Calvin College

BHT Dorm Project

Final Technical Report

Engineering 333

2010

Background

Calvin College dorms have a chronic issue with wasting energy. The dorms have little insulation, high infiltration rates, and are heated by low efficiency boilers. These existing characteristics combine for a larger required heating load and increased energy usage. The excess heat, due to poor temperature control, is often vented out through the windows whenever students deem necessary. This project will attempt to reduce wasted energy and efficiently distribute heat as needed.

Introduction

The Thermal Systems Design class of 2010 was challenged with retrofitting the Bolt-Heyns-Timmer (BHT) dorm to decrease energy consumption and improve efficiency. The class was presented with the following problem statement: *"The goal for the [BHT] heating system renovation is a 30% reduction in energy use compared to the existing system."* When addressing this problem of energy production and supply, the class set a control volume solely around BHT.

In order to accomplish this task, the class was separated into six groups focusing on energy modeling, infrastructure, heating, cooling, ventilation, and financial analysis. An executive team was also formed with a leader from each group. The executive team was tasked with determining the overall direction of the project and facilitating communication for the whole class.

Procedure

To determine the optimal design, a thorough understanding of the existing system was first required. Using the BHT construction specifications, an energy model of BHT was created and verified with an outside consultant. This model provided a sizing estimate for the heating and cooling groups. Heating and cooling groups developed the following alternatives (Table 1 and Table 2) to meet the required design.

Table 1: Heating Alternatives and Design Criteria

	Biomass Boiler	Geothermal	Hot Water Boiler	Modular Boilers
Cost	$600,000/unit	$788,800 /unit	$80,000/unit	$80,250 / 3 units
Efficiency	Up to 90%	COP = 3 (300%)	Up to 90%	Up to 95%
Fuel Supply	Biomass (wood, leaves, switch grass)	-Electricity -Earth's thermal reservoir	Natural Gas	Natural Gas
System Type	Centralized	Centralized	Centralized	Decentralized

Table 2: Cooling Alternatives and Design Criteria

	Window AC Units	Geothermal	Air Cooled Chiller
Cost	Initial : $80,000 Operating: $25,000/yr	Initial: $788,000 Operating:$11,310/yr	Initial: $193,600 Operating: $21,000/yr
COP	2.8	3	3
Aesthetics	In each room Noise	Bore field Noise	Enclosure Noise
System Type	Decentralized	Centralized	Decentralized

Evaluation of the heating and cooling systems was governed by four main challenges: how much does it cost, how is it made, where to put it, and how to deliver it. After an optimal design was chosen, an energy model of the proposed HVAC system was created. Finally, whether or not the energy efficiency goal was met, the final cost, and the payback feasibility were determined.

Results

The final designs for the BHT dorm renovation project include three modular boilers and two air cooled scroll chillers. The modular boilers proved to be the most cost effective and convenient dorm heating source. The modular boilers have a 1.4MMBTU/hr output and have cyclic control for varying periods of demand. All three boilers will be placed in the BHT mechanical room in the basement. The heat will be distributed through a fan coil system that will be placed throughout the dorms. In addition to implementing fan coils, new piping will also be put into the entire dorm. Due to building code regulations, a ventilation system will also be implemented in the dorm hallways and any rooms that do not meet the fresh air regulation requirement. The chillers used for air conditioning will be two 90 ton chillers with a partial heat recovery system. The air conditioning system will utilize the same fan coils, piping, and ventilation as the heating system.

The cost for the entire heating system will be approximately $675,000 and the entire cost for the cooling system will be approximately $194,000. A 30 year cumulative cost forecast for the proposed heating system is shown in Figure 1. As shown in the graph, the system will not pay for itself within 30 years. Lastly, the yearly operating cost for the cooling system will be approximately $27,500.

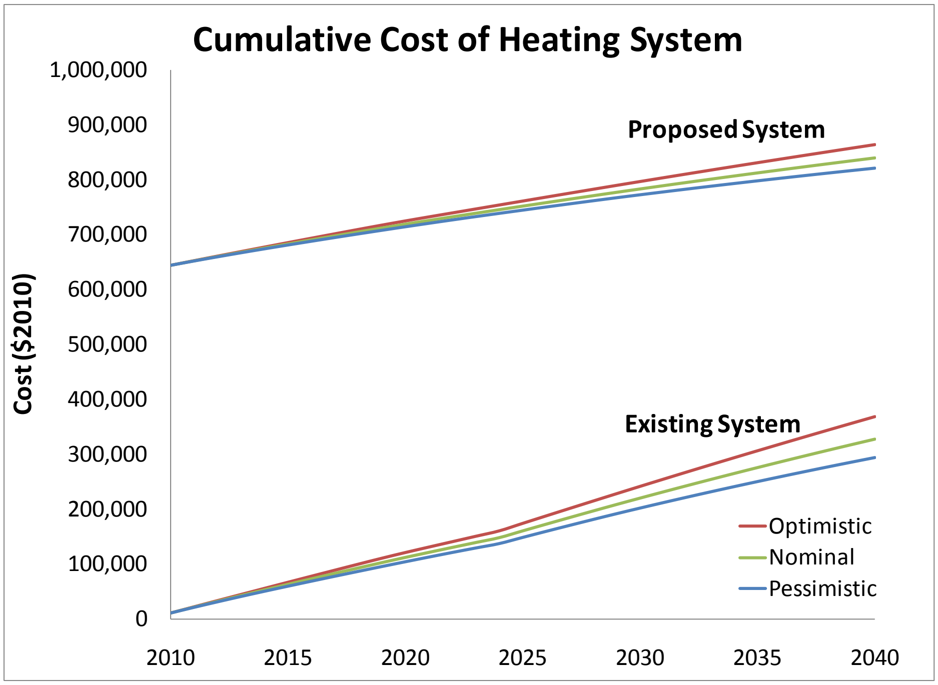

Figure 1: 30 Year Cost Forecast for Existing and Current Heating Systems.

Conclusion

There are three important conclusions that can be drawn from Figure 1. The first conclusion is that there is a very high upfront cost to the system. The second conclusion is that the lines do not cross. This means that even within the lifetime of the system, it will not pay for itself. This is due to the high initial cost and the low amount of total money saved per year. The third conclusion is that the economic uncertainties have no affect on the payback period. The uncertainties in the lines do not bring the systems close enough to argue that with more economic variation there may be a payback.

From the design and optimization of the new system for BHT, it became clear that a more centralized approach would be more beneficial from energy and financial standpoints. A big issue that was discovered throughout the analysis of this project was that the domestic hot water dominates the yearly gas usage for the dorms (Figure 1, Appendix B). It is recommended that Calvin College pursue a centralized system, with a control volume around the whole campus or all the dorms, to increase Calvin's energy efficiency and to be better stewards of God's creation.

Appendices

Appendix A Infrastructure

Objective

The Infrastructure/Power Plant (Infrastructure) team was formed to provide information regarding current energy and infrastructure systems at Calvin College, specifically for the Bolt-Heyns-Timmer (BHT) dormitory. Interfacing mainly with Physical Plant staff at Calvin College, the Infrastructure team gathered pertinent information for other teams (heating, cooling, ventilation, financial/CERF and LEED) to use during the semester project on BHT energy consumption and efficiency.

Background

The Infrastructure/Power Plant team was to investigate all existing energy systems on campus as well as the resources available and constraints due to the current campus infrastructure. The gathering of information was necessary to fully understand the problem definitions as well as making justified engineering design decisions. The Infrastructure/Power Plants team was formed to fill the role of understanding the problem definition from the perspective of the current design and knowing how changes would affect the current design in BHT and the system.

Procedure

During the initial phases of the BHT project, the Infrastructure team recognized that a more organized system of receiving and answering questions was necessary. The Request for Information (RFI) system was established to better facilitate communication between teams. All questions were submitted to a team representative from the leader of each team, and then delegated to the other team members of the Infrastructure group. Once questions were delegated, individual team members sought resources and gathered the information necessary to fully answer the posed questions. Information was compiled in the form of a report and a response to the RFI was sent to the team that asked the question.

The Infrastructure team also set up several meetings with outside sources. On numerous occasions, the team met with employees from the physical plant to learn more about current infrastructure. Meetings took place to find drawings of BHT and learn about energy use at Calvin College in the past. Other meetings were arranged to learn more about the HVAC infrastructure at Calvin College and BHT in particular.

The Infrastructure team provided recommendations for some of the groups during the decision making process in regards to choosing a final design direction. Such input from the Infrastructure team was based on information provided by the Physical Plant and research gathered by the Infrastructure team. Recommendations provided the design groups with a more complete understanding of implementing different designs and the approach Calvin College would take to install and carry through projects.

Results

Throughout the project, Infrastructure received and answered initial questions and then follow-up questions for all other groups on the project. Questions were submitted using a form that can be seen in Appendix A-1. A total of nine official RFI Reports were completed using the format seen in Appendix

A-2. However, more questions were answered than displayed by the table due to the RFI system being implemented during the mid-way point of the project. The Infrastructure team did not have specific results to report upon completion of the project. The purpose of the team was not produce a definite answer for the BHT question, but to aid other teams in their decision making process.

Conclusion/Discussion

Overall, the Infrastructure team concluded the project was successful based on no outstanding questions and the positive feedback received in regards to the RFI system. Should a similar project be approached, the Infrastructure team would use the RFI system from the beginning to best handle the communication between many different individuals and parties involved with the project.

Appendix A-1 Example RFI Questionnaire

Request for Information

Note: Allow at least 3-5 day for response

Save for your records and email Jason a copy

Send attachment to: jasonbusscher@gmail.com with subject line "Request for Information"

Name: "Click and Type Name Here"
Email: "Click and Type email Here"
Group Name: "Click and Type Group Name Here"
Date of Inquiry: Click here to enter a date.

Is this question related to a previous report: Choose an item. "Type Report Number or Delete"

Question:
"Type Question Here"

Objective of Inquiry:
"Type Why The Question is Important to You Here"

Response Deadline:
Click here to enter a date.

Explanation for Response Deadline (if urgent):
"Type Why You Need This Information in Less Than 5 Days"

Other Comments:
"Type Other Potentially Helpful Commets Here"

FOR INFRASTRUCTURE TEAM USE ONLY
Assignment Number: "Type Assignment Number Here"
Category: Choose an item.
Assigned to:Choose an item.
Assigned on:Click here to enter a date.
Due Date:Click here to enter a date.

Send attachment to: jasonbusscher@gmail.com with subject line "Request for Information"

Appendix A-2 RFI Report Form

	Report Number	
	XXX	
Title: Example Report		

1.1 Introduction:

1.2 Summary

1.3 Conclusion

1.4 Recommendation

By: {Infrastructure Team}	**For: {ENGR 333 Team}**	**RFI #:**

Appendix B Energy Model

Introduction

Energy modeling software is a computer simulation used to analyze the energy needs of a building. The software inputs the building's design parameters, such as general construction information, insulation, orientation and number of windows, occupancy schedules, etc. It then generates a model that is able to simulate the energy consumption and requirements throughout a year. eQuest is a free software program from the Department of Energy that was used in modeling the BHT dormitory.

Use of eQuest Model

The program was used to model the layout, construction, and infiltration of the BHT dormatory. From the model, peak HVAC heating loads were produced and assisted in appropriately sizing the proposed heating units for the building. Since actual gas metering data was not available, the estimated annual gas consumption for both the existing and proposed HVAC designs provided opportunities to calculate operating costs of the current and proposed designs. Finally, the model was used to determine whether or not the proposed designs met the goal of a 30% reduction in energy consumption.

Critical Design Parameters

To produce a model of the dormitory in eQuest, a few simplifying assumptions were required. Both models had the boilers turned off during the summer. The existing building model used one natural draft steam boiler that operated up to 24 hours a day once it was turned on during the school year. Heat from the steam boilers was supplied to BHT through fin tubes. A second design used three modular, condensing hot water boilers operating at a 92% efficiency that delivered heat to BHT through the existing fin tubes. The final design again used three modular, condensing hot water boilers, each with a 92% efficiency and a 1,400 kBTU/hr capacity. Heat from the modular boilers was provided to BHT through fan coils, which had the ability to operate 24 hours a day.

Results

The energy model produced a peak building load of 20 (BTU/hr)/sqft. This number was validated by the model produced by GMB Architecture and Engineering. The peak building cooling load was found to be approximately 166 tons, confirming that the 180 ton cooling system would be sufficient for BHT. The total monthly gas consumption for each of the three systems investigated was output. As shown below (Table 1), the system that utilized the current fin tubes along with the proposed modular boilers only yielded at 20% increase in energy efficiency. The final design of pairing a fan coils with the modular boilers increased this efficiency to 55%.

Table 1: Total Monthly Natural Gas Consumption (MMBTU)

	Existing	Fin Tubes	Fan Coils
Jan	406.3	311.6	217.9
Feb	207.6	166	81.3
Mar	57.6	47.6	17.2
Apr	0.6	2.8	0.2
May	0	0	0
Sep	0	0	0
Oct	0.4	1.5	0.2
Nov	14.7	18.9	4.7
Dec	163	134.5	62.4
Total	**850.2**	**682.9**	**383.9**
Efficiency Gained		**20%**	**55%**

Conclusions

The eQuest energy model was able to accurate simulate the energy needs of the BHT dormitory as well as the current and proposed system energy consumptions. The model demonstrated the achievement of a 55% increase in gas consumption energy efficiency in the proposed system, exceeding the initial goal of a 30% increase in energy efficiency. Finally, as illustrated below (Figure 1), the simulation brought to light the domination domestic water heating has on the fuel consumption of BHT. Calvin College should pursue renovating the way domestic hot water is heated if it aspires to further increase the energy efficiency of its dormitories.

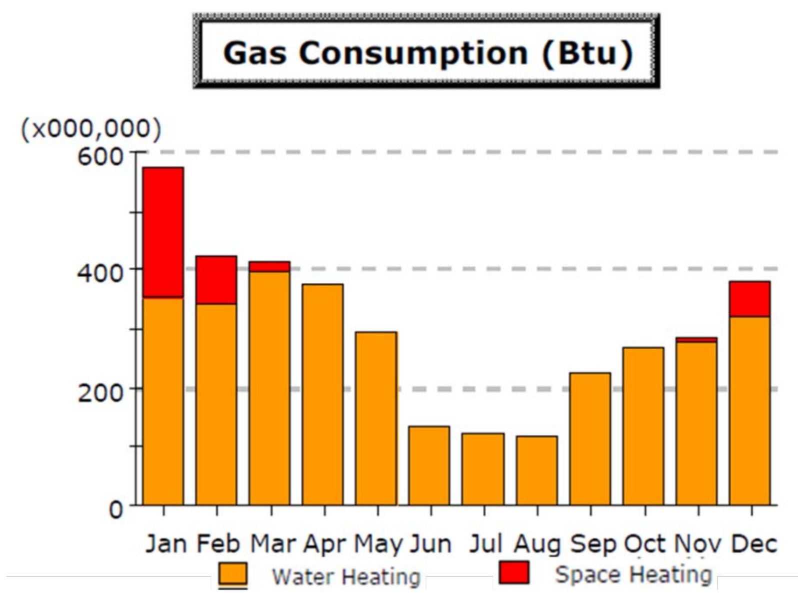

Figure 1: Monthly Gas Consumption for Domestic Hot Water and Space Heating

Energy Modeling List of Figures and Tables

FLOOR AREA	95959	SQFT	8915	M2
VOLUME	863628	CUFT	24458	M3

	COOLING LOAD		HEATING LOAD	
TIME	SEP 9 6PM		JAN 1 4AM	
DRY-BULB TEMP	82 F	28 C	-11 F	-24 C
WET-BULB TEMP	73 F	23 C	-12 F	-24 C
TOT HORIZONTAL SOLAR RAD	124 BTU/H.SQFT	390 W/M2	0 BTU/H.SQFT	0 W/M2
WINDSPEED AT SPACE	6.6 KTS	3.4 M/S	0.0 KTS	0.0 M/S
CLOUD AMOUNT 0(CLEAR)-10	0		0	

	COOLING SENSIBLE (KBTU/H)	COOLING SENSIBLE (KW)	COOLING LATENT (KBTU/H)	COOLING LATENT (KW)	HEATING SENSIBLE (KBTU/H)	HEATING SENSIBLE (KW)
WALL CONDUCTION	136.704	40.054	0.000	0.000	-727.850	-213.260
ROOF CONDUCTION	6.887	2.018	0.000	0.000	-43.237	-12.668
WINDOW GLASS+FRM COND	51.214	15.006	0.000	0.000	-188.487	-55.227
WINDOW GLASS SOLAR	113.153	33.154	0.000	0.000	3.202	0.938
DOOR CONDUCTION	3.913	1.147	0.000	0.000	-9.527	-2.791
INTERNAL SURFACE COND	0.000	0.000	0.000	0.000	0.000	0.000
UNDERGROUND SURF COND	-25.210	-7.387	0.000	0.000	-81.560	-23.897
OCCUPANTS TO SPACE	335.597	98.330	320.198	93.818	14.404	4.220
LIGHT TO SPACE	366.718	107.448	0.000	0.000	2.309	0.676
EQUIPMENT TO SPACE	350.377	102.660	0.000	0.000	123.503	36.186
PROCESS TO SPACE	0.000	0.000	0.000	0.000	0.000	0.000
INFILTRATION	76.305	22.357	196.890	57.689	-1025.253	-300.399
TOTAL	1415.658	414.788	517.087	151.507	-1932.495	-566.221
TOTAL / AREA	0.015	0.047	0.005	0.017	-0.020	-0.064
TOTAL LOAD	1932.746 KBTU/H		566.294 KW		-1932.495 KBTU/H	-566.221 KW
TOTAL LOAD / AREA	20.14 BTU/H.SQFT		63.523 W/M2		20.139 BTU/H.SQFT	63.514 W/M2

Figure 2: Peak Building Cooling and Heating Loads (same for both existing system and final design)

- - - - - - - - - H E A T I N G - - - - - - - - -						- - - E L E C - - -	
HEATING ENERGY (MBTU)	TIME OF MAX DY	HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM HEATING LOAD (KBTU/HR)	ELEC-TRICAL ENERGY (KWH)	MAXIMUM ELEC LOAD (KW)
-186.084	2	7	15.F	13.F	-3263.290	164617.	321.178
-67.434	16	1	13.F	11.F	-938.266	153326.	319.965
-11.886	21	9	15.F	14.F	-263.206	175605.	319.639
-0.052	3	9	34.F	33.F	-13.551	169731.	319.504
0.000	31	1	66.F	63.F	0.000	148383.	319.504
0.000	30	1	63.F	59.F	0.000	83725.	246.751
0.000	31	1	59.F	55.F	0.000	85291.	246.751
0.000	31	1	60.F	60.F	0.000	86601.	246.751
0.000	30	1	48.F	47.F	0.000	155319.	319.504
-0.031	24	9	31.F	28.F	-10.144	168485.	319.504
-2.436	29	8	22.F	20.F	-128.736	160390.	319.515
-51.088	25	1	34.F	33.F	-1656.236	166444.	319.920
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-319.012						1717911.	
					-3263.290		321.178

Table 2: Peak HVAC Heating Load of Final Design

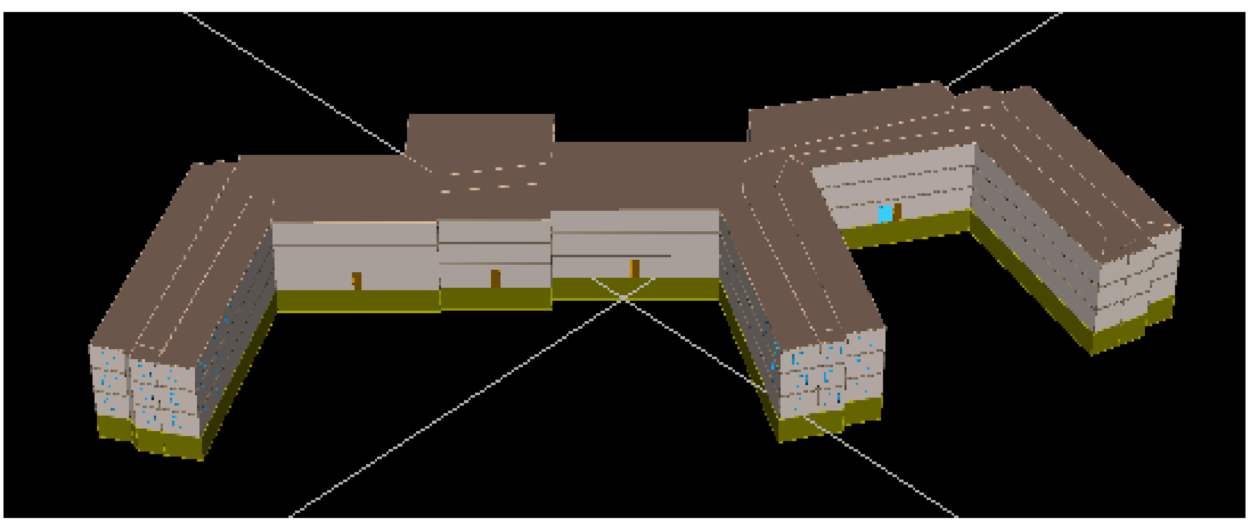


Figure 3: 3D Model of BHT created in eQuest

Table 3 Comparison of HVAC for Existing and Final Design

	Existing System	Final Design
Delivery	Fin Tubes	Fan Coils
Heat Supply Type	Natural Draft Steam Boiler	Condensing Hot Water Boiler
# Units/Dorm	1	3
Efficiency	60%	92%

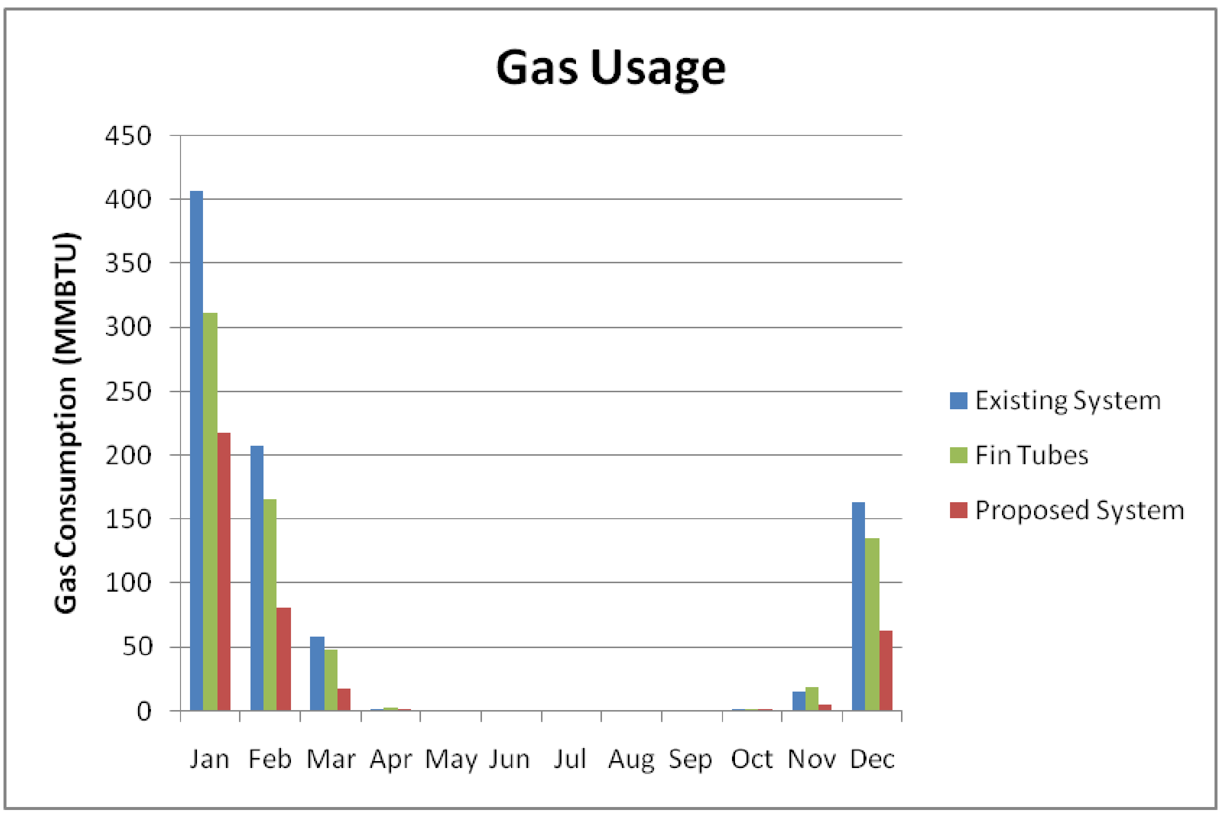


Figure 4: Total Monthly Gas Consumption for Different HVAC Systems

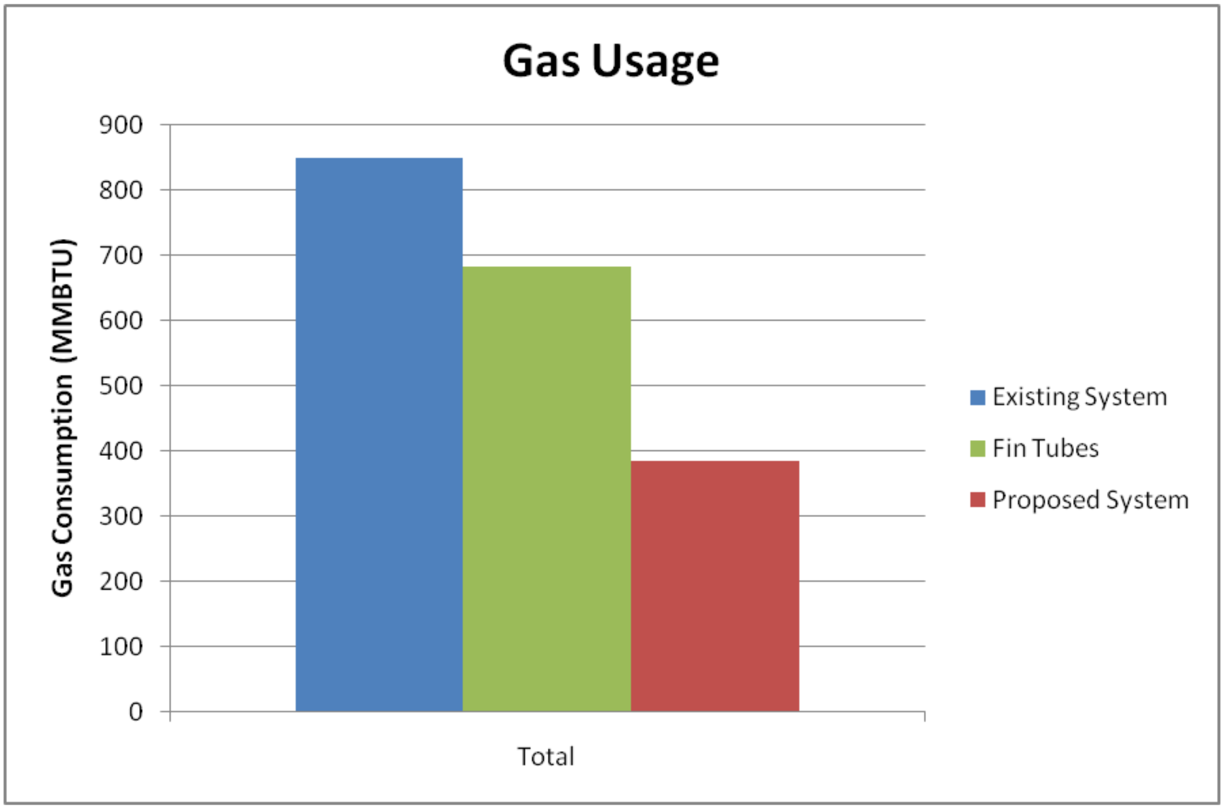


Figure 5: Total Annual Gas Consumption of Different HVAC Systems

Appendix C Heating

Introduction

The purpose of the heating group was to overcome three challenges: how to make the heat, where to put the machines, and how to deliver the heat to the rooms.

Design Process

The design process began with brainstorming ideas of how to heat the dorm more efficiently. Ideas were narrowed to the four most feasible options. These options were then investigated in depth, which involved getting quotes, sizing the system, and researching similar existing systems. Advantages and disadvantages for each option were compared, and the best option was analyzed as a point design. Once all groups agreed on a final design, the details of the system were specified, including distribution, location, and specific component selection.

Design Options

The first design option would burn a biomass fuel (i.e. switch grass or wood pellets) in a boiler to heat up water. The second design option was geothermal heating. This would involve moving heat from underground to the dorm. The third design option would use a large hot water boiler, similar to the boilers in the science power plant, to provide hot water to the dorm. The final design option was to use several high efficiency modular boilers to provide hot water to the dorm. Each option was researched, and Table 1 summarizes the advantages and disadvantages of each.

Table 1 Design Criteria for Different Heating Systems

	Biomass Boiler	Geothermal	Hot Water Boiler	Modular Boilers
Cost	$600,000/unit	$788,800 /unit	$80,000/unit	$80,250 / 3 units
Efficiency	Up to 90%	COP = 3 (300%)	Up to 90%	Up to 95%
Fuel Supply	Biomass (wood, leaves, switch grass)	-Electricity -Earth's thermal reservoir	Natural Gas	Natural Gas
System Type	Centralized	Centralized	Centralized	Decentralized

Design Selection

All of the design options could have met the energy reduction goals, and also could count for LEED credits; however, not all options were feasible to implement at Calvin. A biomass boiler was not selected because the boiler required large fuel storage space and a consistent biomass supply. The option was more renewable than others, but this advantage was not enough to offset the disadvantages. A geothermal heat pump system was considered, but proved to only be financially feasible on a larger scale. A hot water boiler option addressed a larger control volume than the scope of the project, as BHT alone does not need all the heat output from a boiler of this size. The domestic hot water lines run off the current steam boiler in Commons so replacing it with a hot water boiler would introduce a domestic hot water issue, which is outside the realm of our project. Modular boilers were selected because they are energy efficient, cost effective and incorporate redundancy.

Final Design

The final components were selected based on the energy peak load (3.26 MMBTU/hr) calculated by the energy modeling group. For further information on the energy model see Appendix B. Three 1.4 MMBTU/hr Pulse Combustion Hydroponic Boilers manufactured by Fulton were selected to meet the peak load requirement. See Appendix C-1 for further boiler specifications. These units will be located in the mechanical room within the basement of BHT; a drawing of this can be found in Appendix C-2. The existing heat exchangers for heating will be removed, and the pumps will be rebuilt and reused for the modular boilers. The heat will be delivered by fan coil units, similar to the units in most hotel rooms. More specifications for the fan coils can be seen in Appendix F.

Post Design Recommendations

The main post design recommendation is to change the control volume from around BHT to include more of the campus. Calvin College has already shown that they are interested in centralized systems as they provide more redundancy in the system and less individual units to maintain. A more appealing payback period may be achieved with a centralized approach.

Heating System Appendices

Appendix C-1 Boiler Specifications Sheet

Industrial/Commercial Division
Fulton Heating Solutions, Inc.

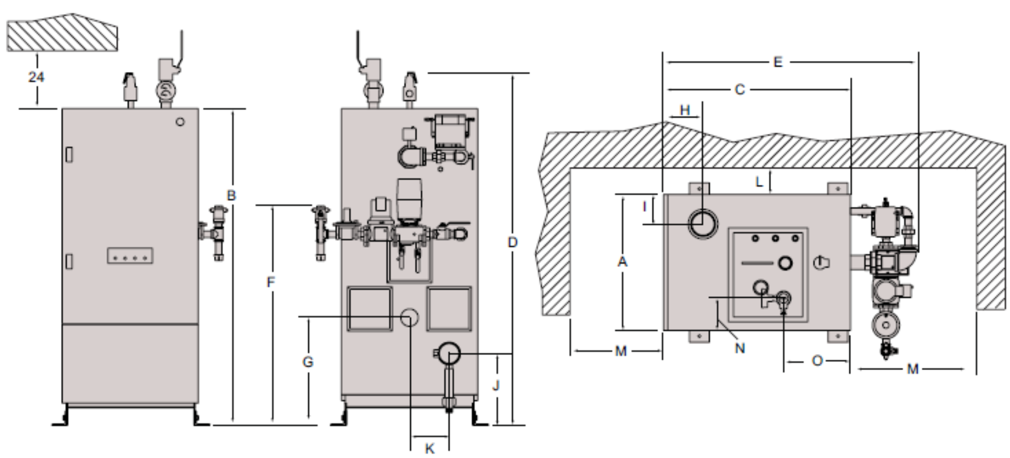
Fulton

Product Data Submittal
Fulton Pulse Model PHW-1400

Pulse Combustion Hydronic Boilers

Dimensions

Model		PHW-1400
A. Boiler Width	IN	33.6
	MM	855
B. Boiler Height	IN	81
	MM	2057
C. Boiler Depth	IN	49.75
	MM	1264
D. Boiler Height w/trim	IN	88.1
	MM	2238
E. Boiler Depth w/trim	IN	62.6
	MM	1591
F. Gas Inlet Height	IN	62
	MM	1575
G. Return Water Inlet	IN	29.8
	MM	756
H. Air Inlet Depth	IN	11.5
	MM	292
I. Air Inlet Width	IN	7.4
	MM	188
J. Exhaust Outlet Height	IN	19.1
	MM	486
K. Exhaust Outlet Width	IN	9
	MM	229
L. Min. Clearance to Walls	IN	1
	MM	26
M. Min. Clearance to Front and Rear	IN	38
	MM	965
N. Water Out From Side	IN	10.6
	MM	270
O. Water Out From Back	IN	17
	MM	432



Specifications

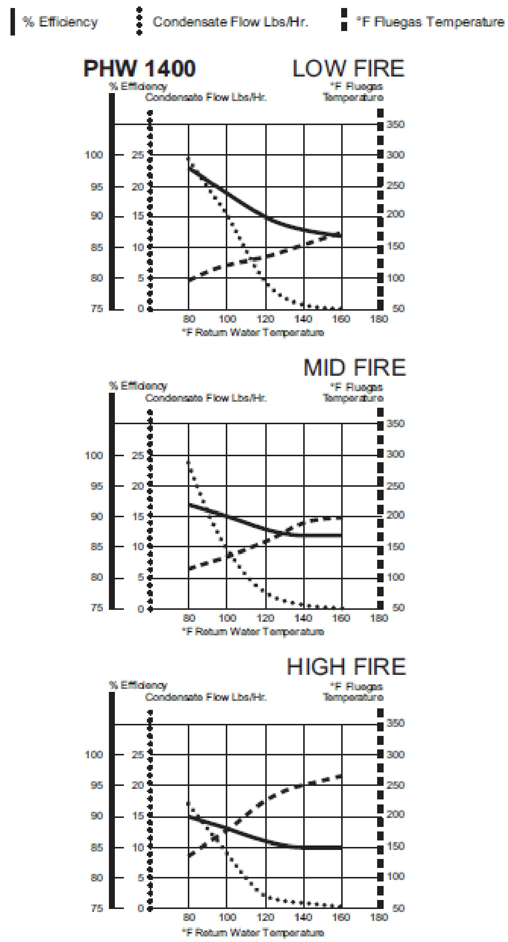
Model		PHW-1400
Fuel		Natural Gas Propane
Input	BTU/Hr.	1,400,000
	KCAL/Hr.	353,000
Fuel Consumption @ rated capacity:		
Natural Gas	FT3/Hr.	1400
	M3/Hr.	39.6
Propane	FT3/Hr.	560
	M3/Hr.	15.9
Electrical Requirements	Amps	
	120V/60/1	4.2 max; 0.6 run mode
	240V/60/1	2.1 max; 0.3 run mode
MAWP	PSI	60/160
	BAR	4.1/11.0
Water Content	Gal	80
	Liters	303
Boiler Connection Sizes		
Safety Valve Inlet	IN	1
	MM	26
Safety Valve Outlet	IN	1.25
	MM	31.8
Water Inlet & Outlet	IN	2.5
	MM	63.5
Air Inlet	IN	4
	MM	102
Gas Inlet	IN	1.25
	MM	31.8
Exhaust Outlet	IN	4
	MM	102
Approximate Weights		
Dry Weight	LB	2,230
	KG	1,148
Shipping Weight	LB	2,900
	KG	1,315
Operating Weight	LB	3,195
	KG	1,450
Floor Loading	LB/FT2	275
	KG/M2	1,306

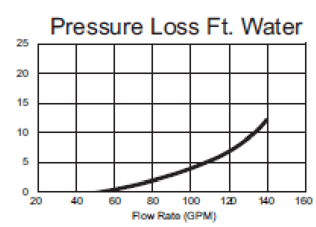
NOTES:
1. **We reserve the right to change specifications and/or dimensions.**
2. **Operating specifications may change based on field conditions.**

Installation Notes

1. Natural Gas Pressure Required: 7" W.C. - 11" W.C.
2. Propane Gas Pressure Required: 11" W.C. - 14" W.C.
3. Any pulse boiler can have the venting extended to 100 ft. and 6 elbows by increasing the vent size one additional pipe diameter. The exception is the PHW1400, which must be upsized from 4" to 6" AFTER the first 10 feet and then may extend an additional 40 feet.

Efficiency Curves

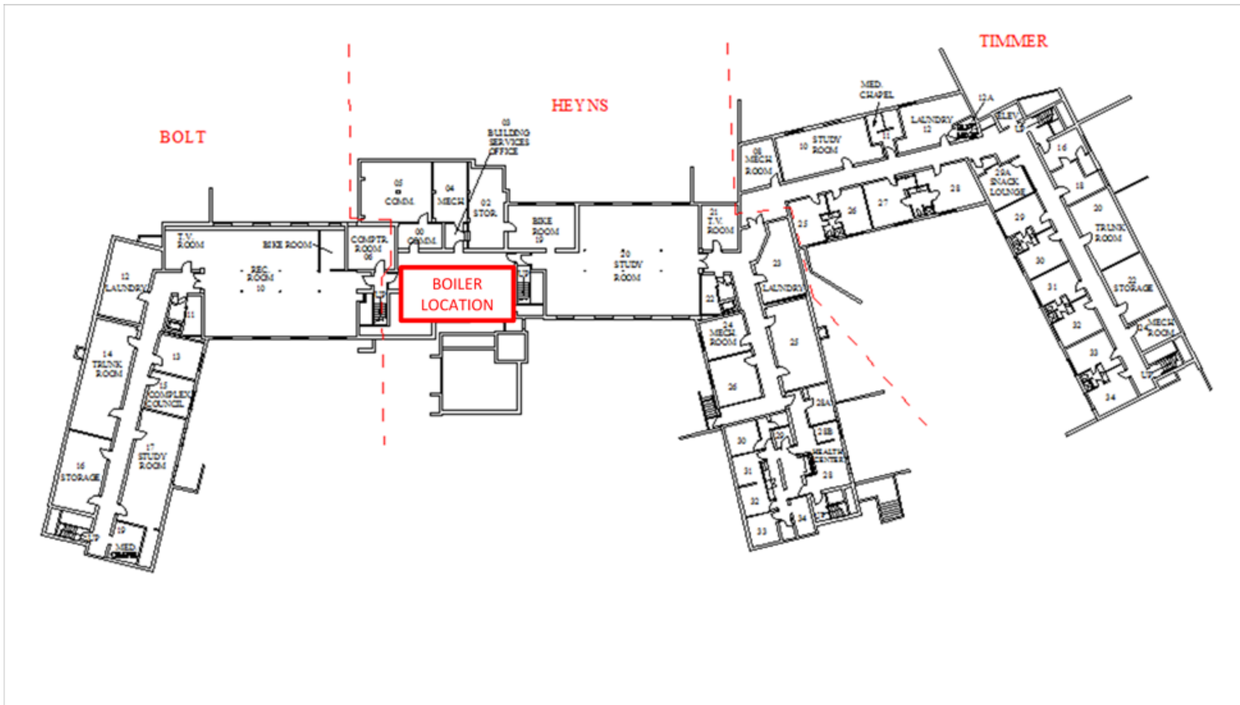




Fulton Heating Solutions, Inc.
972 Centerville Road
Pulaski, New York USA 13142
Call 315-298-5121
Fax 315-298-6390

PHW1400 PDS
4/08
Printed in USA

Appendix C-2 Boiler Location



Appendix D Cooling

Introduction

The cooling team was charged with the task of designing a cooling system to retrofit into the Bolt-Heyns-Timmer (BHT) residence hall. The system must be as efficient as possible as well as fit into the vision of Calvin College. The three main tasks of the cooling team were to decide how to make cooling, where to locate the machines that produce cooling, and finally how to deliver cooling to the conditioned spaces inside the building.

Procedure

The current infrastructure of BHT provides no means for cooling the dorm other than opening windows. The design process started with an initial brainstorm session by all team members to identify all options for cooling a residential area. These ideas were filtered down to a list of three feasible options. The team then developed design criteria and the three feasible systems were then analyzed and compared. After this process, a final design was chosen and detailed out and then recommend to Calvin.

Results

The three feasible design options analyzed for this project were window AC units, geothermal cooling, and an air cooled chiller. The designs were compared on the following criteria: cost, coefficient of performance (COP), aesthetics, and system type. Cost analysis included both initial outlays to purchase and install the equipment and yearly operating and maintenance costs. COP comparison looked at the COP for each system to compare their efficiency. Aesthetics looked at how the system fit with Calvin's campus in terms of sight and sound. Finally, system type was a comparison of the benefits of being either a centralized or decentralized system with respect to the campus. A table with this information for each system is found in Appendix D-1.

The air-cooled chiller was the most feasible option based on the selection criteria mentioned above. To reiterate, is has mild costs, high efficiency, average aesthetics, and a de-centralized system type. Once the chiller option had been chosen, further details needed to be designed such as size, type, and location. The size of a chiller is based on tonnage of heat it can remove. A 10 ton chiller for example can remove a maximum of 10 tons or 120,000 BTU/hr of heat from a building. The amount of heat required to be removed from BHT was initially estimated using a scaling ratio, which can be seen in Appendix D-2 for details. The results of these calculations were a cooling system with 180 tons of capacity.

Next, the number of the chillers had to be determined. There were two different feasible options: one 180 ton chiller or two 90 ton chillers. Each option has strengths and weaknesses as shown in Table 2, found in Appendix D-3. A two 90 ton chiller system was chosen based on its strengths and weaknesses with noise and redundancy being the major deciding factors. Chillers vary based on the type of compressor that is used in their refrigeration cycle. For the large application being considered in BHT, only two compressor types were feasible: screw and scroll. Each compressor type has strengths and weaknesses as shown in Table 2 found in Appendix D-3. Scroll compressors were selected for the final chiller design because they offer a heat recovery system and they are quieter.

The location of the chillers also had to be determined. Many of the chillers around campus are housed on the roof of the building which they air condition. However, BHT does not have the necessary infrastructure to support this option. Because of this, the chillers needed to be placed on the ground near the building. Calvin policy mandates that they be in an enclosure that blends in with the rest of the campus architecture. Air-cooled chillers draw a high volume of air, so they must be as open to the atmosphere as possible. Therefore, an enclosure similar to the one at the Seminary building, as seen in Figure 1 in Appendix D-4, will house the chillers. Noise considerations also were made when selecting the chiller location. The best location for the chillers is shown in Figure 2, found in Appendix D-5. This location is best for noise considerations as well as sight considerations as the future renovation of Commons seeks to maintain a visual line of sight from the dining hall to the Spoelhof Field house Complex.

Finally, the specific brand and model of the chiller had to be chosen. Calvin College has a strong preference and long relationship with Trane, a provider of HVAC systems. The model for the air-cooled chiller was therefore selected from Trane's product line. This model number was determined to be CGAM090F with partial heat recovery (Appendix D-11). Figure 3 in Appendix D-6 shows an example of a CGAM model air-cooled chiller from Trane. For a cost analysis of the chiller the electric usage and utilization were calculated as shown in Appendix D-7 and Appendix D-8 respectively. The results of these calculations, electric usage of 208 kW and utilization of 70%, were reported to the Finance Team. Also, the partial heat recovery option for the chiller was analyzed as shown in Appendix D-9. The Finance Team took the results to predict a payback for this added system.

Conclusion

The system described above is the best option for cooling in BHT. This system is feasible to install with the right amount of financial investment. However, cooling in the dorm provides no financial benefit to Calvin. Currently there is no student demand for cooling during the summer in the dorms. Over the past summers guests were given the choice between an air conditioned rooms with higher rent or a non air conditioned room. Guests chose 100 percent of the time to not have air-conditioning. Secondly, there are not enough summer programs at Calvin College to entirely fill up BHT with students. With a partially filled dorm during the summer, the chillers will always being running at a low capacity which is inefficient and costly. Financially, the chiller system is not feasible because the high initial cost cannot be justified by the low demand for air conditioning in the dorms during the summer months.

While an air-cooled chiller was the best cooling system for the dormitory BHT, a different system may have been considered if designed for the entire campus. Calvin has a very centralized approach to energy delivery, and this approach is best for considering air conditioning as well. Air conditioning with a large geothermal heat pump system would be both more aesthetically pleasing and cost-effective in the long term. The cost per ton of heat removal goes down as a geothermal system grows, and one with the magnitude of seven dormitories rather than one would warrant serious considerations. A more in-depth analysis of a geothermal system can be found in Appendix D-10.

Cooling System Appendices

Appendix D-1 System Design Alternatives Table

Table 1: System design alternative and criteria

	Window AC Units	Geothermal	Air Cooled Chiller
Cost	Initial : $80,000 Operating: $25,000/yr	Initial: $788,000 Operating:$11,310/yr	Initial: $193,600 Operating: $21,000/yr
COP	2.8	3	3
Aesthetics	In each room Noise	Bore field Noise	Enclosure Noise
System Type	Decentralized	Centralized	Decentralized

Appendix D-2 Sizing Calculations

Table 1: System Sizing Calculations

van Reken square footage	34523 ft^2	
BHT square footage	88158 ft^2	
van Reken chiller	60	ton
sizing factor based off square footage	2.6	
Minimum BHT chiller size	153.2	ton
Nominal size	180	ton

Appendix D-3 Chiller Comparison Tables

Table 2: Comparison of the different number of chillers[2]

System	Strengths	Weaknesses
One 180 ton chiller	• Less space required • More efficient	• Nosier
Two 90 ton chillers	• Redundancy • More flexible unloading • Partial heat recovery option • Quiet	• More space required

Table 3: Comparison of the different compressor types[2]

Compressor	Strengths	Weaknesses
Screw	• More efficient • Unloads better (10% increments)	• Nosier
Scroll	• Quiet • Partial heat recovery option	• Poor unloading (0 or 100%)

Appendix D-4 Seminary Chiller Picture

Figure 1: Picture of air cooled chillers at Calvin Seminary

Appendix D-5 Chiller Location Schematic

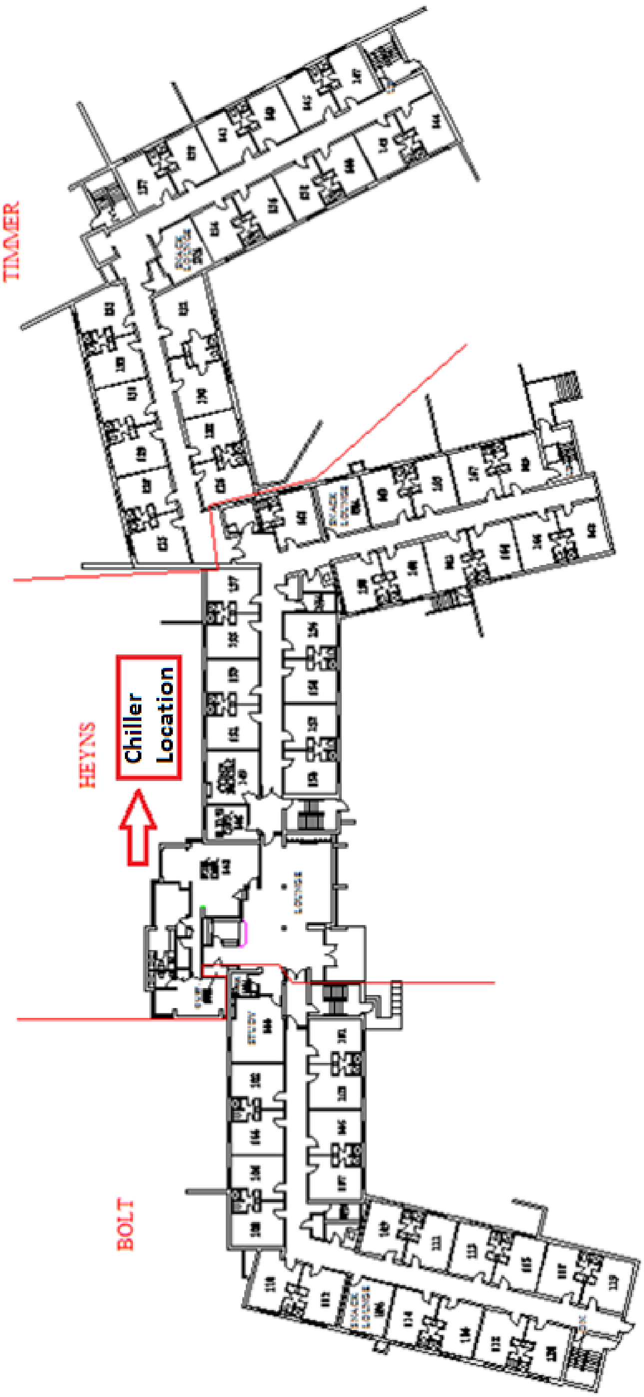


Figure 2: Schematic of BHT showing new chiller location

Appendix D-6 Chiller Picture

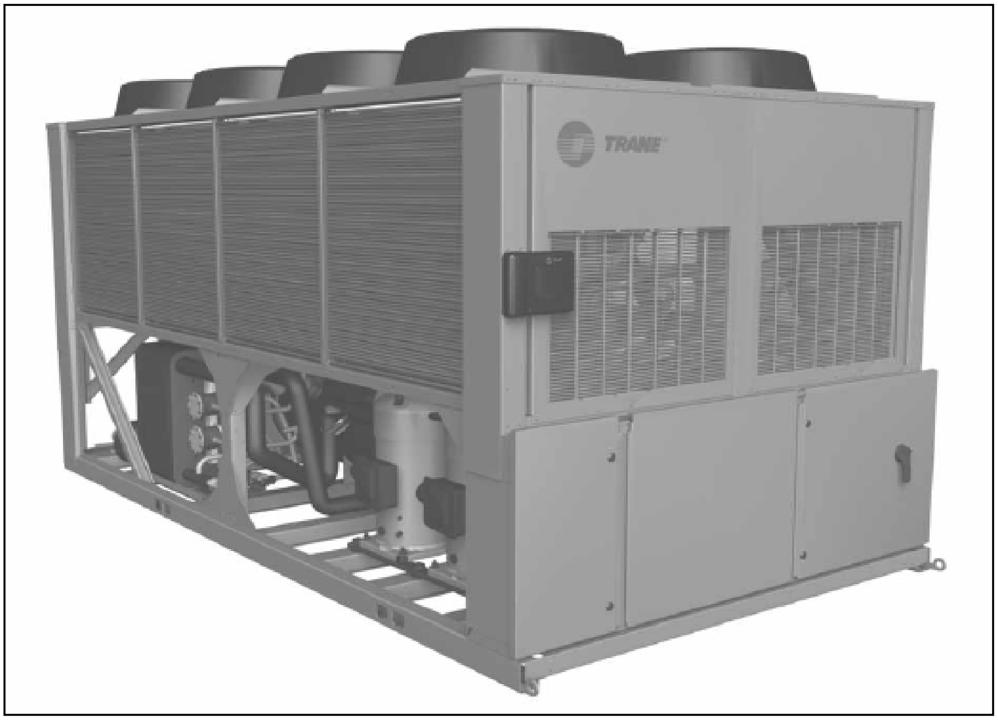


Figure 3: Trane model CGAM air cooled chiller (100-120 ton)[1]

Appendix D-7 Chiller Electric Usage

The electricity usage of the chiller can be determined from the unit's Energy Efficiency Ratio (EER). A Trane model CGAM 90 ton air-cooled chiller scores an EER of 10.4 Appendix D-11. This means that on average, the chiller removes 10.4 BTU/hr of heat for every watt of electricity it uses. To calculate the peak electricity used, this value is converted to tons of cooling and then scaled up to the 180 ton requirement of BHT.

$$\frac{1\ \mathrm{W}}{10.4\ \mathrm{BTU/hr}}\left(\frac{1\ \mathrm{kW}}{1{,}000\ \mathrm{W}}\right)\left(\frac{12{,}000\ \mathrm{BTU/hr}}{1\ \mathrm{ton}}\right)(180\ \mathrm{ton}) = 208\ \mathrm{kW}$$

Appendix D-8 Chiller Utilization

The chiller is sized for the maximum cooling load required for BHT. For the majority of operation, it is not necessary to run the chiller at this peak load and only a percentage of the full capacity is needed. The utilization of the chiller is the average percentage of full capacity the chiller is running during operation. A rough estimate of the chiller utilization was calculated based on comparing the maximum ambient temperature of 95°F that the chiller is designed for to the average temperature in Grand Rapids, MI for each month of operation (May 15th – September 15th). Using this method, a utilization of 70 percent was estimated (Table 4).

Table 4: Estimation of Chiller Utilization based on Average Monthly Temperatures

	May	June	July	Aug.	Sept.	Avg.
Avg. Temp. (°F)	61	67	72	70	64	67
Max Ambient Temp. (°F)	95	95	95	95	95	95
Utilization	64%	71%	76%	73%	67%	70%

To confirm this utilization an energy modeling program called eQuest was utilized. This program estimated a utilization of 75 percent for the chiller. Both 70 percent and 75 percent were confirmed to be accurate by a Trane representative [2].

Appendix D-9 Partial Heat Recovery

Partial heat recovery retrieves a fraction of the heat removed from the building and puts it to beneficial use such as in a hot water application. Basically a heat exchanger is placed in the chiller to capture a portion of the heat that is normally rejected to the atmosphere by the condenser. For this chiller, the recovery heat exchanger can produce a maximum leaving temperature of 69.4°C (Appendix D-11). Using information provided by Trane of water flowing at 75 gal/min having an increase in temperature of 10 degrees Fahrenheit, the maximum energy recovered was calculated to be 375,300 BTU/hr as shown below.

$$\dot{Q} = \dot{m} c_p \Delta T \tag{1}$$

$$\dot{Q} = \left(37540 \frac{lbm}{hr}\right) * \left(1 \frac{BTU}{lbm - F}\right) * (10\ F) \tag{2}$$

$$\dot{Q} = 375{,}300 \frac{BTU}{hr} \tag{3}$$

Appendix D-10 Geothermal Report

Basics of Geothermal Heating and Cooling Systems

A geothermal system taps the stored energy in the earth's crust. These systems use the earth's relatively constant temperature to provide heating, cooling, hot and cold water for homes or commercial buildings.

For closed loop systems, water or an antifreeze solution is circulated through pipes buried beneath the earth's surface. During the winter, the fluid is heated from the earth and carries the heat through the system and into the building. During the summer, the system reverses the heat cycle in order to cool the building by pulling heat from the building; carrying it through the system and placing it in the ground (see Figure 4).[1]

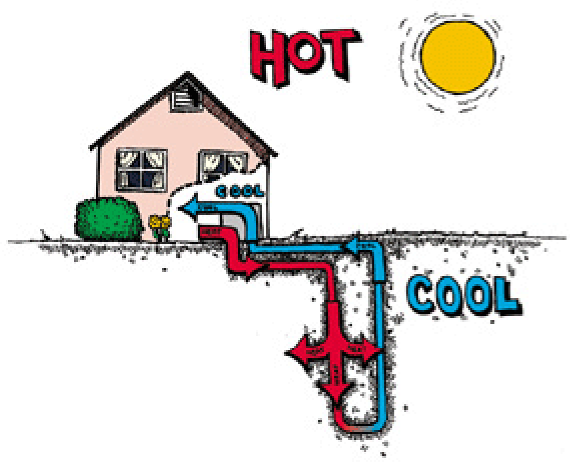


Figure 4: Basic Geothermal System

Calvin's BHT Geothermal System

Geothermal heating and cooling has many advantages to offer. One advantage is the fact that geothermal is a renewable resource. However, all good things come at a cost, and not speaking only of finical cost. We decided not to design a geothermal heating and cooling system for the Bolt Heyns Timmer (BHT) dorm at Calvin College for several different reasons.

The main disadvantage of geothermal heating and cooling is the large upfront expenses. A large portion of this expense comes from the exploration and drilling stages. A survey of the land can take several years to complete. Calvin already has a small geothermal heating and cooling system in the dorm Kalsbeek Huizenga van Reken (KHVR) which supplies one suite with heating and cooling. In this

[1] *International Ground Source Heat Pump Association*. N.p., 2010. Web. 4 Nov. 2010. <http://www.igshpa.okstate.edu/geothermal/geothermal.htm>.

situation, one small system can be supported by the land. A geothermal system to heat and cool BHT would require a much larger load, and therefore a much larger loop field to draw heat from. To extract this much heat (or cooling) capacity, many bore fields over a large area would have to be drilled.

Upfront (Initial) Costs

Knowing that BHT has a 180 ton cooling load and assuming 150 feet depth of bores, BHT would need 180 bore wells. This estimate is based on rule of thumb estimates from GMB Architecture and Engineering (GMB). This size would be difficult to implement for BHT because it is in close proximity to many other buildings. Bore wells would have to have to be placed a considerable distance away from BHT. The heat or cooling capacity will be lost by long transits of piping. Inefficiencies would occur because of the heat transfer along the pipes and from pumps propelling solutions long distances. This causes the system to have to work harder and possibly drilling another bore well or increasing another's size to account for these losses.

The initial cost for a geothermal system for BHT would be $788,800 provided from Midwest Geothermal's rule of thumb estimates. This estimate for a 272 ton peak heating load and includes PE piping, vault, valves, and termination of lines into building.

Initial high costs can be a hindrance to investing in new technology. One way to lower or counteract inefficiencies (as mentioned above) would be to correct the heating and cooling differences by injecting water from the loops at Calvin into the BHT piping system. Another positive to this piping connection would be that it creates some redundancy in the system if the geothermal field were to go out on a cold day in January. Although a piping connection between Calvins's current piping infrastructure and the new installed geothermal pipes could prove to have some advantages, this connection is a very complicated process that involves 40 degree temperature changes (140 and 180 F) and complex valves and piping. If the design is to avoid the integrations between piping systems then a secondary or backup heat sources is required. The system cannot fail, which is why a backup system, secondary system or integration between systems is necessary which adds another item to the overall cost.

General Geothermal System Concerns

In some cases, a site that has been extracting heat or cooling for years may suddenly stop producing heating or cooling elements for a building. When this does happen, it can last for 10 years in some cases. This would be a concern for Calvin because the geothermal system would be extracting heat from the earth during the winter and would rarely be putting heat back into the earth during the summer through air conditioning. The dorms are not used as much in the summer compared to the winter. Essentially, the proposed BHT geothermal system would be a closed loop process in terms of the medium used for heat transfer but would be an open loop system in regards to the heat flow (more heat is taken from the ground then what is put back into ground). The main concept of a geothermal system is to use it as a heat exchanger. If certain measures aren't taken into account, the wells could have a potential to “dry out” from their heat source.[2] One environmental problem that may arise is harmful gases escaping from deep within the earth through the drilling of the bore hole. The system must be able to contain any leaked gases, and disposing of the gas can be very costly. It is unknown if these gases occur in the vicinity of Calvin, but it is possible that these gases do exist, and safety measures should be followed.

If we were to design a geothermal system for BHT, then we would design a closed-loop system. Many closed-loop systems use an antifreeze solution to keep the loop water from freezing in cold temperature conditions. Most antifreeze solutions have very low toxicity, but many produce CFCs (chlorofluorocarbon) and HCFCs (hydrochlorofluorocarbon), which add to environmental concerns. In addition, antifreeze solutions increase fluid viscosity, making the system work harder and adding to the cost to pump the fluid.[3] Another option for a closed-loop system is a refrigerant-loop system. However, refrigerant loop systems have several disadvantages. This includes environmental issues related to the system's use of refrigerant, corrosion issues, (since they use copper piping, which needs anodic protection) and the need to maintain refrigerant temperatures within certain limits to keep from freezing or baking the ground, and there are difficulties in finding and fixing leaks.

Installation Time

Installation of any cooling system needs to be able to be installed during a summer period. If a system takes longer than a summer to complete would put a hindrance for students to be able to move in during the fall. Typical installation time for a geothermal system the size that BHT requires could take longer than a summer. There aren’t estimates for a installing a geothermal system the size of BHT but it would be safe to assume that it would take longer than a summer. Physically the installation could be done in a summer but it would require hiring extra workers and equipment which would lead to an even greater upfront cost for the installation of the geothermal system.

Conclusion

Although geothermal is a great resource, the class decided not to choose geothermal as the means for cooling BHT for many of the reasons listed. The scope of the project was to cool BHT; although the class believes that geothermal would be a viable option for heating and cooling for all of the residence halls. The larger scope gives a greater chance of cancelling out inefficiencies and using higher efficient systems. Geothermal is still a relatively new implemented idea that still has many bugs to work out. The cooling team found my quotes for geothermal systems. These large varieties give a predictable but unreliable final outcome.

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[2] Swain, . *Five Disadvantages of Geothermal Energy*. N.p., n.d. Web. 20 Nov. 2010. <http://www.associatedcontent.com/article/288108/five_disadvantages_of_geothermal_energy.html?cat=15>.

[3] *Geothermal Advantages & Disadvantages*. N.p., n.d. Web. 20 Nov. 2010. <http://cipco.apogee.net/geo/gdfdgad.asp>.

Appendix D-11 References

1. "Air-Cooled Scroll Chillers." *Trane Product Catalog*. Trane, 2010. Web. 10 Dec. 2010. <http://www.trane.com/CPS/Uploads/UserFiles/Chillers/ScrollLiquid/CGAM/CG-PRC017-EN_07012010.pdf>.

2. Pabst, Dan, and Chad Nyenhuis. Personal interview. 26 Oct. 2010.

Appendix E   Ventilation

Introduction

The purpose of the ventilation group was to investigate the current ventilation situation of BHT and bring the ventilation system in compliance with ASHRAE 62.1 code.

Procedure

As a requirement for retrofitting Bolt Heyns Timmer (BHT) with a new heating and air conditioning system, the dorm's ventilation must be brought in compliance with code. ASHRAE 62.1 stipulates regulations for air quality in living quarters and general gathering areas. By reviewing dorm schematics and discussing with the Calvin Physical Plant and Ashley Baker of GMB Engineering, the current ventilation situation was analyzed and a final point design for the new system was formed.

As stated, the floor plan schematics were analyzed and compared to ASHRAE 62.1's standards. For existing buildings, if the window area in a room yields 4% of the floor area, then that particular room satisfies the code requirements. All standard two-person occupant dorm rooms passed with this exception to ASHRAE code, otherwise these rooms would have needed 36 cubic feet of air per minute (CFM) per room. However, all of the hallways, Timmer's quads and kitchens did not pass, along with the common lobby area of BHT according to the equation provided by ASHRAE 62.1:

$$CFM\ required = \frac{Rp*Pz+Ra*Az}{Ez} \qquad (1)$$

Where R_P is a coefficient determined by room purpose, P_z is room occupancy density, R_a is a coefficient of floor area determined by room usage and A_z is floor area. The denominator, E_z, is the scaling correction factor determined by exhaust location. Equation 1 yields the CFM needed in each of the following locations.[4]

Table 1: CFM required by site

Location	CFM
Hallways	75
Kitchens	18
Quads	55
Lobby	150

Table 1 shows the required flow rate of air through each area of the dorm. The damper systems in BHT will also need to be upgraded. In the base case study, the bathroom damper, according to GMB, removes 75 CFM per fixture (i.e. toilet, shower) therefore approximately 150 CFM is removed through each bathroom's exhaust system. With the excess air being flushed throughout the hallways and other rooms that failed, the old damper system will need to be upgraded to release the air introduced to the building by the new system.

[4] ASHRAE 62.1 pdf file

Conclusion

The final point design for the ventilation system relied heavily on the heating and cooling group's selection of fan coil units to condition the air. Using their selected fan coils, a ventilation hole can be drilled through the wall to the fan coil and preheat or cool the outside air relevant to the time of year. Each unit displaces 220 CFM, which is well above any of the location requirements for ventilation. As the maximum amount of fresh air required in the hallways per unit is 75 CFM, each unit will recycle over half of the heated air from the living space; only the required amount of fresh air will be drawn in from the outside. The cost of this system is only the fan coils, which are already implemented by the heating and cooling group, as well as more extensive labor. A general rule of thumb, provided by Trane, was $4 to $5 per CFM needed.

Furthermore, an additional design option was researched and considered. With Calvin desiring LEED accreditation, according to the project assignment, the following system could be implemented. According to ASHRAE 62.1 standard, buildings requiring over 5000 CFM (existing BHT requires 700 CFM) are required to install a heat recovery wheel. In addition, the standard dormitory rooms will need to be flushed with the appropriate amount of fresh air according to LEED certification, about 40CFM's. An additional rule of thumb provided by Trane brings the cost of the ventilation system to $8 to $10 per CFM. Also, with this heat recovery wheel, 3 rooms would be sacrificed to install a vertical shaft for a central ducting system. While this would bring LEED accreditation, the aesthetics of the building may suffer; the ceilings in the hallways would be lowered, some rooms would be vacant due to the vertical shaft, and ambient noise produced by the central shaft would be introduced. These repercussions of the ventilation system renovation should play a crucial role in considering LEED accreditation attainment. Also, each individual dorm room would require ventilation ducting run to it, incurring a large cost, but ensuring that the dorms do not become stale or stuffy during the winter months.

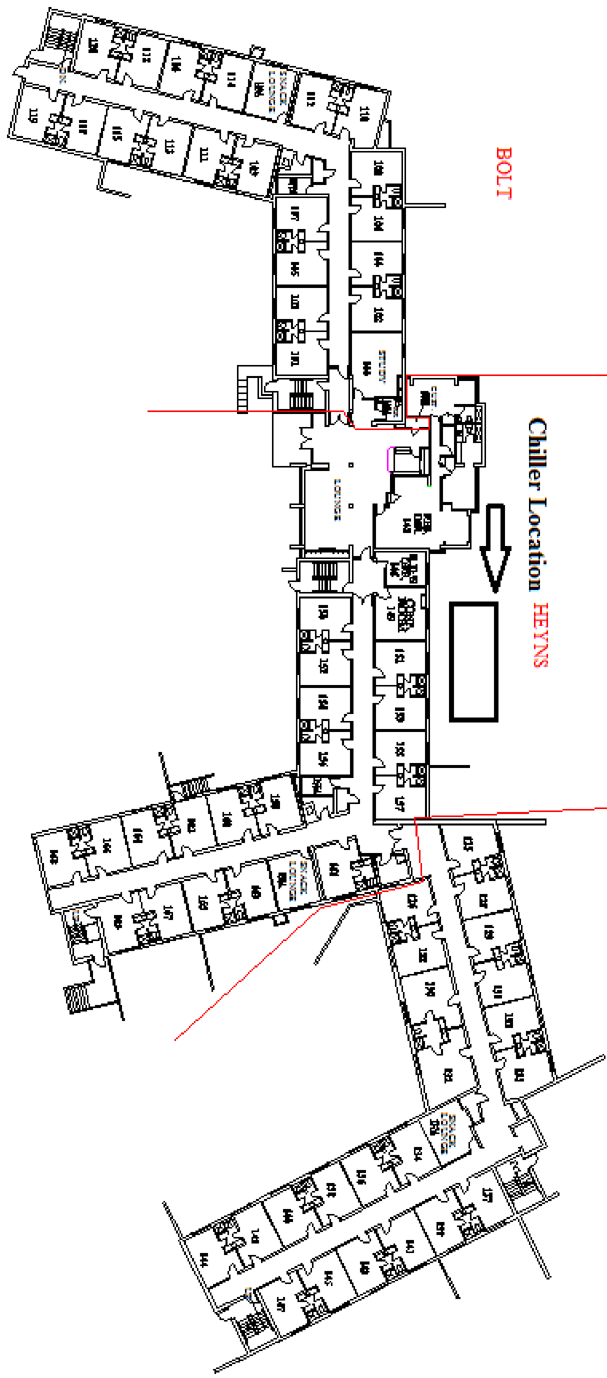
Table 2: Cost Comparison

	Systems		
	Code	**LEED**	
CFM	700	8000	**ft^3/min**
Cost	20,000	100,000	**$**

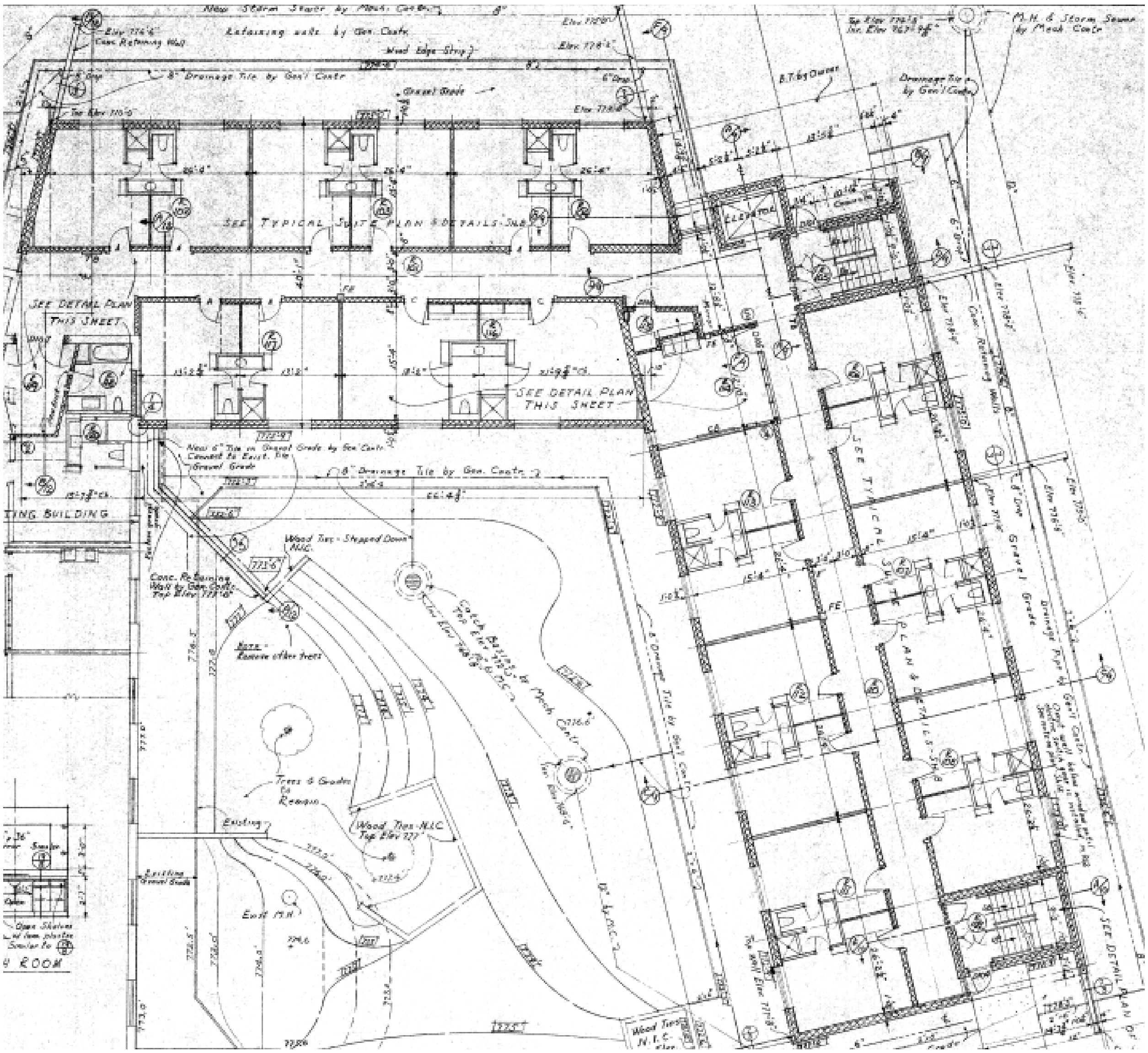
Both of the costs in Table 2 are scaled by a 20% safety factor to compensate for unexpected construction costs due to the infrastructure issues with BHT. While the original heat coil system does not achieve LEED accreditation, considering the cost and aesthetic appeal, the cheaper system is recommended to be installed for the class project. The heat coils are able to motion air, remove stagnant air in the rooms, and do so at a lower cost, and ultimately appears to be the best choice for BHT.

Ventilation Appendices

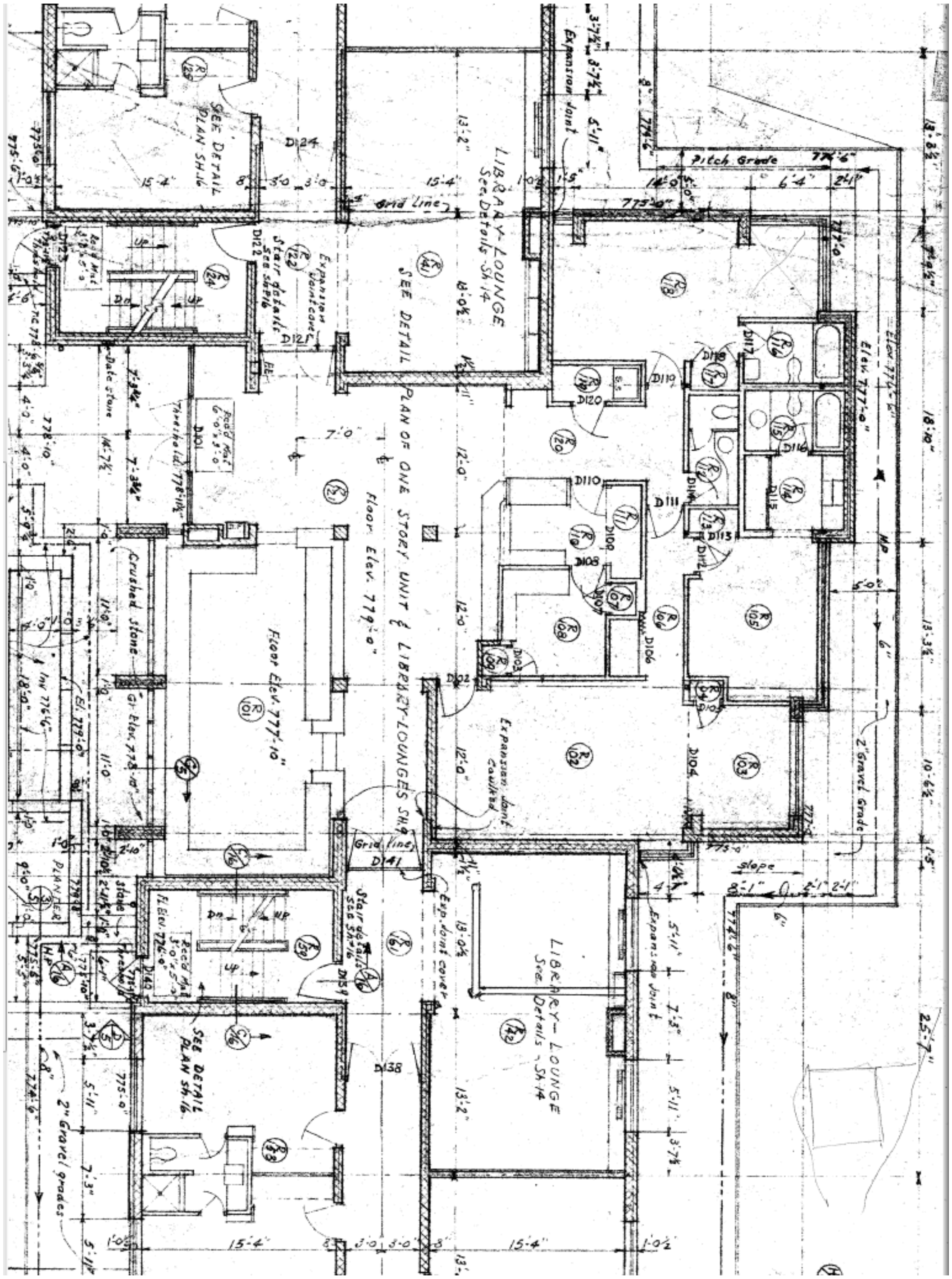
Appendix E-1 BHT Layout



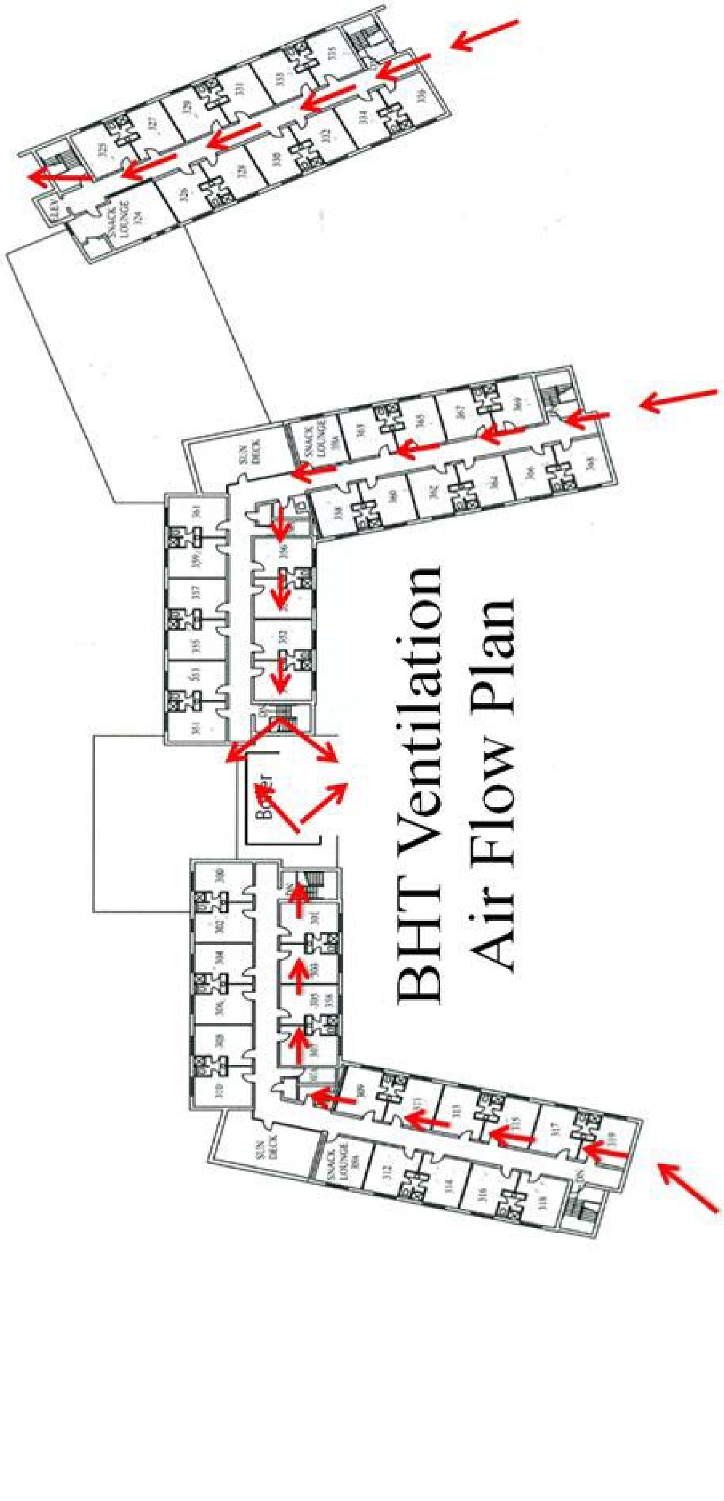
Appendix E-2 Timmer Quads Close-up



Appendix E-3 Lobby Schematics



Appendix E-4 Ventilation Flow Plan



Appendix F Delivery

Introduction

The issue of delivery was apparent in all three mains systems in the project: ventilation, heating, and cooling. To solve this issue, a group of individuals was tasked with designing a system that would both deliver heating and cooling, as well as fulfill the ventilation requirements in the building.

Procedure

The current heat delivery system in BHT uses finned tube radiators and natural convection to heat the living spaces. This system is old and outdated however it works for heating the dorms. To retrofit the dorm, the group developed a list of alternative designs to achieve the goal of heating and cooling delivery.

Results

Three feasible designs considered for delivery were finned tube radiators, forced air vents, and fan coil units. The designs were evaluated by their ability to deliver heat, cold, and ventilation, their efficiency, and also their ease of install and aesthetics. The first option, finned tube radiators, cannot deliver cold air to the dorms living space and cannot ventilate. Finned tubes only achieved about a 20% increase of efficiency over the existing system (Figure 6, Appendix B). The next option, forced air vents, provided the ability to supply heating and cooling to the dorm as well as ventilation. However, a forced air system would require an extensive remodel of the dorm to incorporate all ducting and diffusers. This could be as extensive as building exterior ventilation shafts onto the building or using at least one dorm per floor as a mechanical room; both of which are not aesthetically pleasing.

T

he design chosen for the dorm was fan coil units. Fan coil units help achieve the 30% increase in efficiency of the heating system, provide individual control, and are aesthetically pleasing. Fan coils also can provide ventilation to the areas described in Appendix E.

The fan coils will be placed where the finned tube radiators are currently located, as shown in Figure in Appendix F-1, and would be piped as shown in Figure 2*:* Dormitory piping schematic and Figure found in Appendix F-3. The size of each fan coil unit was determined through basic rule of thumb provided from Trane Corporation which states 400 square feet of floor area per 1 ton of capacity. The number of fan coils needed for the building was also calculated using this rule of thumb. Details of these calculations can be found in Table 1 and Table 2 in Appendix F-3.

Conclusions

The fan coils were the best option for delivering the heat, cold, and ventilation. Fan coils provide basic control of the heating can cooling in each room and have the option to provide sophisticated linked control with a larger investment. The fan coils made up a large portion of our system's costs; however this is expected due to the challenges that come with extensive installation in an existing building.

Delivery Appendices

Appendix F-1   Fan Coil Locations

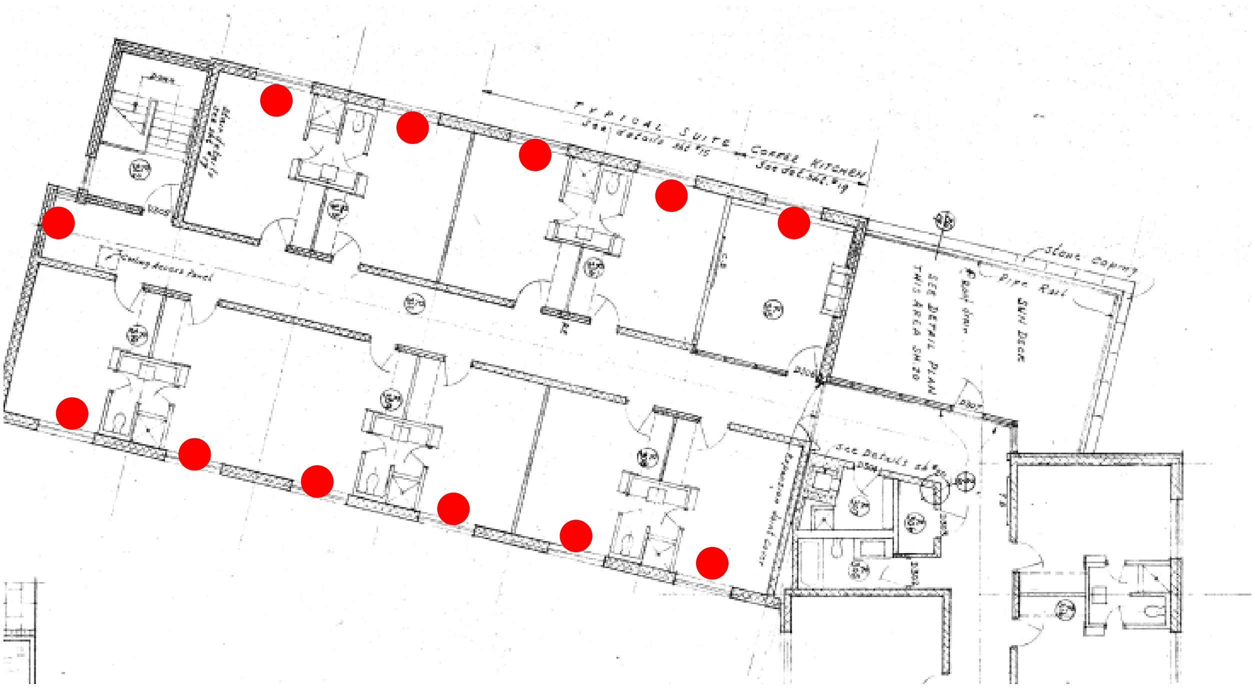


Figure 1: Schematic of Bolt Hall with red dots representing fan coil units

Appendix F-2 Fan Coil Piping Diagrams

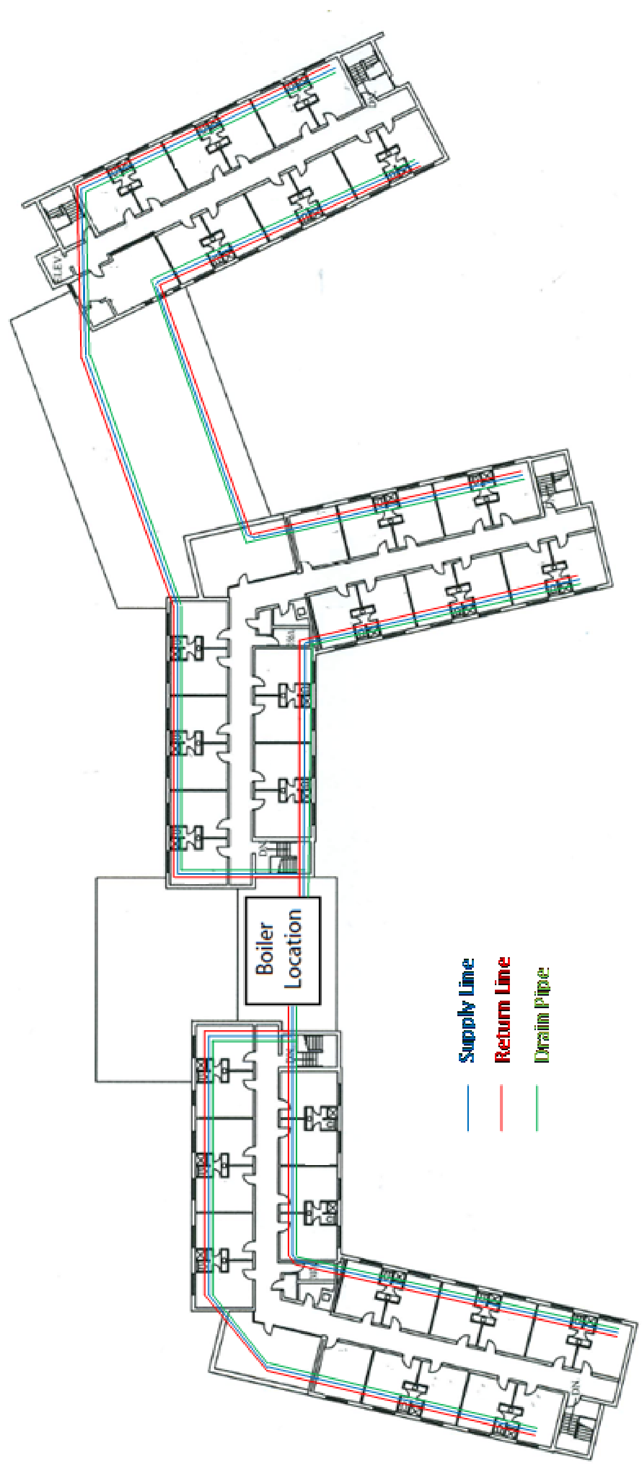


Figure 2*:* Dormitory piping schematic

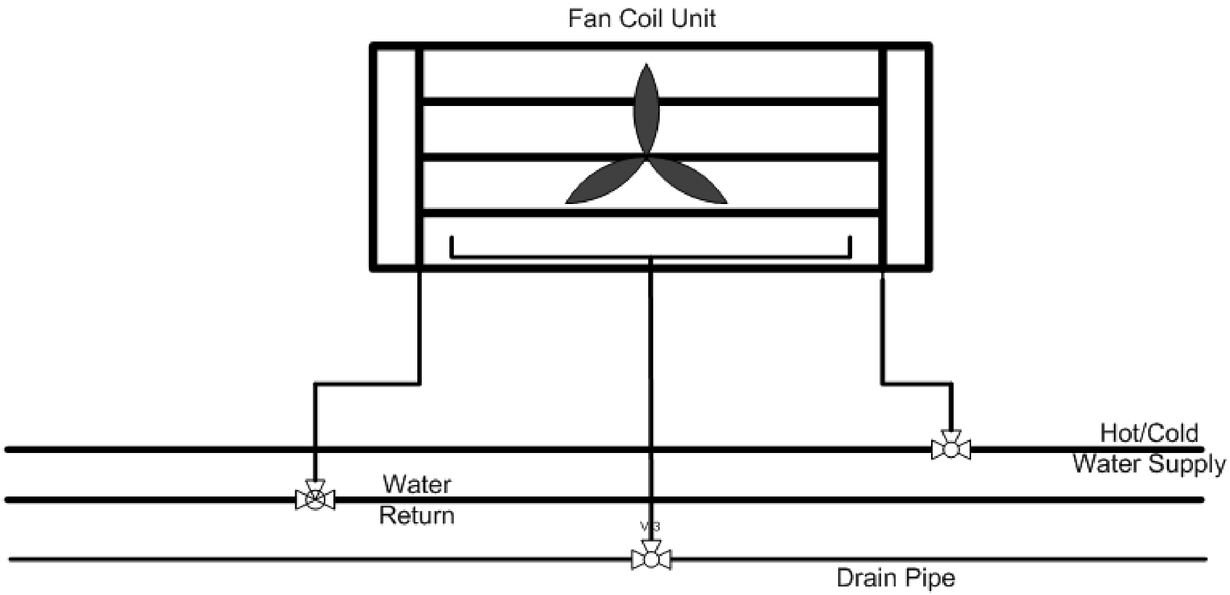


Figure 3: Individual fan coil piping schematic

Appendix F-3 Fan Coil Sizing and Quantity

Table 1: Fan coil sizing calculation table

Area of room	
200	sq. feet
Rule of thumb	
400	sq. feet/ ton
Room Requirements	
0.5	ton/ room

Table 2: Fan coil quantity calculation table

	Needed Coils				
	Basement	1st floor	2nd floor	3rd floor	total
dorms	10	61	65	52	188
kitchens	1	3	3	3	10
stair wells*	6	6	6	6	24
hall*	4	6	6	5	21
CJ		3	3	2	8
RD		4			4
Common area*	14	2			16
misc	18				18
			Total Small	Total Big	
			228	61	
* shaded cell indicates larger size fan coil					

Appendix G Finance

Introduction

The financial team analyzed the initial and lifetime costs for each design to determine the feasibility of the project. Various economic cases were analyzed as well as varying prices for future energy values. These numbers were used to analyze a possible payback period for a new heating system as well as the lifetime cost of implementing a cooling system in the dorms. In addition to tracking the lifetime costs of the heating and cooling systems, the finance team was also in charge of analyzing possible CERF opportunities and the payback for any projects.

Description

Energy projection values shown in Figures 3 and 4 were used along with nominal, pessimistic, and optimistic economic cases as shown in Table 1. Each heating and cooling system was analyzed on a 30 year time line taking into account the time value of money. Energy projections were extrapolated from 2030 to 2040 since the Department of Energy does not provide data for this time period.

Table 1: Case Descriptions

Interest Rate		Inflation Rate	
Pessimistic	5.0%	Pessimistic	2.0%
Nominal	6.0%	Nominal	3.5%
Optimistic	10.0%	Optimistic	8.0%

Equipment, installation, and maintenance costs were all provided by the heating, cooling, infrastructure, and ventilation teams. The proposed heating system was analyzed in comparison with the dorm's existing heating system whereas the proposed cooling system was analyzed on its own. The cost to run the existing heating system was calculated based on the amount of space heat calculated by the energy modeling group.

The only reasonable CERF option that was looked into was a partial heat recovery for the cooling system chillers. This system would take waste heat from the chillers and use it to heat up the domestic hot water supply.

Results

Based on values provided by the heating and cooling teams, the total cost for the proposed heating system would be approximately $675,000 and the proposed cooling system would be approximately $194,000. The cost breakdown of these systems is shown in Finance Figures and Tables following the conclusion.

The cumulative cost of the proposed heating system as well as the existing heating system is shown in Figure 1. As shown on the graph, the lines never cross, meaning that payback will never occur on a 30 year time line. In addition, the uncertainty of the economic forecast will have little effect of the overall cost of the system. It is quite apparent that the up-front costs are too high to achieve payback.

The cumulative cost of the proposed cooling system is shown in Figure 1 and 2. The upfront costs for this system are lower because the cooling system will utilize the same fan coils, piping, and ventilation as the heating system. Once again, the cumulative cost is very expensive and will end up costing more than the heating system on a 30 year time line.

The cumulative cost of the cooling system would be less if the partial heat recovery option were added. This option would cost approximately $29,000 and would pay for itself in less than five years. A complete financial analysis of this CERF option is shown in Figure 7.

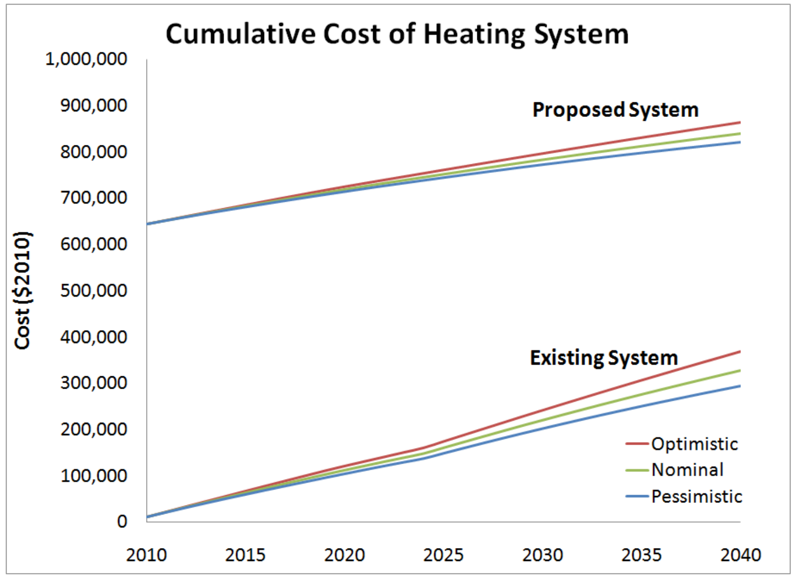


Figure 1: Overall Cost of the Proposed Heating System

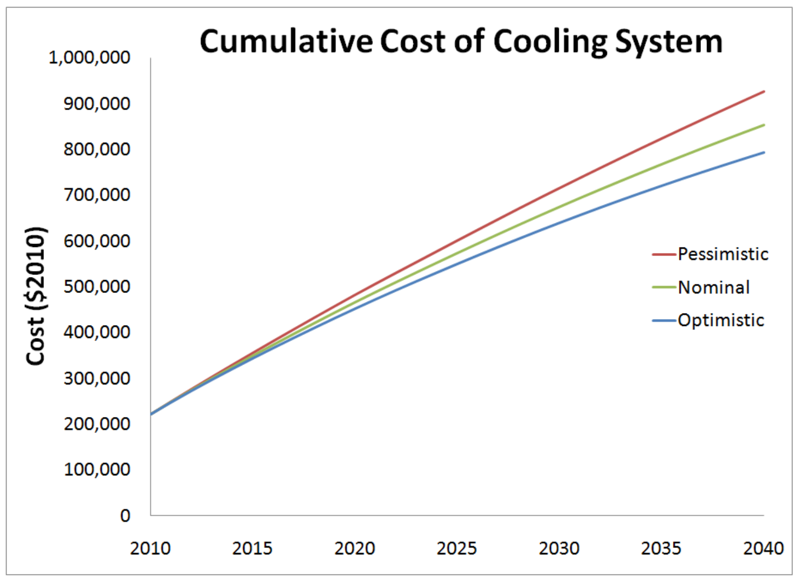


Figure 2: Overall Cost of the Proposed Cooling System

Conclusion

After analyzing the proposed heating and cooling systems on a financial basis, it is apparent that retrofitting the BHT HVAC system will not be financially beneficial. The upfront costs of the heating system are too high to justify and the large operating costs of the cooling system and lack of demand make it impractical. The finance team recommends that Calvin continue heating and cooling the campus based on a main centralized system instead of individual HVAC systems in each dorm.

Finance Figures and Tables

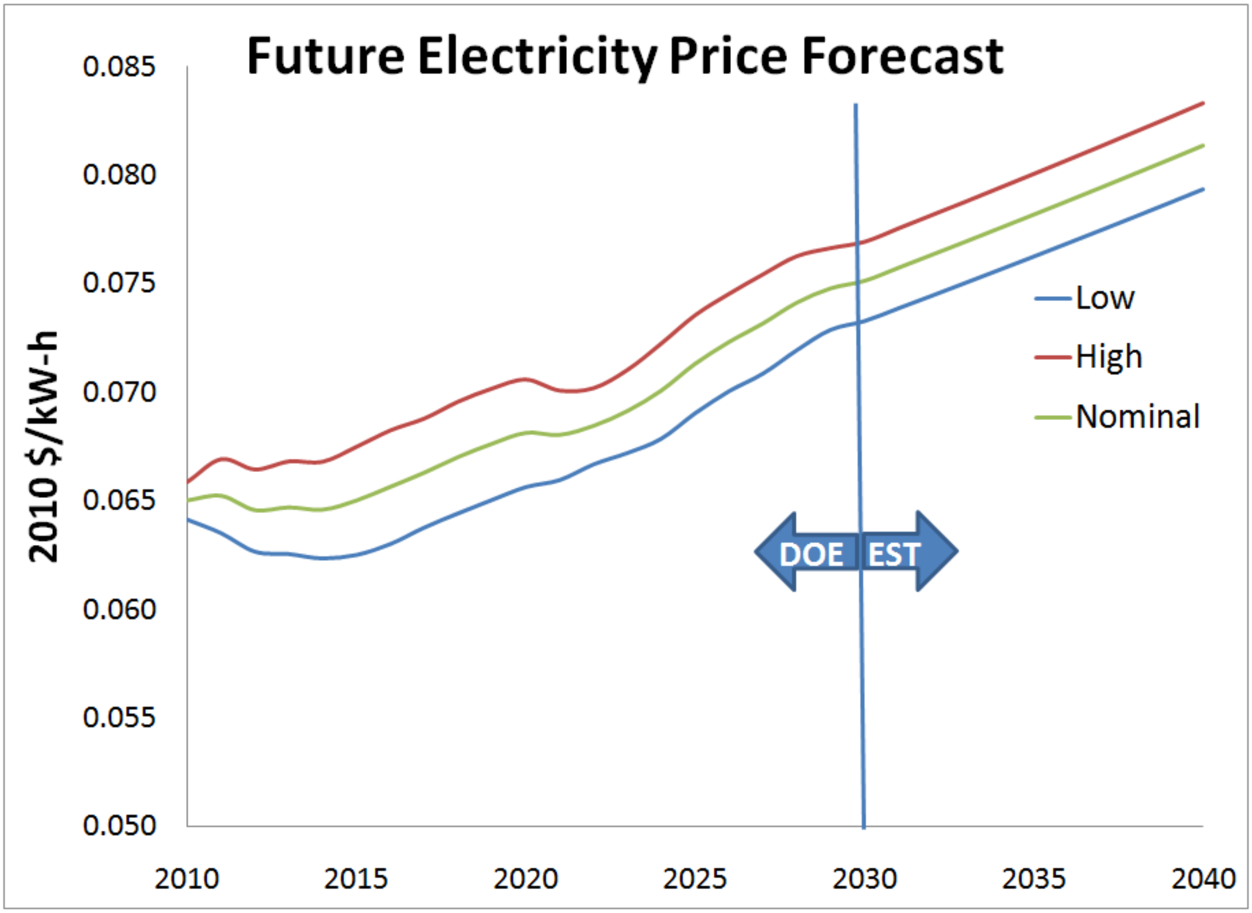


Figure 3: Electricity Price Forecast

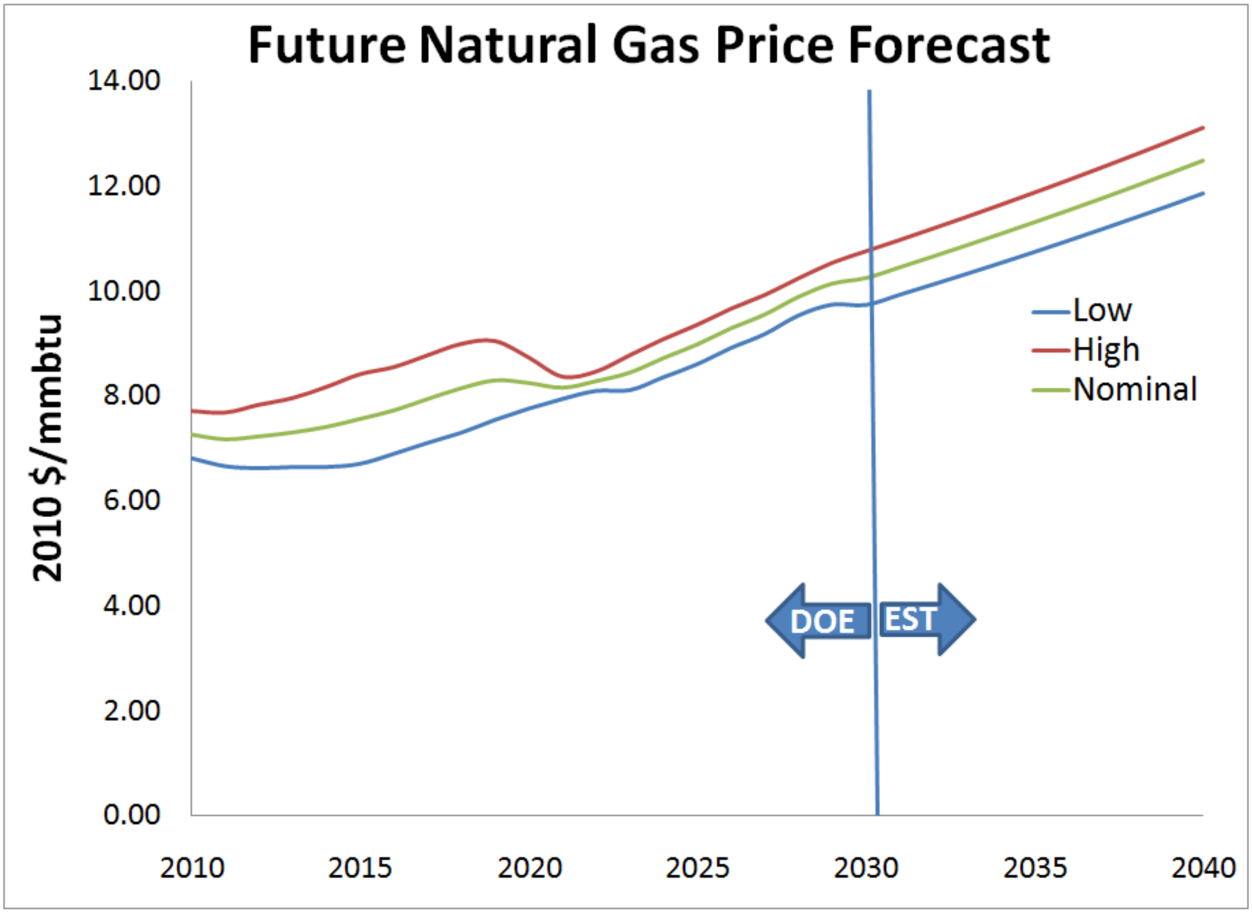


Figure 4: Natural Gas Price Forecast

Table 2: Heating and Cooling System Cost Breakdown

Heating System Costs

Item	Cost
Boiler Cost (Qty 3)	$ 80,250
Install	$ 80,250
Piping	$ 202,500
Fan Coils	$ 300,000
Ventilation	$ 11,750
Total	**$ 674,750**

Cooling System Costs

Item	Cost
Chillers (Qty 2)	$ 93,600
Install	$ 100,000
Total	**$ 193,600**

Table 3: Ventilation Cost Breakdown

ECONOMIC ANALYSIS OF BHT VENTILATION				
Bolt				
Floor area	1125	ft^2/floor		
Ventilation factor	0.06	CFM/ft^2		
Cost(no recovery wheel)				
low	4	$/CFM	891	$
high	5	$/CFM	1113.75	$
Cost(Recovery Wheel)				
low	8	$/CFM	1782	$
high	10	$/CFM	2227.5	$
COSTS INCLUDE 10% Safety factor				
Heyns				
Floor area	1125	ft^2/floor		
Ventilation factor	0.06	CFM/ft^2		
Cost(no recovery wheel)				
low	4	$/CFM	891	$
high	5	$/CFM	1113.75	$
Cost(Recovery Wheel)				
low	8	$/CFM	1782	$
high	10	$/CFM	2227.5	$
Timmer				
Floor area	1235	ft^2/floor		
Ventilation factor	0.06	CFM/ft^2		
Cost(no recovery wheel)				
low	4	$/CFM	978.12	$
high	5	$/CFM	1222.65	$
Cost(Recovery Wheel)				
low	8	$/CFM	1956.24	$
high	10	$/CFM	2445.3	$
Common Area/RD Living area				
Floor area	2450	ft^2/floor		
Ventilation factor	0.06	CFM/ft^2		
Cost(no recovery wheel)				
low	4	$/CFM	1940.4	$
high	5	$/CFM	2425.5	$
Cost(Recovery Wheel)				
low	8	$/CFM	3880.8	$
high	10	$/CFM	4851	$
TOTAL COSTS				
No Recovery wheel				
Low	4700.52			
High	5875.65			
Trane Recovery Wheel				
Low	9401.04			
High	11751.3			

Table 4: Heating Optimistic Case Parameters

Financial Parameters	
Interest Rate	10.0%
Inflation	8.0%

Current System		
Boiler		
Required Input	850.2	Mbtu / yr
Annual Maintenance Cost	$5,000	per yr
Later Maintenance	$ 10,000	

New System		
Boiler + Ventilation		
Required Input	383.9	Mbtu / yr
Annual Maintenance	$2,600	per yr
Equipment Cost	$133,350	
Installation Cost	$0	

Fan Coils				
	54	Large	200	Small
Power	0.135	kW	0.06	kW
Utilization	40%			
$800	per yr			
$502,500				
$0				
Hours of Operation			4320	
Annual Power Consumption			33333	kW-hr / yr

Table 5: Heating Optimistic Case Future Values

Year	Energy Cost				Future Value - Annual Operating Cost						
	Present		Future		Current System			New System			
	Gas	Electricity	Gas	Electricity	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr						
0	7.70	0.07	7.70	0.07	$6,549	$5,000	$11,549	$2,957	$2,196	$3,400	$8,553
1	7.67	0.07	8.29	0.07	$7,045	$5,400	$12,445	$3,181	$2,410	$3,672	$9,263
2	7.82	0.07	9.12	0.08	$7,756	$5,832	$13,588	$3,502	$2,584	$3,966	$10,052
3	7.95	0.07	10.02	0.08	$8,515	$6,299	$14,814	$3,845	$2,806	$4,283	$10,934
4	8.16	0.07	11.10	0.09	$9,440	$6,802	$16,243	$4,263	$3,030	$4,626	$11,919
5	8.40	0.07	12.35	0.10	$10,499	$7,347	$17,846	$4,741	$3,306	$4,996	$13,043
6	8.54	0.07	13.55	0.11	$11,522	$7,934	$19,457	$5,203	$3,611	$5,395	$14,209
7	8.76	0.07	15.02	0.12	$12,771	$8,569	$21,340	$5,767	$3,931	$5,827	$15,524
8	8.98	0.07	16.63	0.13	$14,135	$9,255	$23,390	$6,382	$4,293	$6,293	$16,969
9	9.04	0.07	18.07	0.14	$15,360	$9,995	$25,355	$6,936	$4,677	$6,797	$18,409
10	8.72	0.07	18.84	0.15	$16,014	$10,795	$26,808	$7,231	$5,080	$7,340	$19,652
11	8.36	0.07	19.49	0.16	$16,566	$11,658	$28,225	$7,480	$5,448	$7,928	$20,855
12	8.46	0.07	21.29	0.18	$18,103	$12,591	$30,694	$8,174	$5,893	$8,562	$22,629
13	8.77	0.07	23.84	0.19	$20,271	$13,598	$33,869	$9,153	$6,440	$9,247	$24,840
14	9.07	0.07	26.65	0.21	$22,659	$14,686	$37,345	$10,232	$7,075	$9,986	$27,293
15	9.35	0.07	29.65	0.23	$25,206	$31,722	$56,928	$11,382	$7,778	$10,785	$29,945
16	9.65	0.07	33.07	0.26	$28,116	$34,259	$62,376	$12,696	$8,513	$11,648	$32,857
17	9.91	0.08	36.68	0.28	$31,186	$37,000	$68,186	$14,082	$9,304	$12,580	$35,966
18	10.23	0.08	40.88	0.30	$34,759	$39,960	$74,720	$15,695	$10,160	$13,586	$39,442
19	10.53	0.08	45.44	0.33	$38,629	$43,157	$81,786	$17,443	$11,027	$14,673	$43,143
20	10.75	0.08	50.10	0.36	$42,594	$46,610	$89,204	$19,233	$11,953	$15,847	$47,034
21	10.96	0.08	55.19	0.39	$46,922	$50,338	$97,260	$21,187	$13,013	$17,115	$51,315
22	11.18	0.08	60.80	0.42	$51,689	$54,365	$106,055	$23,340	$14,166	$18,484	$55,990
23	11.41	0.08	66.97	0.46	$56,941	$58,715	$115,656	$25,711	$15,422	$19,963	$61,096
24	11.63	0.08	73.78	0.50	$62,726	$63,412	$126,138	$28,323	$16,789	$21,560	$66,672
25	11.87	0.08	81.27	0.55	$69,099	$68,485	$137,584	$31,201	$18,277	$23,285	$72,763
26	12.10	0.08	89.53	0.60	$76,120	$73,964	$150,083	$34,371	$19,897	$25,148	$79,416
27	12.35	0.08	98.63	0.65	$83,853	$79,881	$163,734	$37,863	$21,661	$27,159	$86,684
28	12.59	0.08	108.65	0.71	$92,373	$86,271	$178,644	$41,710	$23,581	$29,332	$94,623
29	12.85	0.08	119.69	0.77	$101,758	$93,173	$194,931	$45,948	$25,671	$31,679	$103,298
30	13.10	0.08	131.85	0.84	$112,097	$100,627	$212,723	$50,616	$27,946.78	$34,213	$112,776

Table 6: Heating Optimistic Case Present Values

Year	Present Value - Annual Operating Cost							Present Value - Cummulative System	
	Current System			New System					
	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total	Current	New
	per yr							per yr	
0	$6,549	$5,000	$11,549	$2,957	$2,196	$3,400	$8,553	$11,549	$644,403
1	$6,337	$4,857	$11,194	$2,861	$2,167	$3,303	$8,332	$22,743	$652,735
2	$6,275	$4,718	$10,994	$2,833	$2,091	$3,208	$8,133	$33,736	$660,867
3	$6,196	$4,584	$10,780	$2,798	$2,042	$3,117	$7,957	$44,516	$668,824
4	$6,179	$4,453	$10,632	$2,790	$1,983	$3,028	$7,801	$55,148	$676,626
5	$6,181	$4,325	$10,507	$2,791	$1,947	$2,941	$7,679	$65,655	$684,305
6	$6,102	$4,202	$10,304	$2,755	$1,912	$2,857	$7,525	$75,958	$691,829
7	$6,083	$4,082	$10,165	$2,747	$1,872	$2,776	$7,395	$86,123	$699,224
8	$6,056	$3,965	$10,021	$2,735	$1,839	$2,696	$7,270	$96,145	$706,494
9	$5,919	$3,852	$9,771	$2,673	$1,802	$2,619	$7,094	$105,916	$713,588
10	$5,551	$3,742	$9,293	$2,506	$1,761	$2,544	$6,812	$115,209	$720,400
11	$5,165	$3,635	$8,800	$2,332	$1,698	$2,472	$6,502	$124,009	$726,903
12	$5,077	$3,531	$8,608	$2,292	$1,653	$2,401	$6,346	$132,617	$733,249
13	$5,113	$3,430	$8,544	$2,309	$1,625	$2,332	$6,266	$141,160	$739,515
14	$5,141	$3,332	$8,473	$2,321	$1,605	$2,266	$6,192	$149,633	$745,707
15	$5,144	$6,474	$11,618	$2,323	$1,587	$2,201	$6,111	$161,252	$751,819
16	$5,161	$6,289	$11,450	$2,330	$1,563	$2,138	$6,031	$172,702	$757,850
17	$5,149	$6,109	$11,258	$2,325	$1,536	$2,077	$5,938	$183,960	$763,789
18	$5,162	$5,935	$11,097	$2,331	$1,509	$2,018	$5,858	$195,057	$769,646
19	$5,160	$5,765	$10,925	$2,330	$1,473	$1,960	$5,763	$205,982	$775,409
20	$5,118	$5,600	$10,718	$2,311	$1,436	$1,904	$5,651	$216,701	$781,061
21	$5,071	$5,440	$10,512	$2,290	$1,406	$1,850	$5,546	$227,212	$786,607
22	$5,025	$5,285	$10,310	$2,269	$1,377	$1,797	$5,443	$237,522	$792,050
23	$4,979	$5,134	$10,113	$2,248	$1,348	$1,746	$5,342	$247,635	$797,392
24	$4,933	$4,987	$9,921	$2,228	$1,320	$1,696	$5,244	$257,555	$802,635
25	$4,888	$4,845	$9,733	$2,207	$1,293	$1,647	$5,147	$267,288	$807,783
26	$4,844	$4,706	$9,550	$2,187	$1,266	$1,600	$5,053	$276,838	$812,836
27	$4,799	$4,572	$9,371	$2,167	$1,240	$1,554	$4,961	$286,209	$817,797
28	$4,755	$4,441	$9,197	$2,147	$1,214	$1,510	$4,871	$295,406	$822,669
29	$4,712	$4,314	$9,026	$2,128	$1,189	$1,467	$4,783	$304,432	$827,452
30	$4,669	$4,191	$8,860	$2,108	$1,164	$1,425	$4,697	$313,292	$832,149

Table 7: Heating Nominal Case Parameters

Financial Parameters	
Interest Rate	6.0%
Inflation	3.5%

Current System		
Boiler		
Required Input	850.2	Mbtu / yr
Annual Maintenance Cost	$5,000	per yr
Later Maintenance	$ 10,000	

New System		
Boiler + Ventilation		
Required Input	383.9	Mbtu / yr
Annual Maintenance Cost	$2,600	per yr
Equipment Cost	$133,350	
Installation Cost	$0	

Fan Coils				
	54	Large	200	Small
Power	0.135	kW	0.06	kW
Utilization	40%			
$800	per yr			
$502,500				
$0				
Hours of Operation			4320	
Annual Power Consumption			33333	kW-hr / yr

Table 8: Heating Nominal Case Future Values

Year	Energy Cost				Future Value - Annual Operating Cost						
	Present		Future		Current System			New System			
	Gas	Electricity	Gas	Electricity	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr						
0	7.25	0.07	7.25	0.07	$6,164	$5,000	$11,164	$2,783	$2,167	$3,400	$8,350
1	7.16	0.07	7.41	0.07	$6,299	$5,175	$11,474	$2,844	$2,250	$3,519	$8,613
2	7.21	0.06	7.73	0.07	$6,571	$5,356	$11,927	$2,967	$2,305	$3,642	$8,914
3	7.29	0.06	8.08	0.07	$6,871	$5,544	$12,414	$3,102	$2,390	$3,770	$9,262
4	7.40	0.06	8.49	0.07	$7,215	$5,738	$12,953	$3,258	$2,470	$3,902	$9,630
5	7.55	0.06	8.96	0.08	$7,622	$5,938	$13,560	$3,442	$2,573	$4,038	$10,053
6	7.71	0.07	9.48	0.08	$8,059	$6,146	$14,205	$3,639	$2,689	$4,179	$10,507
7	7.93	0.07	10.09	0.08	$8,575	$6,361	$14,937	$3,872	$2,811	$4,326	$11,009
8	8.13	0.07	10.71	0.09	$9,106	$6,584	$15,690	$4,112	$2,941	$4,477	$11,530
9	8.28	0.07	11.29	0.09	$9,598	$6,814	$16,413	$4,334	$3,071	$4,634	$12,039
10	8.23	0.07	11.62	0.10	$9,876	$7,053	$16,929	$4,459	$3,202	$4,796	$12,458
11	8.14	0.07	11.89	0.10	$10,108	$7,300	$17,408	$4,564	$3,310	$4,964	$12,838
12	8.27	0.07	12.50	0.10	$10,623	$7,555	$18,179	$4,797	$3,447	$5,138	$13,381
13	8.43	0.07	13.19	0.11	$11,212	$7,820	$19,032	$5,063	$3,603	$5,317	$13,983
14	8.71	0.07	14.10	0.11	$11,986	$8,093	$20,080	$5,412	$3,780	$5,504	$14,696
15	8.97	0.07	15.03	0.12	$12,777	$16,753	$29,530	$5,769	$3,981	$5,696	$15,447
16	9.28	0.07	16.09	0.13	$13,678	$17,340	$31,018	$6,176	$4,178	$5,896	$16,250
17	9.54	0.07	17.12	0.13	$14,558	$17,947	$32,505	$6,573	$4,376	$6,102	$17,051
18	9.88	0.07	18.35	0.14	$15,598	$18,575	$34,173	$7,043	$4,588	$6,315	$17,947
19	10.13	0.07	19.47	0.14	$16,557	$19,225	$35,782	$7,476	$4,791	$6,537	$18,804
20	10.24	0.08	20.37	0.15	$17,318	$19,898	$37,216	$7,820	$4,981	$6,765	$19,566
21	10.44	0.08	21.50	0.16	$18,282	$20,594	$38,877	$8,255	$5,197	$7,002	$20,454
22	10.65	0.08	22.70	0.16	$19,301	$21,315	$40,616	$8,715	$5,422	$7,247	$21,384
23	10.86	0.08	23.97	0.17	$20,376	$22,061	$42,437	$9,201	$5,657	$7,501	$22,358
24	11.08	0.08	25.30	0.18	$21,511	$22,833	$44,344	$9,713	$5,902	$7,763	$23,378
25	11.30	0.08	26.71	0.18	$22,709	$23,632	$46,341	$10,254	$6,157	$8,035	$24,446
26	11.53	0.08	28.20	0.19	$23,974	$24,460	$48,433	$10,825	$6,423	$8,316	$25,565
27	11.76	0.08	29.77	0.20	$25,309	$25,316	$50,625	$11,428	$6,701	$8,607	$26,737
28	11.99	0.08	31.43	0.21	$26,719	$26,202	$52,921	$12,065	$6,991	$8,909	$27,965
29	12.23	0.08	33.18	0.22	$28,207	$27,119	$55,326	$12,737	$7,294	$9,220	$29,251
30	12.48	0.08	35.02	0.23	$29,778	$28,068	$57,846	$13,446	$7,609.71	$9,543	$30,599

Table 9: Heating Nominal Case Present Values

Year	Present Value - Annual Operating Cost							Present Value - Cummulative System	
	Current System			New System					
	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total	Current	New
	per yr							per yr	
0	$6,164	$5,000	$11,164	$2,783	$2,167	$3,400	$8,350	$11,164	$644,200
1	$5,943	$4,882	$10,825	$2,683	$2,122	$3,320	$8,126	$21,989	$652,326
2	$5,848	$4,767	$10,615	$2,640	$2,051	$3,242	$7,933	$32,604	$660,259
3	$5,769	$4,655	$10,423	$2,605	$2,007	$3,165	$7,777	$43,027	$668,036
4	$5,715	$4,545	$10,260	$2,581	$1,956	$3,090	$7,627	$53,287	$675,663
5	$5,695	$4,438	$10,133	$2,572	$1,923	$3,018	$7,512	$63,420	$683,176
6	$5,681	$4,333	$10,014	$2,565	$1,896	$2,946	$7,407	$73,434	$690,583
7	$5,703	$4,231	$9,934	$2,575	$1,869	$2,877	$7,321	$83,368	$697,904
8	$5,713	$4,131	$9,844	$2,580	$1,845	$2,809	$7,234	$93,212	$705,138
9	$5,681	$4,033	$9,715	$2,565	$1,818	$2,743	$7,126	$102,926	$712,264
10	$5,514	$3,938	$9,453	$2,490	$1,788	$2,678	$6,956	$112,379	$719,220
11	$5,325	$3,845	$9,170	$2,404	$1,744	$2,615	$6,763	$121,549	$725,983
12	$5,279	$3,755	$9,034	$2,384	$1,713	$2,553	$6,650	$130,584	$732,633
13	$5,257	$3,666	$8,923	$2,374	$1,689	$2,493	$6,556	$139,506	$739,189
14	$5,301	$3,580	$8,881	$2,394	$1,672	$2,434	$6,500	$148,388	$745,689
15	$5,331	$6,991	$12,322	$2,407	$1,661	$2,377	$6,445	$160,710	$752,135
16	$5,384	$6,826	$12,210	$2,431	$1,645	$2,321	$6,397	$172,920	$758,532
17	$5,406	$6,665	$12,071	$2,441	$1,625	$2,266	$6,332	$184,991	$764,864
18	$5,465	$6,508	$11,972	$2,468	$1,607	$2,213	$6,288	$196,963	$771,151
19	$5,472	$6,354	$11,826	$2,471	$1,583	$2,160	$6,215	$208,789	$777,366
20	$5,400	$6,204	$11,604	$2,438	$1,553	$2,109	$6,101	$220,393	$783,467
21	$5,378	$6,058	$11,436	$2,428	$1,529	$2,060	$6,017	$231,829	$789,484
22	$5,356	$5,915	$11,271	$2,418	$1,505	$2,011	$5,934	$243,100	$795,418
23	$5,334	$5,776	$11,110	$2,409	$1,481	$1,964	$5,853	$254,210	$801,271
24	$5,313	$5,639	$10,952	$2,399	$1,458	$1,917	$5,774	$265,162	$807,045
25	$5,291	$5,506	$10,797	$2,389	$1,435	$1,872	$5,696	$275,960	$812,741
26	$5,270	$5,376	$10,646	$2,379	$1,412	$1,828	$5,619	$286,606	$818,360
27	$5,248	$5,250	$10,498	$2,370	$1,390	$1,785	$5,544	$297,104	$823,905
28	$5,227	$5,126	$10,353	$2,360	$1,368	$1,743	$5,471	$307,457	$829,375
29	$5,206	$5,005	$10,211	$2,351	$1,346	$1,702	$5,398	$317,667	$834,774
30	$5,185	$4,887	$10,072	$2,341	$1,325	$1,662	$5,328	$327,739	$840,102

Table 3: Heating Pessimistic Case Parameters

Financial Parameters	
Interest Rate	5.0%
Inflation	2.0%

Current System		
Boiler		
Required Input	850.2	Mbtu / yr
Annual Maintenance Cost	$5,000	per yr
Later Maintenance	$ 10,000	

New System		
Boiler + Ventilation		
Required Input	383.9	Mbtu / yr
Annual Maintenance Cost	$2,600	per yr
Equipment Cost	$133,350	
Installation Cost	$0	

Fan Coils					
	54	Large	200	Small	
Power	0.135	kW	0.06	kW	
Utilization	40%				
$800	per yr				
$502,500					
$0					
Hours of Operation			4320		
Annual Power Consumption			33333	kW-hr / yr	

Table 11: Heating Pessimistic Case Future Values

Year	Energy Cost				Future Value - Annual Operating Cost						
	Present		Future		Current System			New System			
	Gas	Electricity	Gas	Electricity	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr						
0	6.80	0.06	6.80	0.06	$5,779	$5,000	$10,779	$2,610	$2,137	$3,400	$8,147
1	6.65	0.06	6.78	0.06	$5,763	$5,100	$10,863	$2,602	$2,159	$3,468	$8,229
2	6.61	0.06	6.87	0.07	$5,844	$5,202	$11,046	$2,639	$2,172	$3,537	$8,349
3	6.63	0.06	7.03	0.07	$5,980	$5,306	$11,286	$2,700	$2,212	$3,608	$8,520
4	6.63	0.06	7.18	0.07	$6,101	$5,412	$11,513	$2,755	$2,249	$3,680	$8,684
5	6.69	0.06	7.39	0.07	$6,281	$5,520	$11,802	$2,836	$2,300	$3,754	$8,890
6	6.88	0.06	7.75	0.07	$6,589	$5,631	$12,219	$2,975	$2,365	$3,829	$9,169
7	7.09	0.06	8.15	0.07	$6,925	$5,743	$12,668	$3,127	$2,441	$3,906	$9,473
8	7.28	0.06	8.54	0.08	$7,257	$5,858	$13,115	$3,277	$2,516	$3,984	$9,776
9	7.53	0.07	9.00	0.08	$7,650	$5,975	$13,626	$3,454	$2,590	$4,063	$10,108
10	7.74	0.07	9.44	0.08	$8,026	$6,095	$14,121	$3,624	$2,666	$4,145	$10,435
11	7.93	0.07	9.86	0.08	$8,383	$6,217	$14,600	$3,785	$2,733	$4,227	$10,746
12	8.08	0.07	10.25	0.08	$8,715	$6,341	$15,056	$3,935	$2,818	$4,312	$11,065
13	8.10	0.07	10.48	0.09	$8,906	$6,468	$15,374	$4,021	$2,897	$4,398	$11,317
14	8.35	0.07	11.01	0.09	$9,362	$6,597	$15,959	$4,227	$2,984	$4,486	$11,698
15	8.59	0.07	11.57	0.09	$9,833	$13,459	$23,292	$4,440	$3,097	$4,576	$12,113
16	8.90	0.07	12.22	0.10	$10,392	$13,728	$24,120	$4,692	$3,205	$4,667	$12,565
17	9.17	0.07	12.84	0.10	$10,915	$14,002	$24,917	$4,928	$3,307	$4,761	$12,996
18	9.52	0.07	13.60	0.10	$11,563	$14,282	$25,846	$5,221	$3,424	$4,856	$13,502
19	9.73	0.07	14.18	0.11	$12,053	$14,568	$26,621	$5,442	$3,539	$4,953	$13,934
20	9.72	0.07	14.45	0.11	$12,286	$14,859	$27,145	$5,548	$3,629	$5,052	$14,229
21	9.92	0.07	15.03	0.11	$12,782	$15,157	$27,939	$5,772	$3,732	$5,153	$14,657
22	10.12	0.07	15.64	0.12	$13,299	$15,460	$28,759	$6,005	$3,837	$5,256	$15,098
23	10.32	0.08	16.27	0.12	$13,836	$15,769	$29,605	$6,248	$3,945	$5,361	$15,554
24	10.53	0.08	16.93	0.12	$14,395	$16,084	$30,479	$6,500	$4,056	$5,469	$16,024
25	10.74	0.08	17.62	0.13	$14,977	$16,406	$31,383	$6,763	$4,170	$5,578	$16,511
26	10.95	0.08	18.33	0.13	$15,582	$16,734	$32,316	$7,036	$4,287	$5,690	$17,013
27	11.17	0.08	19.07	0.13	$16,211	$17,069	$33,280	$7,320	$4,408	$5,803	$17,532
28	11.39	0.08	19.84	0.14	$16,866	$17,410	$34,276	$7,616	$4,532	$5,919	$18,068
29	11.62	0.08	20.64	0.14	$17,547	$17,758	$35,306	$7,923	$4,660	$6,038	$18,621
30	11.85	0.08	21.47	0.14	$18,256	$18,114	$36,370	$8,243	$4,791.19	$6,159	$19,193

Table 42: Heating Pessimistic Case Present Values

Year	Present Value - Annual Operating Cost							Present Value - Cummulative System	
	Current System			New System					
	Gas	Maintinance	Total	Gas	Electricity	Maintinance	Total	Current	New
	per yr							per yr	
0	$5,779	$5,000	$10,779	$2,610	$2,137	$3,400	$8,147	$10,779	$643,997
1	$5,488	$4,857	$10,345	$2,478	$2,056	$3,303	$7,837	$21,125	$651,834
2	$5,301	$4,718	$10,019	$2,394	$1,970	$3,208	$7,572	$31,144	$659,406
3	$5,166	$4,584	$9,749	$2,332	$1,911	$3,117	$7,360	$40,893	$666,766
4	$5,019	$4,453	$9,472	$2,266	$1,850	$3,028	$7,144	$50,365	$673,910
5	$4,922	$4,325	$9,247	$2,222	$1,802	$2,941	$6,966	$59,612	$680,876
6	$4,917	$4,202	$9,118	$2,220	$1,765	$2,857	$6,842	$68,730	$687,718
7	$4,921	$4,082	$9,003	$2,222	$1,735	$2,776	$6,733	$77,733	$694,450
8	$4,912	$3,965	$8,877	$2,218	$1,703	$2,696	$6,617	$86,610	$701,067
9	$4,931	$3,852	$8,783	$2,227	$1,670	$2,619	$6,516	$95,393	$707,583
10	$4,928	$3,742	$8,669	$2,225	$1,637	$2,544	$6,406	$104,063	$713,989
11	$4,901	$3,635	$8,536	$2,213	$1,598	$2,472	$6,283	$112,599	$720,272
12	$4,853	$3,531	$8,384	$2,191	$1,569	$2,401	$6,162	$120,982	$726,433
13	$4,723	$3,430	$8,153	$2,133	$1,537	$2,332	$6,002	$129,136	$732,435
14	$4,728	$3,332	$8,060	$2,135	$1,507	$2,266	$5,908	$137,196	$738,343
15	$4,730	$6,474	$11,204	$2,136	$1,490	$2,201	$5,826	$148,400	$744,170
16	$4,761	$6,289	$11,049	$2,150	$1,468	$2,138	$5,756	$159,449	$749,926
17	$4,762	$6,109	$10,871	$2,150	$1,443	$2,077	$5,670	$170,321	$755,596
18	$4,805	$5,935	$10,740	$2,170	$1,423	$2,018	$5,610	$181,060	$761,206
19	$4,770	$5,765	$10,535	$2,154	$1,400	$1,960	$5,514	$191,595	$766,720
20	$4,630	$5,600	$10,231	$2,091	$1,368	$1,904	$5,363	$201,826	$772,083
21	$4,588	$5,440	$10,028	$2,072	$1,339	$1,850	$5,261	$211,854	$777,344
22	$4,546	$5,285	$9,831	$2,053	$1,312	$1,797	$5,161	$221,685	$782,505
23	$4,505	$5,134	$9,639	$2,034	$1,284	$1,746	$5,064	$231,324	$787,569
24	$4,463	$4,987	$9,451	$2,015	$1,258	$1,696	$4,969	$240,775	$792,538
25	$4,423	$4,845	$9,267	$1,997	$1,231	$1,647	$4,876	$250,042	$797,414
26	$4,382	$4,706	$9,089	$1,979	$1,206	$1,600	$4,785	$259,131	$802,198
27	$4,342	$4,572	$8,914	$1,961	$1,181	$1,554	$4,696	$268,045	$806,894
28	$4,302	$4,441	$8,744	$1,943	$1,156	$1,510	$4,609	$276,788	$811,503
29	$4,263	$4,314	$8,577	$1,925	$1,132	$1,467	$4,524	$285,366	$816,027
30	$4,224	$4,191	$8,415	$1,907	$1,109	$1,425	$4,441	$293,781	$820,468

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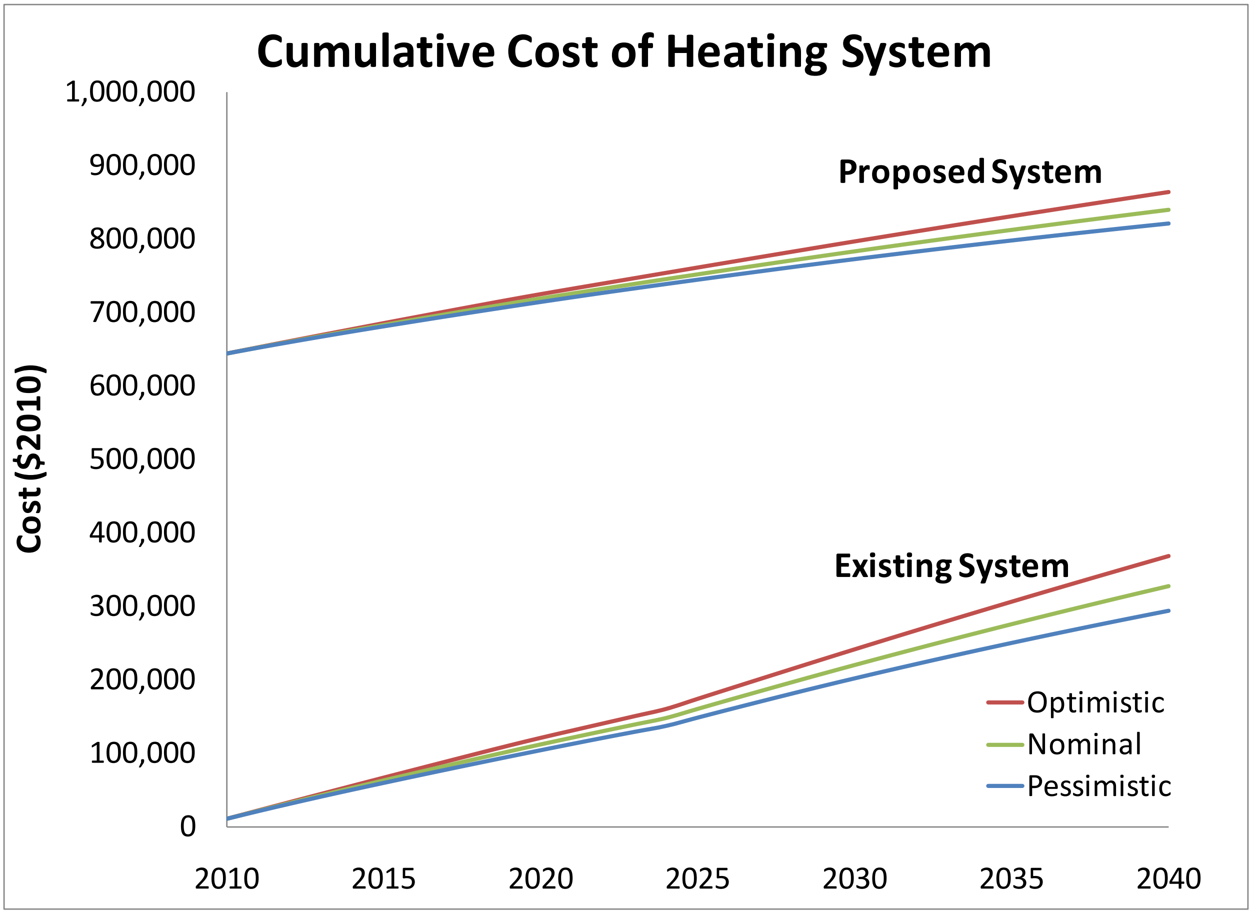

Figure 5: Cumulative Cost of Operating new and Retrofitted Heating System

Table 13: Summer Dorm Usage 2010

<table>
<tr><td colspan="2">Total Groups</td><td>35</td></tr>
<tr><td colspan="2">Rooms Utilized</td><td>1016</td></tr>
<tr><td colspan="2">Room Rate
(per suite)
Based on Accommodation</td><td>Single, Private</td></tr>
<tr><td rowspan="4">Total Income</td><td>Double, Private</td><td>$42.50</td></tr>
<tr><td>Single, Shared</td><td>$47.90</td></tr>
<tr><td>Double, Shared</td><td>$47.90</td></tr>
<tr><td>$318,151</td><td>$66.40</td></tr>
<tr><td colspan="2">5 year Average Income</td><td>$260,000 per year</td></tr>
<tr><td colspan="2">Projected Room Rate Increase for AC</td><td>$3 - $5</td></tr>
<tr><td colspan="3">“There has been no demand for rooms with AC at a higher rate.”
Jeff Stob, Director of Conference & Campus Events</td></tr>
</table>

Table 14: Cooling Optimistic Case Parameters

Financial Parameters	
Interest Rate	10.0%
Inflation	8.0%

Energy & Costs						
	Fan Coils				Chiller	
	54	Large	200	Small	180	ton
Power	0.135	kW	0.06	kW	1.008888	kW / ton
Utilization	40%				71%	
Hours of Operation			2880		hr / yr	
Annual Power Consumption			22222.1	kW-hr / yr	371335	kW-hr / yr
Total			393557		kW-hr / yr	
Equipment Cost			$0		$93,600	
Installation Cost			$0		$100,000	
Annual Maintenance Cost			$0	per yr	$1,996	per yr

CERF					
Chiller		Heat Ex.		Energy Recovery	
				375300	btu / hr
0	kW	0	kW	110.0	kW
71%		71%		71%	
2880		hr / yr		2880	hr / yr
0	kW-hr / yr	0	kW-hr / yr	Annual Energy Saving	
Total		0	kW-hr / yr	767.41	Mbtu / yr
$10,400		$4,200			
$10,400		$4,200			
$0	per yr	$0	per yr		

Table 15: Cooling Optimistic Case Future Values

Year	Energy Cost				Future Value		
	Present		Future		Annual		
	Gas	Electricity	Gas	Electricity	Operating	Saving	Net
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr		
0	$ 7.70	$ 0.066	$ 7.70	$ 0.07	($27,925)	$5,911	$5,911
1	$ 7.67	$ 0.067	$ 8.29	$ 0.07	($30,605)	$6,359	$6,359
2	$ 7.82	$ 0.066	$ 9.12	$ 0.08	($32,837)	$7,001	$7,001
3	$ 7.95	$ 0.067	$ 10.02	$ 0.08	($35,647)	$7,686	$7,686
4	$ 8.16	$ 0.067	$ 11.10	$ 0.09	($38,492)	$8,521	$8,521
5	$ 8.40	$ 0.068	$ 12.35	$ 0.10	($41,970)	$9,477	$9,477
6	$ 8.54	$ 0.068	$ 13.55	$ 0.11	($45,798)	$10,400	$10,400
7	$ 8.76	$ 0.069	$ 15.02	$ 0.12	($49,829)	$11,527	$11,527
8	$ 8.98	$ 0.070	$ 16.63	$ 0.13	($54,383)	$12,759	$12,759
9	$ 9.04	$ 0.070	$ 18.07	$ 0.14	($59,207)	$13,864	$13,864
10	$ 8.72	$ 0.071	$ 18.84	$ 0.15	($64,293)	$14,455	$14,455
11	$ 8.36	$ 0.070	$ 19.49	$ 0.16	($68,972)	$14,953	$14,953
12	$ 8.46	$ 0.070	$ 21.29	$ 0.18	($74,601)	$16,340	$16,340
13	$ 8.77	$ 0.071	$ 23.84	$ 0.19	($81,468)	$18,297	$18,297
14	$ 9.07	$ 0.072	$ 26.65	$ 0.21	($89,390)	$20,453	$20,453
15	$ 9.35	$ 0.074	$ 29.65	$ 0.23	($98,167)	$22,752	$22,752
16	$ 9.65	$ 0.075	$ 33.07	$ 0.26	($107,348)	$25,378	$25,378
17	$ 9.91	$ 0.075	$ 36.68	$ 0.28	($117,237)	$28,149	$28,149
18	$ 10.23	$ 0.076	$ 40.88	$ 0.30	($127,932)	$31,375	$31,375
19	$ 10.53	$ 0.077	$ 45.44	$ 0.33	($138,804)	$34,868	$34,868
20	$ 10.75	$ 0.077	$ 50.10	$ 0.36	($150,434)	$38,447	$38,447
21	$ 10.96	$ 0.078	$ 55.19	$ 0.39	($163,688)	$42,353	$42,353
22	$ 11.18	$ 0.078	$ 60.80	$ 0.42	($178,110)	$46,656	$46,656
23	$ 11.41	$ 0.079	$ 66.97	$ 0.46	($193,804)	$51,396	$51,396
24	$ 11.63	$ 0.079	$ 73.78	$ 0.50	($210,882)	$56,618	$56,618
25	$ 11.87	$ 0.080	$ 81.27	$ 0.55	($229,465)	$62,371	$62,371
26	$ 12.10	$ 0.081	$ 89.53	$ 0.60	($249,687)	$68,708	$68,708
27	$ 12.35	$ 0.081	$ 98.63	$ 0.65	($271,692)	$75,688	$75,688
28	$ 12.59	$ 0.082	$ 108.65	$ 0.71	($295,636)	$83,378	$83,378
29	$ 12.85	$ 0.083	$ 119.69	$ 0.77	($321,693)	$91,850	$91,850
30	$ 13.10	$ 0.083	$ 131.85	$ 0.84	($350,047)	$101,181	$101,181

Table 16: Cooling Optimistic Case Present Values

Year	Present Value							
	Annual			Cumulative			Cumulative	
	Operatin	Saving	Net	w/o CERF	CERF Saving	w/ CERF	w/o CERF	w/ CERF
	per yr			Total			Total	
0	($27,925)	$5,911	$5,911	($221,525)	($23,289)	($244,814)	$221,525	$244,814
1	($27,823)	$5,781	$5,781	($249,348)	($17,508)	($266,856)	$249,348	$266,856
2	($27,138)	$5,786	$5,786	($276,486)	($11,722)	($288,208)	$276,486	$288,208
3	($26,782)	$5,775	$5,775	($303,268)	($5,948)	($309,216)	$303,268	$309,216
4	($26,291)	$5,820	$5,820	($329,559)	($127)	($329,687)	$329,559	$329,687
5	($26,060)	$5,884	$5,884	($355,619)	$5,757	($349,862)	$355,619	$349,862
6	($25,852)	$5,871	$5,871	($381,471)	$11,627	($369,843)	$381,471	$369,843
7	($25,570)	$5,915	$5,915	($407,041)	$17,543	($389,498)	$407,041	$389,498
8	($25,370)	$5,952	$5,952	($432,411)	$23,495	($408,916)	$432,411	$408,916
9	($25,109)	$5,880	$5,880	($457,520)	$29,375	($428,146)	$457,520	$428,146
10	($24,788)	$5,573	$5,573	($482,308)	$34,948	($447,360)	$482,308	$447,360
11	($24,174)	$5,241	$5,241	($506,482)	$40,189	($466,293)	$506,482	$466,293
12	($23,770)	$5,207	$5,207	($530,252)	$45,395	($484,857)	$530,252	$484,857
13	($23,598)	$5,300	$5,300	($553,851)	$50,695	($503,155)	$553,851	$503,155
14	($23,539)	$5,386	$5,386	($577,390)	$56,081	($521,309)	$577,390	$521,309
15	($23,500)	$5,447	$5,447	($600,890)	$61,528	($539,363)	$600,890	$539,363
16	($23,362)	$5,523	$5,523	($624,252)	$67,051	($557,201)	$624,252	$557,201
17	($23,195)	$5,569	$5,569	($647,447)	$72,620	($574,827)	$647,447	$574,827
18	($23,010)	$5,643	$5,643	($670,457)	$78,263	($592,194)	$670,457	$592,194
19	($22,696)	$5,701	$5,701	($693,152)	$83,964	($609,188)	$693,152	$609,188
20	($22,361)	$5,715	$5,715	($715,513)	$89,679	($625,834)	$715,513	$625,834
21	($22,119)	$5,723	$5,723	($737,632)	$95,402	($642,230)	$737,632	$642,230
22	($21,880)	$5,732	$5,732	($759,513)	$101,134	($658,379)	$759,513	$658,379
23	($21,644)	$5,740	$5,740	($781,156)	$106,874	($674,283)	$781,156	$674,283
24	($21,410)	$5,748	$5,748	($802,566)	$112,622	($689,944)	$802,566	$689,944
25	($21,179)	$5,757	$5,757	($823,745)	$118,378	($705,367)	$823,745	$705,367
26	($20,950)	$5,765	$5,765	($844,695)	$124,143	($720,552)	$844,695	$720,552
27	($20,724)	$5,773	$5,773	($865,419)	$129,917	($735,502)	$865,419	$735,502
28	($20,500)	$5,782	$5,782	($885,919)	$135,698	($750,221)	$885,919	$750,221
29	($20,279)	$5,790	$5,790	($906,199)	$141,489	($764,710)	$906,199	$764,710
30	($20,061)	$5,799	$5,799	($926,259)	$147,287	($778,972)	$926,259	$778,972

Table 17: Cooling Nominal Case Parameters

Financial Parameters	
Interest Rate	6.0%
Inflation	3.5%

Energy & Costs						
	Fan Coils				Chiller	
	54	Large	200	Small	180	ton
Power	0.135	kW	0.06	kW	1.008888	kW / ton
Utilization	40%				71%	
Hours of Operation		2880			hr / yr	
Annual Power Consumption		22222.1	kW-hr / yr		371335	kW-hr / yr
Total		393557			kW-hr / yr	
Equipment Cost		$0			$93,600	
Installation Cost		$0			$100,000	
Annual Maintenance Cost		$0	per yr		$1,996	per yr

CERF					
Chiller		Heat Ex.		Energy Recovery	
				375300	btu / hr
0	kW	0	kW	110.0	kW
71%		71%		71%	
2880		hr / yr		2880	hr / yr
0	kW-hr / yr	0	kW-hr / yr	Annual Energy Saving	
Total		0	kW-hr / yr	767.41	Mbtu / yr
$10,400		$4,200			
$10,400		$4,200			
$0	per yr	$0	per yr		

Table 18: Cooling Nominal Case Future Values

Year	Energy Cost				Future Value		
	Present		Future		Annual		
	Gas	Electricity	Gas	Electricity	Operating	Saving	Net
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr		
0	$ 7.25	$ 0.07	$ 7.25	$ 0.07	($27,577)	$5,563.75	$5,563.75
1	$ 7.16	$ 0.07	$ 7.41	$ 0.07	($28,629)	$5,686.05	$5,686.05
2	$ 7.21	$ 0.06	$ 7.73	$ 0.07	($29,352)	$5,930.71	$5,930.71
3	$ 7.29	$ 0.06	$ 8.08	$ 0.07	($30,435)	$6,201.85	$6,201.85
4	$ 7.40	$ 0.06	$ 8.49	$ 0.07	($31,453)	$6,512.67	$6,512.67
5	$ 7.55	$ 0.06	$ 8.96	$ 0.08	($32,753)	$6,879.57	$6,879.57
6	$ 7.71	$ 0.07	$ 9.48	$ 0.08	($34,203)	$7,273.99	$7,273.99
7	$ 7.93	$ 0.07	$ 10.09	$ 0.08	($35,726)	$7,740.35	$7,740.35
8	$ 8.13	$ 0.07	$ 10.71	$ 0.09	($37,349)	$8,219.18	$8,219.18
9	$ 8.28	$ 0.07	$ 11.29	$ 0.09	($38,983)	$8,663.67	$8,663.67
10	$ 8.23	$ 0.07	$ 11.62	$ 0.10	($40,626)	$8,913.95	$8,913.95
11	$ 8.14	$ 0.07	$ 11.89	$ 0.10	($41,996)	$9,123.80	$9,123.80
12	$ 8.27	$ 0.07	$ 12.50	$ 0.10	($43,714)	$9,588.84	$9,588.84
13	$ 8.43	$ 0.07	$ 13.19	$ 0.11	($45,665)	$10,120.38	$10,120.38
14	$ 8.71	$ 0.07	$ 14.10	$ 0.11	($47,859)	$10,819.04	$10,819.04
15	$ 8.97	$ 0.07	$ 15.03	$ 0.12	($50,351)	$11,532.55	$11,532.55
16	$ 9.28	$ 0.07	$ 16.09	$ 0.13	($52,796)	$12,346.35	$12,346.35
17	$ 9.54	$ 0.07	$ 17.12	$ 0.13	($55,244)	$13,140.24	$13,140.24
18	$ 9.88	$ 0.07	$ 18.35	$ 0.14	($57,879)	$14,079.22	$14,079.22
19	$ 10.13	$ 0.07	$ 19.47	$ 0.14	($60,404)	$14,944.70	$14,944.70
20	$ 10.24	$ 0.08	$ 20.37	$ 0.15	($62,787)	$15,631.53	$15,631.53
21	$ 10.44	$ 0.08	$ 21.50	$ 0.16	($65,472)	$16,502.21	$16,502.21
22	$ 10.65	$ 0.08	$ 22.70	$ 0.16	($68,271)	$17,421.38	$17,421.38
23	$ 10.86	$ 0.08	$ 23.97	$ 0.17	($71,191)	$18,391.75	$18,391.75
24	$ 11.08	$ 0.08	$ 25.30	$ 0.18	($74,235)	$19,416.17	$19,416.17
25	$ 11.30	$ 0.08	$ 26.71	$ 0.18	($77,411)	$20,497.66	$20,497.66
26	$ 11.53	$ 0.08	$ 28.20	$ 0.19	($80,722)	$21,639.37	$21,639.37
27	$ 11.76	$ 0.08	$ 29.77	$ 0.20	($84,175)	$22,844.69	$22,844.69
28	$ 11.99	$ 0.08	$ 31.43	$ 0.21	($87,776)	$24,117.14	$24,117.14
29	$ 12.23	$ 0.08	$ 33.18	$ 0.22	($91,532)	$25,460.46	$25,460.46
30	$ 12.48	$ 0.08	$ 35.02	$ 0.23	($95,449)	$26,878.61	$26,878.61

Table 19: Cooling Nominal Case Present Values

Year	Present Value							
	Annual			Cumulative			Cumulative	
	Operating	Saving	Net	w/o CERF	CERF Saving	w/ CERF	w/o CERF	w/ CERF
	per yr			Total			Total	
0	($27,577)	$5,564	$5,564	($221,177)	($23,636)	($244,813)	$221,177	$244,813
1	($27,008)	$5,364	$5,364	($248,185)	($18,272)	($266,457)	$248,185	$266,457
2	($26,123)	$5,278	$5,278	($274,308)	($12,994)	($287,302)	$274,308	$287,302
3	($25,554)	$5,207	$5,207	($299,862)	($7,787)	($307,649)	$299,862	$307,649
4	($24,913)	$5,159	$5,159	($324,776)	($2,628)	($327,404)	$324,776	$327,404
5	($24,475)	$5,141	$5,141	($349,251)	$2,513	($346,738)	$349,251	$346,738
6	($24,112)	$5,128	$5,128	($373,362)	$7,641	($365,721)	$373,362	$365,721
7	($23,760)	$5,148	$5,148	($397,122)	$12,789	($384,334)	$397,122	$384,334
8	($23,433)	$5,157	$5,157	($420,556)	$17,945	($402,610)	$420,556	$402,610
9	($23,074)	$5,128	$5,128	($443,630)	$23,073	($420,556)	$443,630	$420,556
10	($22,685)	$4,978	$4,978	($466,315)	$28,051	($438,264)	$466,315	$438,264
11	($22,123)	$4,806	$4,806	($488,438)	$32,857	($455,580)	$488,438	$455,580
12	($21,725)	$4,765	$4,765	($510,162)	$37,623	($472,540)	$510,162	$472,540
13	($21,409)	$4,745	$4,745	($531,572)	$42,367	($489,204)	$531,572	$489,204
14	($21,168)	$4,785	$4,785	($552,740)	$47,153	($505,587)	$552,740	$505,587
15	($21,010)	$4,812	$4,812	($573,749)	$51,965	($521,784)	$573,749	$521,784
16	($20,783)	$4,860	$4,860	($594,532)	$56,825	($537,707)	$594,532	$537,707
17	($20,516)	$4,880	$4,880	($615,048)	$61,705	($553,343)	$615,048	$553,343
18	($20,277)	$4,933	$4,933	($635,325)	$66,637	($568,688)	$635,325	$568,688
19	($19,964)	$4,939	$4,939	($655,289)	$71,577	($583,713)	$655,289	$583,713
20	($19,577)	$4,874	$4,874	($674,867)	$76,451	($598,416)	$674,867	$598,416
21	($19,259)	$4,854	$4,854	($694,126)	$81,305	($612,821)	$694,126	$612,821
22	($18,946)	$4,835	$4,835	($713,071)	$86,139	($626,932)	$713,071	$626,932
23	($18,638)	$4,815	$4,815	($731,709)	$90,954	($640,754)	$731,709	$640,754
24	($18,335)	$4,795	$4,795	($750,043)	$95,750	($654,294)	$750,043	$654,294
25	($18,037)	$4,776	$4,776	($768,080)	$100,526	($667,554)	$768,080	$667,554
26	($17,743)	$4,757	$4,757	($785,823)	$105,282	($680,541)	$785,823	$680,541
27	($17,455)	$4,737	$4,737	($803,279)	$110,019	($693,259)	$803,279	$693,259
28	($17,172)	$4,718	$4,718	($820,450)	$114,737	($705,713)	$820,450	$705,713
29	($16,893)	$4,699	$4,699	($837,343)	$119,436	($717,907)	$837,343	$717,907
30	($16,619)	$4,680	$4,680	($853,962)	$124,116	($729,845)	$853,962	$729,845

Table 20: Cooling Pessimistic Case Parameters

Financial Parameters	
Interest Rate	5.0%
Inflation	2.0%

Energy & Costs						
	Fan Coils				Chiller	
	54	Large	200	Small	180	ton
Power	0.135	kW	0.06	kW	1.008888	kW / ton
Utilization	40%				71%	
Hours of Operation			2880		hr / yr	
Annual Power Consumption			22222.1	kW-hr / yr	371335	kW-hr / yr
Total			393557		kW-hr / yr	
Equipment Cost			$0		$93,600	
Installation Cost			$0		$100,000	
Annual Maintenance Cost			$0	per yr	$1,996	per yr

CERF					
Chiller		Heat Ex.		Energy Recovery	
				375300	btu / hr
0	kW	0	kW	110.0	kW
71%		71%		71%	
2880		hr / yr		2880	hr / yr
0	kW-hr / yr	0	kW-hr / yr	Annual Energy Savings	
Total		0	kW-hr / yr	767.41	Mbtu / yr
$10,400		$4,200			
$10,400		$4,200			
$0	per yr	$0	per yr		

Table 21: Cooling Pessimistic Case Future Values

Year	Energy Cost				Future Value		
	Present		Future		Annual Operating		
	Gas	Electricity	Gas	Electricity		Saving	Net
	$ / Mbtu	$ / kW-hr	$ / Mbtu	$ / kW-hr	per yr		
0	$ 6.80	$ 0.06	$ 6.80	$ 0.06	($27,229)	$5,216.46	$5,216.46
1	$ 6.65	$ 0.06	$ 6.78	$ 0.06	($27,522)	$5,201.53	$5,201.53
2	$ 6.61	$ 0.06	$ 6.87	$ 0.07	($27,724)	$5,275.40	$5,275.40
3	$ 6.63	$ 0.06	$ 7.03	$ 0.07	($28,233)	$5,397.46	$5,397.46
4	$ 6.63	$ 0.06	$ 7.18	$ 0.07	($28,712)	$5,506.85	$5,506.85
5	$ 6.69	$ 0.06	$ 7.39	$ 0.07	($29,357)	$5,669.69	$5,669.69
6	$ 6.88	$ 0.06	$ 7.75	$ 0.07	($30,167)	$5,947.09	$5,947.09
7	$ 7.09	$ 0.06	$ 8.15	$ 0.07	($31,114)	$6,250.58	$6,250.58
8	$ 7.28	$ 0.06	$ 8.54	$ 0.08	($32,039)	$6,550.10	$6,550.10
9	$ 7.53	$ 0.07	$ 9.00	$ 0.08	($32,971)	$6,905.14	$6,905.14
10	$ 7.74	$ 0.07	$ 9.44	$ 0.08	($33,913)	$7,244.85	$7,244.85
11	$ 7.93	$ 0.07	$ 9.86	$ 0.08	($34,751)	$7,566.45	$7,566.45
12	$ 8.08	$ 0.07	$ 10.25	$ 0.08	($35,807)	$7,866.22	$7,866.22
13	$ 8.10	$ 0.07	$ 10.48	$ 0.09	($36,791)	$8,038.71	$8,038.71
14	$ 8.35	$ 0.07	$ 11.01	$ 0.09	($37,867)	$8,450.22	$8,450.22
15	$ 8.59	$ 0.07	$ 11.57	$ 0.09	($39,247)	$8,875.97	$8,875.97
16	$ 8.90	$ 0.07	$ 12.22	$ 0.10	($40,581)	$9,379.83	$9,379.83
17	$ 9.17	$ 0.07	$ 12.84	$ 0.10	($41,838)	$9,851.75	$9,851.75
18	$ 9.52	$ 0.07	$ 13.60	$ 0.10	($43,282)	$10,437.46	$10,437.46
19	$ 9.73	$ 0.07	$ 14.18	$ 0.11	($44,689)	$10,879.30	$10,879.30
20	$ 9.72	$ 0.07	$ 14.45	$ 0.11	($45,818)	$11,089.68	$11,089.68
21	$ 9.92	$ 0.07	$ 15.03	$ 0.11	($47,084)	$11,537.70	$11,537.70
22	$ 10.12	$ 0.07	$ 15.64	$ 0.12	($48,385)	$12,003.82	$12,003.82
23	$ 10.32	$ 0.08	$ 16.27	$ 0.12	($49,722)	$12,488.78	$12,488.78
24	$ 10.53	$ 0.08	$ 16.93	$ 0.12	($51,097)	$12,993.32	$12,993.32
25	$ 10.74	$ 0.08	$ 17.62	$ 0.13	($52,509)	$13,518.25	$13,518.25
26	$ 10.95	$ 0.08	$ 18.33	$ 0.13	($53,961)	$14,064.39	$14,064.39
27	$ 11.17	$ 0.08	$ 19.07	$ 0.13	($55,454)	$14,632.59	$14,632.59
28	$ 11.39	$ 0.08	$ 19.84	$ 0.14	($56,987)	$15,223.75	$15,223.75
29	$ 11.62	$ 0.08	$ 20.64	$ 0.14	($58,564)	$15,838.79	$15,838.79
30	$ 11.85	$ 0.08	$ 21.47	$ 0.14	($60,184)	$16,478.68	$16,478.68

Table 22: Cooling Pessimistic Case Present Values

Year	Present Value							
	Annual			Cumulative			Cumulative	
	Operating	Saving	Net	w/o CERF	CERF Saving	w/ CERF	w/o CERF	w/ CERF
	per yr			Total			Total	
0	($27,229)	$5,216	$5,216	($220,829)	($23,983.54)	($244,813)	$220,829	$244,813
1	($26,212)	$4,954	$4,954	($247,041)	($19,029.70)	($266,071)	$247,041	$266,071
2	($25,147)	$4,785	$4,785	($272,188)	($14,244.76)	($286,433)	$272,188	$286,433
3	($24,388)	$4,663	$4,663	($296,576)	($9,582.23)	($306,158)	$296,576	$306,158
4	($23,622)	$4,530	$4,530	($320,198)	($5,051.73)	($325,250)	$320,198	$325,250
5	($23,002)	$4,442	$4,442	($343,200)	($609.38)	($343,809)	$343,200	$343,809
6	($22,511)	$4,438	$4,438	($365,711)	$3,828.43	($361,883)	$365,711	$361,883
7	($22,112)	$4,442	$4,442	($387,823)	$8,270.61	($379,553)	$387,823	$379,553
8	($21,686)	$4,433	$4,433	($409,509)	$12,703.97	($396,805)	$409,509	$396,805
9	($21,253)	$4,451	$4,451	($430,762)	$17,155.09	($413,607)	$430,762	$413,607
10	($20,820)	$4,448	$4,448	($451,582)	$21,602.80	($429,979)	$451,582	$429,979
11	($20,318)	$4,424	$4,424	($471,900)	$26,026.74	($445,873)	$471,900	$445,873
12	($19,939)	$4,380	$4,380	($491,838)	$30,406.95	($461,431)	$491,838	$461,431
13	($19,511)	$4,263	$4,263	($511,349)	$34,670.05	($476,679)	$511,349	$476,679
14	($19,126)	$4,268	$4,268	($530,475)	$38,937.98	($491,537)	$530,475	$491,537
15	($18,879)	$4,269	$4,269	($549,354)	$43,207.47	($506,146)	$549,354	$506,146
16	($18,591)	$4,297	$4,297	($567,944)	$47,504.48	($520,440)	$567,944	$520,440
17	($18,254)	$4,298	$4,298	($586,198)	$51,802.77	($534,395)	$586,198	$534,395
18	($17,985)	$4,337	$4,337	($604,183)	$56,139.75	($548,043)	$604,183	$548,043
19	($17,685)	$4,305	$4,305	($621,868)	$60,445.06	($561,423)	$621,868	$561,423
20	($17,268)	$4,180	$4,180	($639,136)	$64,624.64	($574,512)	$639,136	$574,512
21	($16,900)	$4,141	$4,141	($656,037)	$68,766.01	($587,271)	$656,037	$587,271
22	($16,540)	$4,104	$4,104	($672,577)	$72,869.52	($599,707)	$672,577	$599,707
23	($16,188)	$4,066	$4,066	($688,765)	$76,935.50	($611,830)	$688,765	$611,830
24	($15,843)	$4,029	$4,029	($704,609)	$80,964.32	($623,644)	$704,609	$623,644
25	($15,506)	$3,992	$3,992	($720,115)	$84,956.29	($635,158)	$720,115	$635,158
26	($15,176)	$3,955	$3,955	($735,291)	$88,911.77	($646,379)	$735,291	$646,379
27	($14,853)	$3,919	$3,919	($750,144)	$92,831.09	($657,313)	$750,144	$657,313
28	($14,537)	$3,883	$3,883	($764,681)	$96,714.57	($667,967)	$764,681	$667,967
29	($14,228)	$3,848	$3,848	($778,909)	$100,562.55	($678,346)	$778,909	$678,346
30	($13,925)	$3,813	$3,813	($792,834)	$104,375.34	($688,459)	$792,834	$688,459

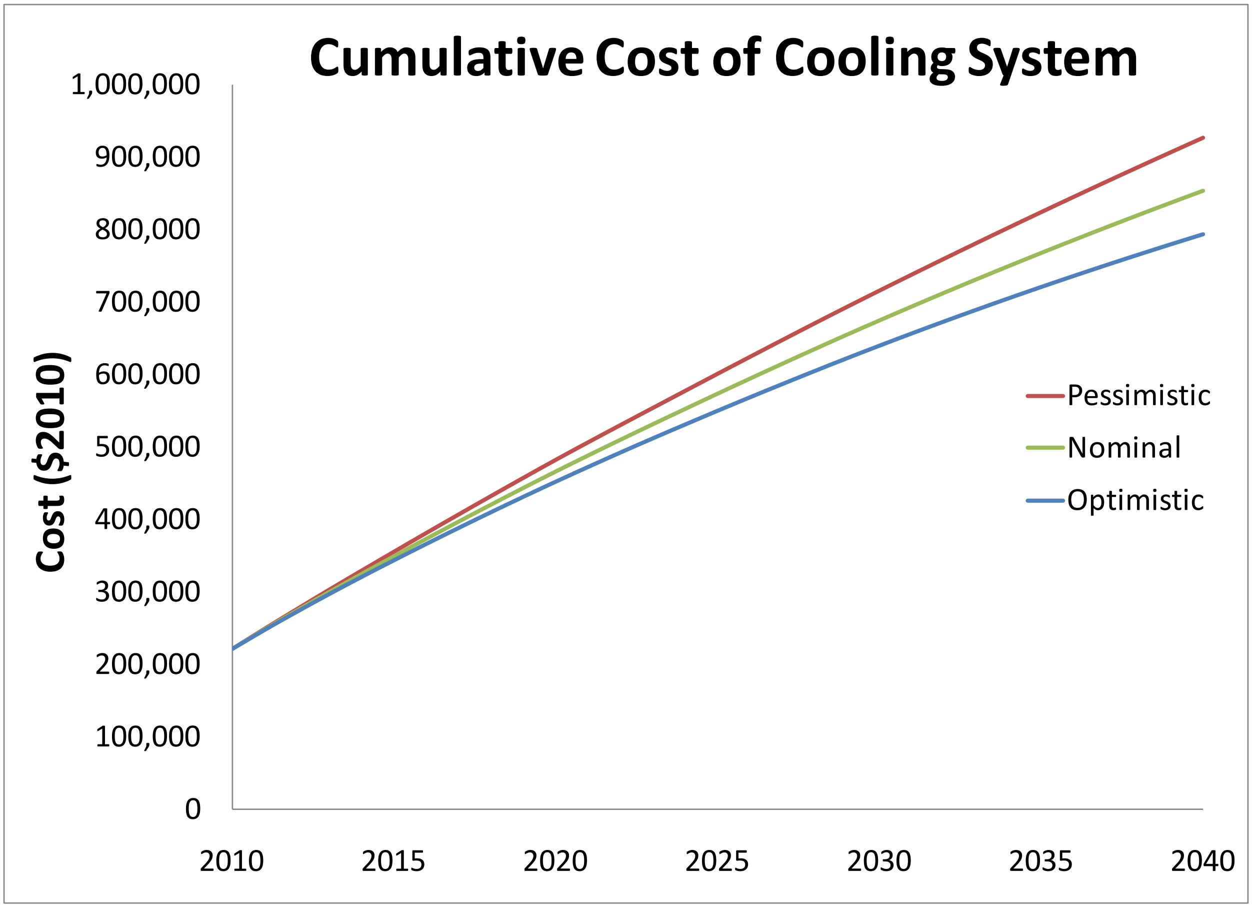

Figure 6: Cumulative Cost of Operating Cooling System

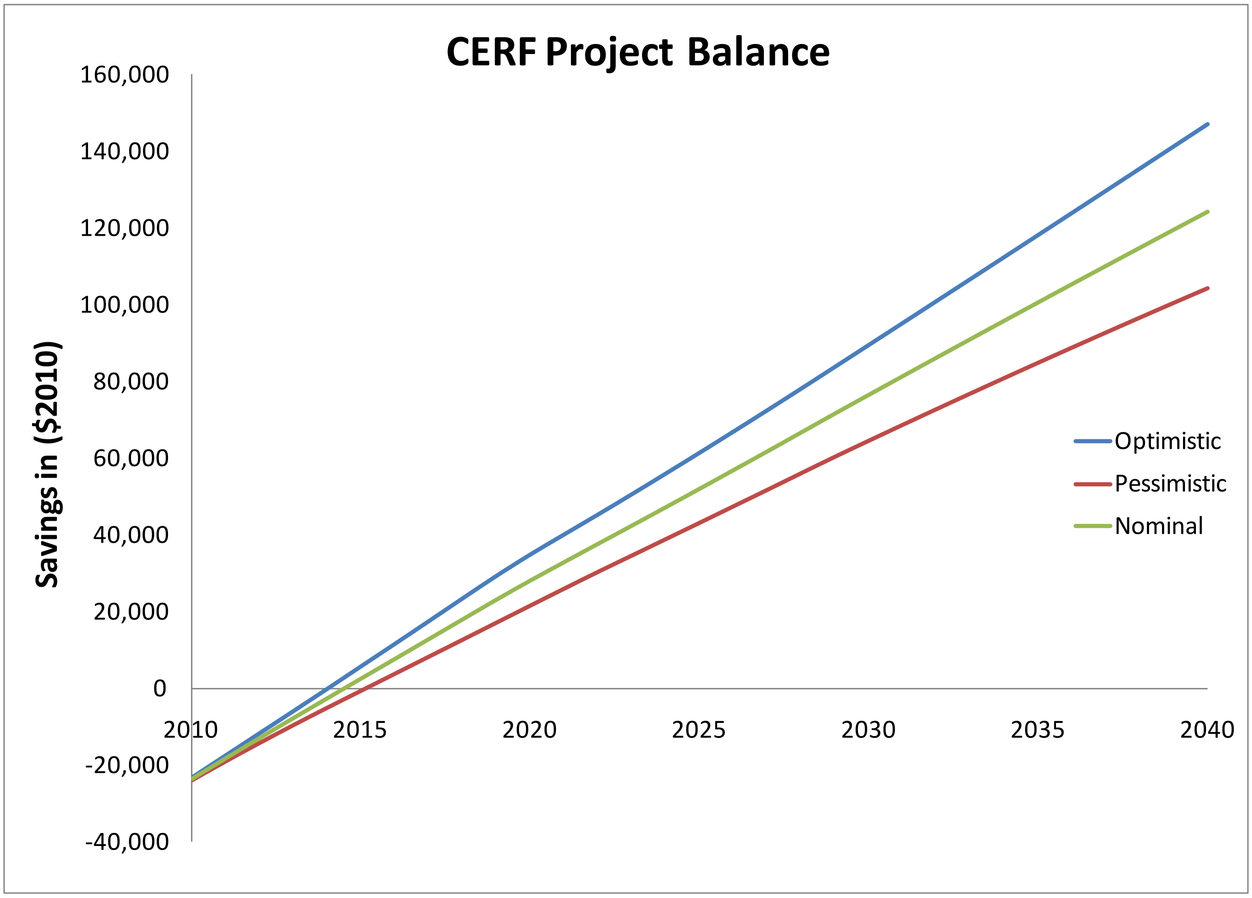

Figure 7: Cerf Projected Project Balance

Appendix H LEED

Introduction

LEED was developed by the U.S. Green Building Council to provide third-party verification that a building was built and designed using strategies intended to lower environmental impact and improve energy performance. LEED is intended to provide building owners and operators a plan for identifying and employing practical green building, design, construction, operations, and maintenance solutions.

Feasibility Process

For the renovation of BHT, the team evaluated using the rating system based on LEED 2009 for New Construction and Major Renovations. Screenshots of the checklist are included in the attached appendix.

Results

For BHT's current HVAC system, LEED certification is only achievable through a holistic renovation that includes the ventilation system. A holistic approach involves changing not only the HVAC and ventilation systems, but also operations and maintenance of the dorm. Combining the proposed design with a holistic renovation would earn 49 LEED points, which equates to basic certification. The proposed design does not include a renovation of the ventilation system, meaning LEED certification is not feasible.

Recommendations

To pursue LEED certification, a series of recommendations have been compiled and included in the appendix. By implementing the changes using a holistic approach, Calvin will be able to achieve LEED certification for the BHT dormitory. It is estimated that LEED accreditation fees will cost an additional $4,849 to become certified.

Sources

LEED 2009 for New Construction and Major Renovation project checklist:

- "*LEED 2009 for New Construction and Major Renovations Checklist.*" *U.S. Green Building Council*. USGBC, 25 Aug. 2010. Web. 11 Dec. 2010. <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220>.

Cost values from RS Means: Residential Detailed Costs 2009 textbook:

- *"RS Means Residential Detailed Costs 2009."* N.p.: Reed construction data, 2009. Print.

Current fees for LEED certification from the Green Building Certification Institute

- "*CURRENT CERTIFICATION FEES.*" *GBCI.org*. Green Building Certification Institute, 2010. Web. 11 Dec. 2010. <http://www.gbci.org/main-nav/building-certification/resources/fees/current.aspx>.

LEED Tables and Figures

Table 1: New Construction and Major Renovations LEED Points

	HVAC System Only	
LEED Pts	**Best Case**	**Holistic Renovation**
SS	0	16
WE	0	4
EA	19	9
MR	0	9
IEQ	4	10
IO	1	1
RP	0	0
Total	**24**	**49**
	Not Certified	**Certified**

Y	?	N			
16	5	4	**Sustainable Sites**	Possible Points:	26
Y			Prereq 1	Construction Activity Pollution Prevention	
1			Credit 1	Site Selection	1
5			Credit 2	Development Density and Community Connectivity	5
		1	Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation—Public Transportation Access	6
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
	3		Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	3
		1	Credit 4.4	Alternative Transportation—Parking Capacity	2
		1	Credit 5.1	Site Development—Protect or Restore Habitat	1
1			Credit 5.2	Site Development—Maximize Open Space	1
	1		Credit 6.1	Stormwater Design—Quantity Control	1
	1		Credit 6.2	Stormwater Design—Quality Control	1
1			Credit 7.1	Heat Island Effect—Non-roof	1
		1	Credit 7.2	Heat Island Effect—Roof	1
1			Credit 8	Light Pollution Reduction	1

4	2		**Water Efficiency**	Possible Points:	10
Y			Prereq 1	Water Use Reduction—20% Reduction	
2			Credit 1	Water Efficient Landscaping	2 to 4
	2		Credit 2	Innovative Wastewater Technologies	2
2			Credit 3	Water Use Reduction	2 to 4

9	3		**Energy and Atmosphere**	Possible Points:	35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
1			Credit 1	Optimize Energy Performance	1 to 19
2			Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
2			Credit 4	Enhanced Refrigerant Management	2
	3		Credit 5	Measurement and Verification	3
2			Credit 6	Green Power	2

9	9		**Materials and Resources**	Possible Points:	14
Y			Prereq 1	Storage and Collection of Recyclables	
3			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
1			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
1	2		Credit 2	Construction Waste Management	1 to 2
1	2		Credit 3	Materials Reuse	1 to 2

Y	?	N			
			Materials and Resources, Continued		
1	2		Credit 4	Recycled Content	1 to 2
1	2		Credit 5	Regional Materials	1 to 2
	1		Credit 6	Rapidly Renewable Materials	1
1			Credit 7	Certified Wood	1
10	2	3	**Indoor Environmental Quality**	Possible Points:	15
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
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 and Sealants	1
1			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
1			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Product	1
	1		Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
	1		Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
		1	Credit 8.1	Daylight and Views—Daylight	1
		1	Credit 8.2	Daylight and Views—Views	1
1		5	**Innovation and Design Process**	Possible Points:	6
		1	Credit 1.1	Innovation in Design: Specific Title	1
		1	Credit 1.2	Innovation in Design: Specific Title	1
		1	Credit 1.3	Innovation in Design: Specific Title	1
		1	Credit 1.4	Innovation in Design: Specific Title	1
		1	Credit 1.5	Innovation in Design: Specific Title	1
1			Credit 2	LEED Accredited Professional	1
		4	**Regional Priority Credits**	Possible Points:	4
		1	Credit 1.1	Regional Priority: Specific Credit	1
		1	Credit 1.2	Regional Priority: Specific Credit	1
		1	Credit 1.3	Regional Priority: Specific Credit	1
		1	Credit 1.4	Regional Priority: Specific Credit	1
49	21	16	**Total**	Possible Points:	110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Figure 1: LEED 2009 New Construction and Major Renovations Project Checklist