland was Zone 4A. Taking the values given above as the basis for design, comparisons were made to required values for envelope compliance as referenced by Table 5.5-4 for Climate Zone 4A in Standard 90.1-2004. Due to the fact that the building in question is a student dormitory, all comparisons were made to 'residential' requirements given by the table except for the attic area, which was compared to 'non-residential' requirements.

Actual U-Values for the assemblies were determined using Appendix A of the Standard and the correlating maximum R-Values as specified in the design documents. The roof U-Value was determined using Table A2.4 for a wood-framed attic with advanced framing. The U-Value for most of the standard exterior walls was determined using Table A3.3, and the U-Values for the masonry walls in the stairwells was determined using the R_u-Value of the masonry from Table A3.1C and the effective R-Value of the insulation from Table A3.1D. The C-Factor for those walls below grade was determined using Table A4.2. For typical floors, Table A5.2 was used to determine the U-Value, and for the unheated slab-on-grade flooring in the basement, Table A6.3 was used. The U-Value for the doors was determined by simply taking the inverse of their maximum allowed R-Value.

After analyzing the entire building envelope, it becomes apparent that the window glazing is incompliant by a slight margin. The maximum SHGC given by the design documents is 0.49, which is greater than that allowed by the maximum SHGC of 0.39 specified by Table 5.5-4, making the entire system incompliant. Typical interior floors are also greatly deficient as they are lacking insulation; however, the fact that the entire building is conditioned should make this requirement unnecessary. A full comparison of the compliance of the design to Standard 90.1-2004 is available in Appendix B of this report.

HVAC SYSTEMS COMPLIANCE

ASHRAE Standard 90.1-2004 stipulates two separate approaches for determining the compliance of building HVAC systems: the Simplified Approach Option and the Mandatory Provisions and Prescriptive Path Option. The Simplified Approach Option may only be used with buildings of no more than 2 stories and no more than 25,000 SF; therefore, the Mandatory Provisions and Prescriptive Path Option will be used in this report.

The mandatory provisions of this method require that certain pieces of mechanical equipment meet required minimum performance criteria. Of those equipment types specified, only the geothermal heat pumps needed to be analyzed. Table D-1 in Appendix D of this report shows the EER values of each pump under cooling conditions and the COPs of each pump under heating conditions. The energy recovery units were not specified and are, therefore, allowed to be used. After analysis, it was determined that all mechanical equipment complied with Standard 90.1-2004.

Other provisions are required by this section as well, many of which must be assumed to be compliant as there is no way to test them in a building that is still not built. While generally required, off-hour controls do not need to be implemented in this building as the HVAC systems are intended to run continuously. Damper leakage rates must be assumed to be less than the maximum allowed. All ductwork and piping must be assumed to have adequate insulation and sealing, and all ductwork must also be assumed to comply with maximum leakage rates.

The prescriptive path of this method also sets requirements for certain systems. While not required due to the small amount of ventilation are being supplied to the spaces, energy recovery was implemented in the design and allowed the building to maintain stable pressurization. Economizers were not required because the building is being built in Climate Zone 4A. Zone controls are designed to prevent reheating and recooling. Maximum allowable nameplate horsepowers for fans are also specified, and Table D-2 of Appendix D of this report shows the comparisons between actual and allowable fan horsepowers.

After analysis, it was determined that all mechanical equipment and HVAC systems complied with Standard 90.1-2004.

SERVICE WATER HEATING COMPLIANCE

ASHRAE Standard 90.1-2004 has certain requirements for the performance of service heating water systems. Some assumptions which must be made are that pipe insulation, temperature controls, and pump controls are compliant with the standard.

The student housing project at the Mount St. Mary's University has one domestic hot water heater that is gas powered. The unit was selected to be able to handle a capacity of 750 GPM/hr with a total output of 500 MBH and a gas input of 600 MBH. The efficiency of the unit is rated at 83%. In order to comply with Standard 90.1-2004, the standing loss, or energy lost when the unit is not operating, is governed by the following equation from Table 7.8 of the Standard:

$$SL = 0.8 * E_t * ((Q/800) + (110 * \sqrt{V}))$$

Where:

SL = Standing Loss
E_t = Thermal Efficiency = 0.83
Q = Input Rate in BTU/hr = 600,000
V = Rated Volume in Gallons = 750

This equation is used for gas storage water heaters with input capacities greater than 75 MBH and capacities per gallon of less than 4 MBH/gal. Utilizing the above equation, the standing loss of this unit must be no greater than 516 BTU/hr. The manufacturer of this unit guarantees this by stating that the unit is compliant to ASHRAE Standard 90.1-2004 for both efficiency and standing loss.

LIGHTING COMPLIANCE

ASHRAE Standard 90.1-2004 stipulates two separate approaches for determining lighting compliance in buildings: the Building Area Method and the Space-By-Space Method. The Building Area Method is simpler, comparing energy consumed by lighting in a building to a general lighting power density for that type of building. The Space-By-Space Method determines entire building compliance by comparing individual spaces instead of the entire building. Total allowable wattages are summed and compared to the sum of the actual building wattages. This approach is more flexible, allowing trade-offs among the spaces so long as the total installed interior lighting power does not exceed the interior lighting power allowance. In this report, the Space-By-Space Method will be used to better show the comparisons between space types.

Assumptions that must be made to utilize the Space-By-Space Method are as follows:

- All spaces in the student housing project are enclosed by partitions 80% or greater than the ceiling height.
- The following space types from Table 9.6.1 of the Standard shall be used:

Space Types	Lighting Power Density
Dormitory-Living Quarters	1.1
Restroom	0.9
Lounge/Recreation	1.2
Laundry-Washing	0.6
Corridor/Transition	0.5
Electrical/Mechanical	1.5
Stairs-Active	0.6
Control Room	0.5
Active Storage	0.8

- Janitor's closets and trash/recycling rooms shall be considered to be active storage, and electrical/telecom rooms shall be considered control rooms.

After analyzing the building for lighting compliance, it is apparent that alone, many of the space types exceed their maximum power allowances; however, the suites are well below their allowances, and when energy trade-offs are factored in, the building as a whole easily complies with Standard 90.1-2004. Appendix C of this report contains space lighting comparisons and calculations.

ELECTRIC MOTOR EFFICIENCY COMPLIANCE

The new student housing project at the Mount St. Mary's University was designed to comply with ASHRAE Standard 90.1-2004 for motor efficiencies. It is specified in Section 15 of the building specifications that all motors of greater than 1 horsepower shall conform to the guidelines set forth in Table 10.8 of the Standard. The Specifications also indicate that for motors of less than 1 horsepower, efficiencies should be greater than those of "average standard industry motors." In this manner, the electric motors within the building can be considered compliant with the Standard.

LOST RENTABLE SPACE

The new student housing project at the Mount St. Mary's University is a dormitory, and the building's purpose is to house as many students as possible within its confines. Space lost to mechanical equipment or ventilation shaft space could potentially limit the size of the dormitory rooms, allowing for fewer students to occupy the building.

The usage of geothermal heat pumps on this project has lessened the need for mechanical space somewhat, as has the implementation of a dedicated outdoor air system (DOAS). While the heat pumps themselves do take up a certain amount of space, the geothermal system requires less equipment to be housed within the building, allowing for the possibility of a smaller mechanical room. The pumps also allow for the DOAS system to be utilized, cutting down greatly on duct shaft space as only ventilation and exhaust air need to be circulated. The energy recovery units are all located in the attic, alleviating the need to allocate space for their operation.

Appendix E of this report shows calculations for not only lost rentable space due to mechanical systems, but also lost rentable space due to all systems as a whole. In both cases, the lost rentable space was very low, being 1.94% for mechanical systems as shown in Table E-1 and 2.55% for all combined building systems as shown in Table E-2.

MECHANICAL SYSTEM FIRST COST

All information required to determine mechanical system first cost was provided by Burdette, Koehler, Murphy, and Associates, Inc., the MEP consulting firm that worked on the Mount St. Mary's student housing project.

The first cost is broken down by materials, labor, taxes, bonding, and other miscellaneous additions to the project scope. The final totals are presented as a total cost and as a cost per square foot of building area.

Mechanical System First Cost	
Total Materials:	$790,900
Total Labor:	$1,440,700
Total Taxes:	$40,400
Total Bond:	$25,000
Scope Additionals:	$18,360
First Cost:	$2,315,360
Total Building Square Footage:	55,580
Cost Per Square Foot:	$41.66

This cost per square foot is fairly high for a mechanical system in a building of this size. For further comparison, one could look at the total estimated building cost of approximately $10,800,000. The geothermal system and heat pumps, the energy recovery units, and, most importantly, the labor to install these systems pushes the cost of the mechanical system up to 21.4% of the entire building cost.

DESIGN LOAD ESTIMATION

There are many factors that contribute to a building's heating and cooling loads. Climate, thermal efficiency of the building's envelope, internal lighting and electrical loads, mechanical systems, and people all contribute to the loads that must then be designed to and compensated for. For the purpose of this report, Carrier HAP was utilized to simulate the new student housing project at the Mount St. Mary's University and to determine the loads and air flow rates required for adequate thermal comfort.

Occupancies, floors areas, and ventilation rates were taken from the design documents, and design outdoor air conditions from Hagerstown, Maryland were used in this simulation due to its close proximity to Emmitsburg. Because the building is a student dormitory, it was assumed that the building should be designed at close to full capacity with an occupancy schedule of 80%. Lighting power densities were taken from Standard 90.1-2004 and were assumed to be on a 60% usage schedule, while the suites were given electrical equipment power densities of 0.75 W/ft^2 on an assumed usage schedule of 80%. All exterior walls, windows, roof areas, and slab-on-grade flooring were taken into account, as well as standard infiltration rates and ventilation rates as required by Standard 62.1-2004.

A brief summary of calculated results as compared to actual design data is provided below. Some inconsistencies between the numbers can be contributed to incorrect estimates of schedules, lighting and electrical equipment power densities, and other general conditions. The large difference in the cooling loads may also be contributed to the fact that the design data is based on the total rated capacity of the building's various geothermal heat pumps; the actual loads being seen by these units are not described on the design documents and are probably less than their rated capacities. System ventilation rates are low due to the fact that the energy recovery units are coupled with natural ventilation and were never meant to account for the entire ventilation requirements of the building. A more detailed breakdown of system loads may be found in Appendix H of this report.

Energy Usage Comparisons				
System	Output	Cooling (ft^2/Ton)	Supply Air (CFM/ft^2)	Ventilation Air (CFM/ft^2)
ERU-1	HAP	634	1.13	0.10
	Design	395	1.13	0.07
ERU-2	HAP	619	1.04	0.10
	Design	426	1.02	0.06
ERU-3	HAP	662	1.04	0.11
	Design	414	1.04	0.06

ENERGY USAGE AND COST ESTIMATION

Carrier HAP was also used to conduct electrical consumption and operating cost simulations. Using the same HAP file used for the design load estimation, electric and natural gas rates from Baltimore Gas and Electric were incorporated into the program for correct rating periods and times of year. The new student housing project was assumed to utilize rates from the Large General Service schedule for Type II-A Market priced service. A detailed breakdown of rating periods, electrical utility rates, and natural gas utility rates can be found in Appendix F of this report.

After running the simulation it was determined that the building's mechanical systems will account for roughly 57% of the building's annual energy consumption and 55% of the annual operating costs. The table below shows a simple breakdown of basic system costs.

Total Costs	
HVAC	$83,753
Non-HVAC	$68,407
Total	$152,160

A more detailed annual cost breakdown by percentage of cost as well as a comparison of monthly heating, cooling, and lighting costs can be found in Appendix G of this report. No energy analysis was preformed by the engineer on this project; such a report was not requested and the engineer did not feel that he had a program at his disposal that would reflect energy usage accurately enough. A more detailed breakdown of system energy consumption and operating costs may be found in Appendix H of this report.

APPENDIX A

LEED-NC Version 2.2 Registered Project Checklist

Mount St. Mary's University Student Housing Project

Yes	?	No			
6		8	**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 and 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 Management**, Quantity Control	1
1			Credit 6.2	**Stormwater Management**, 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			
3		2	**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			
4	1	12	**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	**Fundimental Refrigerant Management**	Required
3	1	6	Credit 1	**Optimize Energy Performance**	1 to 10
		3	Credit 2	**On-Site Renewable Energy**	1 to 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

continued...

Yes	?	No			
	3	10		**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 Interiorr 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 post-industrial)	1
		1	Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ post-industrial)	1
	1		Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
		1	Credit 5.2	**Regional Materials,** 20% Extracted, Processed & Manufactured Regionally	1
		1	Credit 6	**Rapidly Renewable Materials**	1
		1	Credit 7	**Certified Wood**	1

Yes	?	No			
10	4	1		**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**, Verication	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			
3	1	1		**Innovation & Design Process**	5 Points
1			Credit 1.1	**Innovation in Design**: Education Program	1
1			Credit 1.2	**Innovation in Design**: O&M Materials	1
	1		Credit 1.3	**Innovation in Design**: None	1
		1	Credit 1.4	**Innovation in Design**: None	1
1			Credit 2	**LEED™ Accredited Professional**	1

Yes	?	No		
26	9	34	**Project Totals** (pre-certification estimates)	69 Points

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

APPENDIX B

Table B-1: Vertical Glazing Percentage

Vertical Glazing, % of Wall	
Total Wall Area	35400
Total Glazing Area	6050
% Vertical Glazing	17.1

Table B-2: Envelope Comparison for 'Residential' Classification

	Design		Standard 90.1-2004		
Opaque Elements	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Compliant
Roof					
Wood-Framed Attic, Advanced	U - 0.032	30.0	U - 0.034*	30.0*	YES
Walls, Above Grade					
Mass	U - 0.083	10.0	U - 0.104	9.5	YES
Wood-Framed	U - 0.067	19.0	U - 0.089	13.0	YES
Walls, Below Grade					
Below Grade Wall	C - 0.092	10.0	C - 1.140	--	YES
Floors					
Mass	U - 0.322	0.0	U - 0.087	8.3	NO
Slab-On-Grade Floors					
Unheated	F - 0.700	10.0	F - 0.730	--	YES
Opaque Doors					
Swinging	U - 0.125	8.0	U - 0.700	--	YES
Fenestration	Assembly Max. U-Value (Fixed/Operable)	Max. SHGC (All Orientations/ North Oriented)	Assembly Max. U-Value (Fixed/Operable)	Max. SHGC (All Orientations/ North Oriented)	Compliant
Vertical Glazing, % of Wall					
10.1% - 20%	U - 0.49Fixed U - 0.49Operable	0.49All 0.49North	U - 0.57Fixed U - 0.67Operable	0.39All 0.49North	NO

*Roof values were compared to 'Non-Residential' classification.

APPENDIX C

Table C-1: Total Building Lighting Compliance

Space-By-Space Method Wattage Comparisons			
Space Type	Wattage	Allowable Wattage	
Dormitory-Living Quarters	14716	36149	
Restroom	3992	3029	
Lounge/Recreation	2992	3398	
Laundry-Washing	576	157	
Corridor/Transition	8112	2610	
Electrical/Mechanical	512	632	
Stairs-Active	1674	1227	
Control Room	384	99	
Active Storage	384	226	
Total Building	33342	47526	**Compliant**

Table C-2: Basement Lighting Wattages

Basement Lighting Wattages				
Space Designation	Area (SF)	Wattage	Allowable Lighting Power Density (W/SF)	Allowable Wattage
Suite 012	720	312	1.1	792
Bathroom 012	78	84	0.9	70
Suite 013	766	364	1.1	843
Bathroom 013	61	84	0.9	55
Suite 014	694	312	1.1	763
Bathroom 014	84	84	0.9	76
Elect. Equip. Room	142	192	1.5	213
Mechanical Room	279	320	1.5	419
Corridor	534	936	0.5	267
Stairway	160	186	0.6	96
Janitor's Closet	55	64	0.8	44

Table C-3: First Floor Lighting Wattages

First Floor Lighting Wattages				
Space Designation	Area (SF)	Wattage	Allowable Lighting Power Density (W/SF)	Allowable Wattage
Suite 101	708	312	1.1	779
Bathroom 101	84	84	0.9	76
Suite 102	627	286	1.1	690
Bathroom 102	61	84	0.9	55
Stairway	215	248	1.2	248
Double	225	104	1.1	248
Double Bathroom	46	43	0.9	41
Electrical/Telecom	30	64	0.5	15
Small Lounge	133	192	1.4	192
Suite 103	768	312	1.1	845
Bathroom 103	80	84	0.9	72
Suite 104	776	338	1.1	854
Bathroom 104	61	84	0.9	55
Suite 105	607	286	1.1	668
Bathroom 105	61	84	0.9	55
Suite 106	793	364	1.1	872
Bathroom 106	61	84	0.9	55
Suite 107	797	364	1.1	877
Bathroom 107	61	84	0.9	55
Suite 108	776	338	1.1	854
Bathroom 108	61	84	0.9	55
Suite 109	718	338	1.1	790
Bathroom 109	61	84	0.9	55
Suite 110	720	312	1.1	792
Bathroom 110	76	84	0.9	68
Janitor's Closet	49	64	0.8	39
Double	197	78	1.1	217
Double Bathroom	41	43	0.9	37
Corridor	1184	1716	0.5	592
Large Lounge	882	840	1.2	1058
Bathroom	49	32	0.9	44
Laundry	87	192	0.6	52
Trash/Recycling	81	128	0.8	65
Electrical/Telecom	25	64	0.5	13
Suite 111	225	104	1.1	248
Bathroom 111	54	58	0.9	49
Suite 112	720	312	1.1	792
Bathroom 112	78	84	0.9	70
Suite 113	776	364	1.1	854
Bathroom 113	61	84	0.9	55
Suite 114	694	312	1.1	763
Bathroom 114	84	84	0.9	76
Stairway	215	248	0.6	129
Corridor	329	572	0.5	165

Table C-4: Second and Third Floor Lighting Wattages

Second and Third Floor Lighting Wattages				
Space Designation	Area (SF)	Wattage	Allowable Lighting Power Density (W/SF)	Allowable Wattage
Suite 201/301	708	312	1.1	779
Bathroom 201/301	84	84	0.9	76
Suite 202/302	627	286	1.1	690
Bathroom 202/302	61	84	0.9	55
Stairway	215	248	1.2	248
Double	225	104	1.1	248
Double Bathroom	46	43	0.9	41
Electrical/Telecom	30	64	0.5	15
Small Lounge	133	192	1.4	192
Suite 203/303	768	312	1.1	845
Bathroom 203/303	80	84	0.9	72
Suite 204/304	776	338	1.1	854
Bathroom 204/304	61	84	0.9	55
Suite 205/305	607	286	1.1	668
Bathroom 205/305	61	84	0.9	55
Suite 206/306	793	364	1.1	872
Bathroom 206/306	61	84	0.9	55
Suite 207/307	797	364	1.1	877
Bathroom 207/307	61	84	0.9	55
Suite 208/308	776	338	1.1	854
Bathroom 208/308	61	84	0.9	55
Suite 209/309	718	338	1.1	790
Bathroom 209/309	61	84	0.9	55
Suite 210/310	720	312	1.1	792
Bathroom 210/310	76	84	0.9	68
Janitor's Closet	49	64	0.8	39
Double	197	78	1.1	217
Double Bathroom	41	43	0.9	37
Corridor	1184	1716	0.5	592
Large Lounge	735	788	1.2	882
Laundry	87	192	0.6	52
Electrical/Telecom	41	64	0.5	21
Suite 211/311	376	182	1.1	414
Bathroom 211/311	54	58	0.9	49
Suite 212/312	720	312	1.1	792
Bathroom 212/312	78	84	0.9	70
Suite 213/313	776	364	1.1	854
Bathroom 213/313	61	84	0.9	55
Suite 214/314	694	312	1.1	763
Bathroom 214/314	84	84	0.9	76
Stairway	215	248	0.6	129
Corridor	402	728	0.5	201

APPENDIX D

Table D-1: Geothermal Heat Pump Compliances

Heat Pump Compliance					
Cooling Mode:					
Designation	Output (BTU/hr)	Input (W)	Actual EER	Max. Allowable EER a	Compliant
HP-1	21360	2400	8.9	16.2	YES
HP-2	22540	2800	8.1	16.2	YES
HP-3	28900	3200	9.0	16.2	YES
HP-4	11100	1800	6.2	16.2	YES
HP-5	21360	2400	8.9	16.2	YES
HP-6	8180	1200	6.8	16.2	YES
Heating Mode:					
Designation	Output (BTU/hr)	Input (BTU/hr)	Actual COP	Max. Allowable COP b	Compliant
HP-1	21360	8189	2.6	3.1	YES
HP-2	22540	9554	2.4	3.1	YES
HP-3	28900	10919	2.6	3.1	YES
HP-4	11100	6142	1.8	3.1	YES
HP-5	21360	8189	2.6	3.1	YES
HP-6	8180	4095	2.0	3.1	YES

[a]Maximum allowable EER values are based on an EWT temperature of 59 °F. Actual EWT for these units is 77 °F.

[b]Maximum allowable COP values are based on an EWT temperature of 32 °F. Actual EWT for these units is 35 °F.

Table D-2: Allowable Fan Nameplate Power Compliances

Fan Power Compliance					
Fan Designation	Supply Air Flow (CFM)	Type	Allowable Nameplate Motor Power (HP)	Actual Nameplate Motor Power (HP)	Compliant
ERU1-SF	1050	CAV	1.26	0.75	YES
ERU2-SF	1050	CAV	1.26	0.75	YES
ERU3-SF	1050	CAV	1.26	0.75	YES
ERU1-EF	1050	CAV	1.26	0.75	YES
ERU2-EF	1050	CAV	1.26	0.75	YES
ERU3-EF	1050	CAV	1.26	0.75	YES
MECH-EF	375	CAV	0.45	0.10	YES
LAUNDRY-EF	1320	VAV	2.24	0.50	YES

APPENDIX E

Table E-1: Lost Rentable Space Due to Mechanical Systems

Mechanical Rooms and Shaft Space	
Space Type	Total Square Footage
Mechanical Room	279
Elevator Machine Room	50
Heat Pump Closets	600
Mechanical Shafts	105
Stairwell Heaters	42
Total Building Area	55580
Lost Rentable Space	1076
Percent Lost Rentable Space	1.94

Table E-2: Lost Rentable Space Due to All Building Systems

Total Lost Rentable Space	
Mechanical Space	1076
Other Space	340
Total Building Area	55580
Lost Rentable Space	1416
Percent Lost Rentable Space	2.55

APPENDIX F

Table F-1: BG&E Rating Periods

Rating Periods	
Summer:	
Peak	10 AM to 8 PM on Weekdays
Intermediate	7 AM to 10 AM and 8 PM to 11 PM on Weekdays
Off-Peak	All Weekends and Holidays
Non-Summer:	
Peak	7 AM to 11 AM and 5PM to 9 PM on Weekdays
Intermediate	11 AM to 5 PM on Weekdays
Off-Peak	All Weekends and Holidays

Table F-2: Electrical Utility Rates

Delivery Service Customer Charge:	$100.00/Month	
Delivery Charges	Summer ($/kW)	Non-Summer
Transmition Charge for Market-Priced Service:	0.98	0.98
Delivery Service:	2.67	2.67
Energy Charges	Summer (¢/kWh)	Non-Summer
Generation Charge for Market-Priced Service:		
Peak	15.138	12.236
Intermediate	11.835	10.662
Off-Peak	10.340	8.646
Delivery Service Charge:	1.239 ¢/kWh	

Table F-3: Natural Gas Utility Rates

Natural Gas Utility Rates	
Customer Charge	
	$100.00/Month
Delivery Price	
First 10,000 Therms:	19.75 ¢/Therm
All Over:	9.48 ¢/Therm

APPENDIX G

Figure G-1: Annual Systems Cost Breakdown

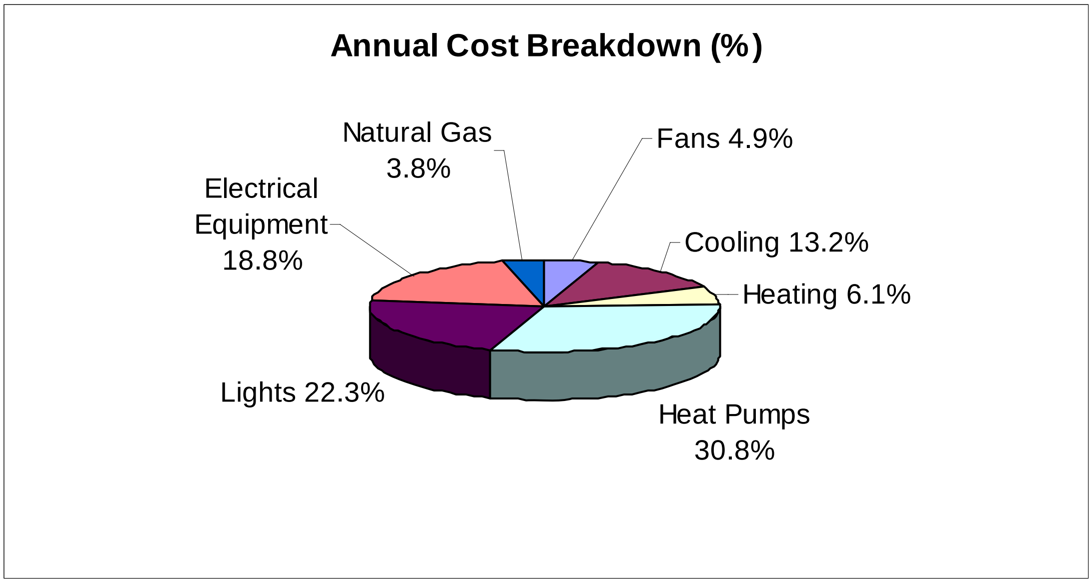
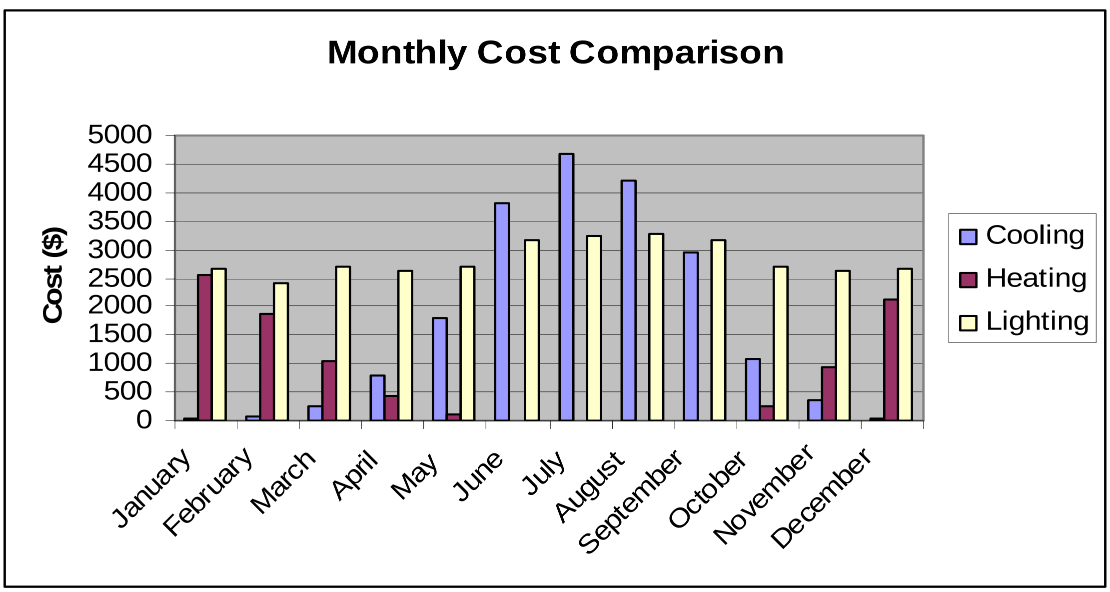


Figure G-2: Monthly System Cost Comparison



APPENDIX H

Air System Design Load Summary for ERU-1

Project Name: Erik Shearer - Mount St. Marys University
Prepared by: psuae
10/27/2006
12:10AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1500 COOLING OA DB / WB 94.0 °F / 75.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 8.0 °F / 5.8 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1866 ft²	54254	-	1866 ft²	-	-
Wall Transmission	7506 ft²	16185	-	7506 ft²	31619	-
Roof Transmission	4859 ft²	40823	-	4859 ft²	36322	-
Window Transmission	1866 ft²	13769	-	1866 ft²	56689	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4859 ft²	0	-	4859 ft²	8581	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	9743 W	33241	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	7510 W	25625	-	0	0	-
People	60	14707	12306	0	0	0
Infiltration	-	14998	8941	-	48940	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	**-**	**213602**	**21247**	**-**	**182151**	**0**
Zone Conditioning	-	208239	21247	-	180627	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Exhaust Fan Load	0 CFM	0	-	0 CFM	0	-
Ventilation Load	1395 CFM	27112	13257	1395 CFM	90303	0
Ventilation Fan Load	0 CFM	0	-	0 CFM	0	-
Space Fan Coil Fans	-	7472	-	-	-7472	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**242823**	**34505**	**-**	**263458**	**0**
Terminal Unit Cooling	-	242823	33463	-	0	0
Terminal Unit Heating	-	0	-	-	263458	-
>> Total Conditioning	**-**	**242823**	**33463**	**-**	**263458**	**0**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

Air System Design Load Summary for ERU-2

Project Name: Erik Shearer - Mount St. Marys University 10/27/2006
Prepared by: psuae 12:15AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1600 COOLING OA DB / WB 93.3 °F / 74.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 8.0 °F / 5.8 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2348 ft²	59249	-	2348 ft²	-	-
Wall Transmission	8643 ft²	19307	-	8643 ft²	36409	-
Roof Transmission	5776 ft²	42343	-	5776 ft²	43177	-
Window Transmission	2348 ft²	17107	-	2348 ft²	71332	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	42 ft²	78	-	42 ft²	326	-
Floor Transmission	6053 ft²	0	-	6053 ft²	10156	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	12209 W	41656	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	11454 W	39081	-	0	0	-
People	73	18035	15634	0	0	0
Infiltration	-	16961	11154	-	57337	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	253816	26787	-	218735	0
Zone Conditioning	-	250646	26787	-	215982	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Exhaust Fan Load	0 CFM	0	-	0 CFM	0	-
Ventilation Load	1828 CFM	34223	21517	1828 CFM	118228	0
Ventilation Fan Load	0 CFM	0	-	0 CFM	0	-
Space Fan Coil Fans	-	8779	-	-	-8779	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	-	293648	48305	-	325431	0
Terminal Unit Cooling	-	293649	47807	-	0	0
Terminal Unit Heating	-	0	-	-	325431	-
>> Total Conditioning	-	293649	47807	-	325431	0
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Air System Design Load Summary for ERU-3

Project Name: Erik Shearer - Mount St. Marys University 10/27/2006
Prepared by: psuae 12:16AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1400 COOLING OA DB / WB 93.3 °F / 74.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 8.0 °F / 5.8 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1637 ft²	40715	-	1637 ft²	-	-
Wall Transmission	7045 ft²	14699	-	7045 ft²	29677	-
Roof Transmission	3276 ft²	29566	-	3276 ft²	24489	-
Window Transmission	1637 ft²	11508	-	1637 ft²	49732	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	21 ft²	38	-	21 ft²	163	-
Floor Transmission	3358 ft²	0	-	3358 ft²	4497	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	8648 W	29505	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	6867 W	23431	-	0	0	-
People	49	11936	9988	0	0	0
Infiltration	-	13097	7700	-	44277	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	**-**	**174495**	**17687**	**-**	**152835**	**0**
Zone Conditioning	-	169943	17687	-	150250	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Exhaust Fan Load	0 CFM	0	-	0 CFM	0	-
Ventilation Load	1445 CFM	27076	14493	1445 CFM	93477	0
Ventilation Fan Load	0 CFM	0	-	0 CFM	0	-
Space Fan Coil Fans	-	6606	-	-	-6606	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**203625**	**32180**	**-**	**237121**	**0**
Terminal Unit Cooling	-	203625	31046	-	0	0
Terminal Unit Heating	-	0	-	-	237249	-
>> Total Conditioning	**-**	**203625**	**31046**	**-**	**237249**	**0**
Key:	**Positive values are clg loads** **Negative values are htg loads**			**Positive values are htg loads** **Negative values are clg loads**		

Annual Component Costs - Mount St. Mary's Student Housing

Erik Shearer - Mount St. Marys University 10/26/2006
psuae 11:57PM

1. Annual Costs

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	7,432	0.165	5.1
Cooling	20,108	0.446	13.7
Heating	9,344	0.207	6.4
Pumps	46,869	1.039	32.0
Cooling Tower Fans	0	0.000	0.0
HVAC Sub-Total	**83,753**	**1.856**	**57.2**
Lights	33,948	0.752	23.2
Electric Equipment	28,658	0.635	19.6
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**62,605**	**1.387**	**42.8**
Grand Total	**146,358**	**3.243**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **45129.0** ft²
Conditioned Floor Area .... **45129.0** ft²

Annual Energy and Emissions Summary

Erik Shearer - Mount St. Marys University
psuae

10/27/2006
02:58AM

Table 1. Annual Costs

Component	Mount St. Mary's Student Housing ($)
HVAC Components	
Electric	83,754
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0
HVAC Sub-Total	**83,754**
Non-HVAC Components	
Electric	62,604
Natural Gas	5,802
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**68,405**
Grand Total	**152,159**

Table 2. Annual Energy Consumption

Component	Mount St. Mary's Student Housing
HVAC Components	
Electric (kWh)	654,698
Natural Gas (Therm)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	494,328
Natural Gas (Therm)	21,900
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0

Annual Energy and Emissions Summary

Erik Shearer - Mount St. Marys University
psuae

10/27/2006
02:58AM

Table 3. Annual Emissions

Component	Mount St. Mary's Student Housing
CO_2 (lb)	0
SO_2 (kg)	0
NOx (kg)	0

Table 4. Annual Cost per Unit Floor Area

Component	Mount St. Mary's Student Housing ($/ft²)
HVAC Components	
Electric	1.856
Natural Gas	0.000
Fuel Oil	0.000
Propane	0.000
Remote HW	0.000
Remote Steam	0.000
Remote CW	0.000
HVAC Sub-Total	**1.856**
Non-HVAC Components	
Electric	1.387
Natural Gas	0.129
Fuel Oil	0.000
Propane	0.000
Remote HW	0.000
Remote Steam	0.000
Non-HVAC Sub-Total	**1.516**
Grand Total	**3.372**
Gross Floor Area (ft²)	45129.0
Conditioned Floor Area (ft²)	45129.0

Note: Values in this table are calculated using the Gross Floor Area.

Annual Energy and Emissions Summary

Erik Shearer - Mount St. Marys University
psuae

10/27/2006
02:58AM

Table 5. Component Cost as a Percentage of Total Cost

Component	Mount St. Mary's Student Housing (%)
HVAC Components	
Electric	55.0
Natural Gas	0.0
Fuel Oil	0.0
Propane	0.0
Remote HW	0.0
Remote Steam	0.0
Remote CW	0.0
HVAC Sub-Total	**55.0**
Non-HVAC Components	
Electric	41.1
Natural Gas	3.8
Fuel Oil	0.0
Propane	0.0
Remote HW	0.0
Remote Steam	0.0
Non-HVAC Sub-Total	**45.0**
Grand Total	**100.0**

Monthly Component Costs - Mount St. Mary's Student Housing

Erik Shearer - Mount St. Marys University
psuae

10/27/2006
01:41AM

1. HVAC Component Costs

Month	Air System Fans ($)	Cooling ($)	Heating ($)	Pumps ($)	Cooling Towers ($)	HVAC Total ($)
January	584	44	2,569	3,684	0	6,881
February	532	66	1,868	3,353	0	5,819
March	589	286	1,058	3,717	0	5,650
April	571	784	418	3,603	0	5,376
May	591	1,800	105	3,725	0	6,221
June	695	3,820	1	4,383	0	8,899
July	708	4,688	0	4,465	0	9,861
August	720	4,193	1	4,539	0	9,453
September	695	2,959	17	4,384	0	8,055
October	588	1,074	238	3,708	0	5,608
November	572	353	931	3,609	0	5,465
December	587	42	2,138	3,699	0	6,466
Total	**7,432**	**20,108**	**9,344**	**46,869**	**0**	**83,753**

2. Non-HVAC Component Costs

Month	Lights ($)	Electric Equipment ($)	Misc. Electric ($)	Misc. Fuel Use ($)	Non-HVAC Total ($)	Grand Total ($)
January	2,669	2,253	0	491	5,412	12,293
February	2,428	2,050	0	453	4,932	10,751
March	2,693	2,273	0	491	5,456	11,106
April	2,609	2,203	0	478	5,290	10,666
May	2,698	2,278	0	491	5,467	11,688
June	3,174	2,680	0	478	6,332	15,231
July	3,234	2,730	0	491	6,455	16,316
August	3,288	2,775	0	491	6,554	16,007
September	3,175	2,680	0	478	6,334	14,389
October	2,686	2,267	0	491	5,444	11,052
November	2,614	2,207	0	478	5,299	10,764
December	2,679	2,262	0	491	5,432	11,898
Total	**33,948**	**28,658**	**0**	**5,802**	**68,407**	**152,160**

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