PROJECT PROPOSAL
AND
FEASIBILITY STUDY

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Team 4: Cleanly Cooling Calvin
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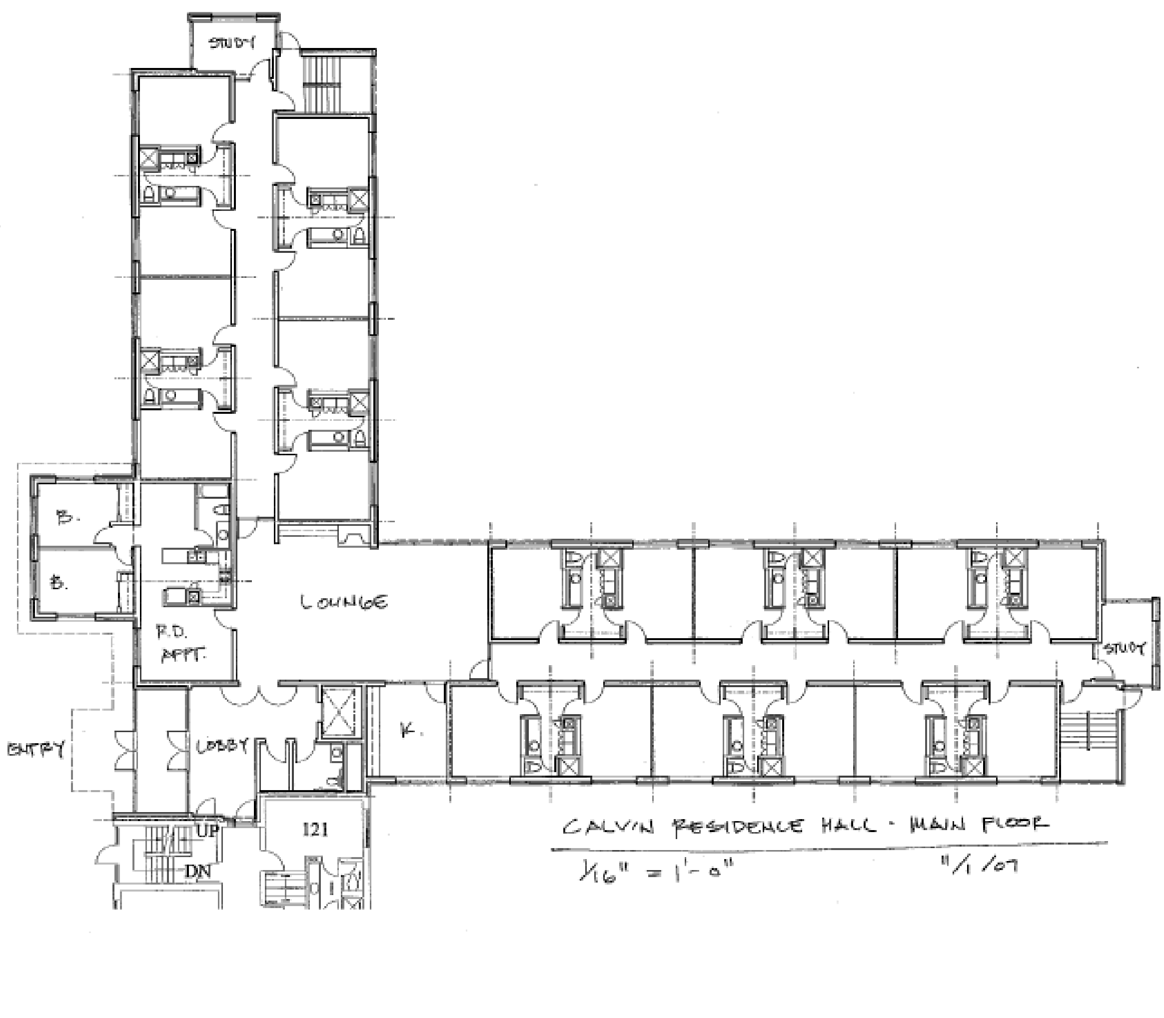

Abstract

This report contains information pertaining to the fall 2007 portion of the senior design project at Calvin College for team 4: Cleanly Cooling Calvin. The report includes a project proposal with an emphasis on the feasibility of the project. This project will spec out a geothermal system for the new dorm wing. Thermocouples will be installed in the new dorm and live data software will be used to compare the traditional heating and cooling system to the geothermal system in terms of power consumption. The report includes alternatives considered, calculations performed, and selections made over the course of the semester.

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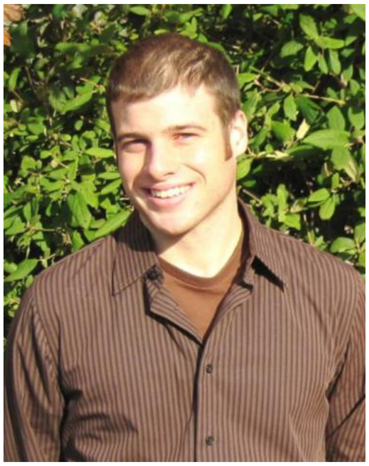

Jordan Wanner is a senior double major, with an international mechanical emphasis, and German. He grew up in the Greater Grand Rapids. This past summer he worked in Germany as an intern at Airbus, a European commercial aircraft manufacturer, as a part of project management for the A380 cargo loading system. He is also a member of Calvin's Renewable Energy Organization and has a passion for clean and sustainable energy and building design. Jordan hopes to begin work after graduation in either the renewable energy industry, or green building design sector.

Christina Overbeck is a Senior Mechanical Engineering Student. She grew up in Seattle, Washington in a community acutely aware of environmental concerns and has since been interested in using her engineering knowledge to create environmentally-friendly products. She was previously an intern at PATH, a nonprofit organization in Seattle, where she worked on a Gates Foundation project to develop inexpensive water purification systems for the lower-middle class in India. The project aims to significantly reduce water-borne illness in India and eventually expand to other countries in the area. Overbeck is also a member of the Calvin Cross Country and Track teams.

Dan VandenAkker is a senior double major in Engineering with a Mechanical Concentration, and Physics with an Optics emphasis. He grew up in the Greater Grand Rapids areas and graduated from South Christian High School. This past summer he worked as an intern at Gentex Corporation, an automotive mirror manufacturer, on increasing the productivity of existing production lines and constructing new production lines. He is also a member of Calvin's Cross Country and Track teams. Dan plans to pursue his Masters of Science in Aeronautics and Astronautics at the University of Washington after his time at Calvin.

1.2. Project Background

With such high numbers of students living on-campus, on campus housing has been limited. This has caused a need for an additional dorm wing which will be added onto Kalsbeek Huizenga residence hall (see appendix 4). As energy prices continue to grow and we become more aware of the environmental concerns of green-house gases, the college seeks to incorporate more green building techniques. Michigan's cold winters and warm summers is an ideal climate for geo-thermal because heat can be dumped into the ground in the summer and taken out of the ground in the winter. Team Cooling Calvin Cleanly plans implement geo-thermal for two suites in the new dorm wing. The system will have an educational aspect comparing a suite heated and cooled using the traditional HVAC system to the suite with geo-thermal. Not only will this create an educational opportunity for Calvin students, but it will also supply Calvin administration with comparative operating costs for future buildings. Calvin has expressed an interest in installing geothermal for the new Commons and Fine Arts Center.

2. PROJECT DESCRIPTION

2.1. Spec. out systems

The standard work of HVAC Engineers includes estimating the heating and cooling loads of a building then designing the HVAC system to meet those load requirements. That is what we will be doing in this part of the project. Working with Engineers at GMB, we will estimate the heating and cooling loads for each suite as well as the common places in the dorm. We will then design two HVAC systems to meet the estimated heating and cooling loads. As was determined with the administration, two first floor suites will be heated and cooled by a geothermal heat pump and the rest of the building will be heated and cooled by the current boiler system and a new chiller.

2.1.1. Geothermal

For the Geothermal system, heating and cooling loads will be needed to estimate the number of well borings and their depths. The amount of space to be heated and cooled will be used to determine the size heating pump required to convert the pre-heated or pre-chilled fluid into hot or cold air to heat or cool the suite. More information on the specifications can be found in the Design Process section of this report.

2.1.2. boiler/chiller

For the boiler/chiller system, heating and cooling loads will be needed to estimate the size of the boilers and chillers needed. The campus is already equipped with a system of boilers as well as loops of heated water around campus. This boiler loop system can be used to supply the heat to the new dorm wing if the existing boilers are large enough to cover the heating load. If the existing boilers are not sufficient, additional boilers will be required. No system of chilled water exists near KH. Thus, the cooling load required by the building will be estimated to determine the size of the chiller which will need to be installed to cool the building.

2.2. Design an educational interface

This third of our project could be argued to be the most important aspect to a successful project. Once the HVAC system is designed and installed, data acquisition (DAQ) devices will be installed around the system to obtain measurements such as temperatures, fluid flow rates, power consumption, occupancy, etc. This information will be feed into DAQ software which will be used to present live data to the interested public through an informational and educational kiosk which will be located in one of the public spaces in the dorm wing.

2.2.1. Kiosk

The kiosk will be the interface to the public used to display live data from the dorm's HVAC systems, the results of our theoretical system comparison calculations (explained in the next section), and information on how the two systems operate as well as why Geothermal is considered a more 'Green' option than the boiler/chiller system. The kiosk will include an interactive computer monitor which displays live data and allows a user to examine more detailed aspects of the system. The kiosk will also be surrounded by informational posters displaying the theoretical system comparison calculations and information about how the systems operate.

2.2.2. Equipment

The equipment necessary for this information kiosk includes the interfaces with the public and all DAQ instrumentation and computer hardware working behind the scenes. The interface components include a touch-screen monitor, a poster displaying our theoretical system comparison calculations, and a poster explaining how these two HVAC systems work. The DAQ instrumentation includes many thermocouples with thermocouple wires, fluid flow meters, occupancy sensors, power consumption meters, and DAQ hardware to process and transmit the data. The computer hardware includes a desktop PC to process all data and display it on the interface monitor as well as any additional components needed to relay the data from the DAQ instrumentation and processing components.

2.3. Calculations comparing system

These calculations are theoretical calculations performed with various HVAC software. This first component of the calculations will be to estimate the heating and cooling loads of the dorm wing. The following calculations will be to compute efficiencies, upfront costs, operational costs, energy consumption and resulting carbon emissions, etc. for both the Geothermal and boiler/chiller systems. In order to make these calculations easily comparable, they will be performed for the entire dorm wing being heating and cooled by one system (i.e. Geothermal wells and heat pumps heat and cool the entire wing for one set of calculations and the boiler/chiller systems heat and cool the entire wing for a second set of calculations).

2.3.1. Efficiencies

A primary measure of operation is efficiency. We want to estimate the overall efficiencies of both systems (i.e. how much heating or cooling results from a certain amount of energy put in to the system). If sufficient information is provided, efficiencies could also be calculated for individual heat pumps and the fin tube radiators.

2.3.2. Cost analysis

Since everything in today's society is driven by the cost economy, we want to determine the costs of the systems. Both the upfront cost will be estimated for the components necessary to meet the heating and cooling loads. This includes all initial equipment costs and installation costs. For the boiler/chiller system, multiple calculations could be performed to account for the existing boiler loop system or to account for installation of a new system separate from the existing loops. The desire for both calculations would be to apply the calculations specifically to this application where the boiler loops are already in place and also to future applications where new boilers and boiler loops would need to be installed. Operational costs will also be computed for each system. These costs are important because will exist through the duration of the building's operation. The operational costs result from power consumption of the systems. The operational costs and initial costs will be combined to compute a breakeven point for the systems. This will tell during which period of time one system is cheaper to have relative to the other.

2.3.3. Energy consumption

Energy consumption is the driver for both operational costs and carbon emissions. Minimal energy consumption is desired, and these calculations will find which system that is. For the Geothermal system, this energy will be electric energy used by the heat pumps from the power grid. For the boiler/chiller system, this energy will be both the electricity for the heat pumps and the fuel used in the boilers and chillers.

2.3.4. Carbon emissions

With many environmental concerns about global warming and excess carbon contributing to warming the atmosphere, our society is very concerned with carbon emissions. The HVAC systems will produce carbon emissions from the energy necessary to create the heated or cooled fluid. This energy consumption was determined in the previous sections. With knowledge of how Calvin receives its electricity, the resulting carbon emissions can be computed. By analyzing the boilers and chiller, the carbon emissions from the fuel consumption can also be estimated.

3. PROJECT ORGANIZATION

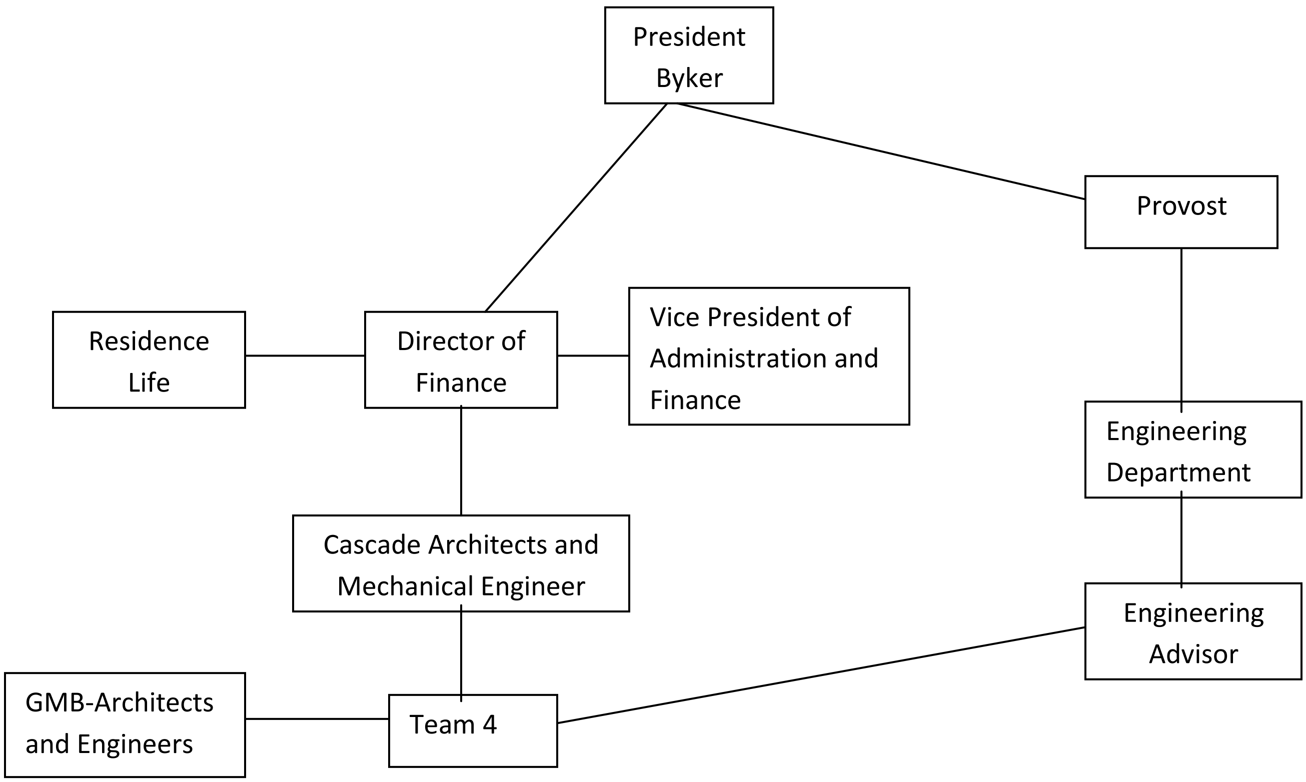

Figure 1: Organization Chart

Each of the components in Figure 1 is described below.

President Byker requested that a new dorm wing be built before the start of the Fall 2008 school year. He has given the budget for the dorm to the Director of Finance. President Byker is also in charge of the Provost which gives money for the senior design projects.

Claudia Beversluis is Calvin's Provost. As the chief academic officer of the College, the Provost is responsible for administering the academic affairs division. This includes senior design projects.

The engineering department seeks to prepare students for their first jobs by requiring senior engineers to do a senior design project. They give each senior design group a budget of 300 dollars.

Each of the four engineering concentrations has advisors that helps critique the senior design project and direct the teams as they make decisions on their projects. Team 4 will be reporting to Professor Neilson.

There is a committee for the new dorm construction. Team four has attended weekly meetings for the new dorm wing. Included in the dorm meetings are members of Residence Life, the Director of Finances, and the Vice President of Administration and Finance.

Residence Life

Dean of Residence Life: John Witty
*Associate Dean of Residence Life***:** Patrick Hummel
*Resident Director**:** Chris Klein*
Vice President for student life: Shirley Vogelzang Hoogstra, J.D.

Residence Life has been active in making decisions on the construction of the new dorm wing. Shirley Hoogstra and John Witty were both very interested in incorporation green design into the dorms.

Samuel L. Wanner, B.A, Calvin's Director of Finance, is an active part of this project. He included $40,000 for our project in the residence hall addition budget.

Henry E. De Vries II, Ph.D.,Vice President of Administration and Finance, is an active member of the project and is a big proponent of geothermal for the dorm wing.

Cascade Architects and Classical Engineering are in charge of the design of the building. The college architect is Frank L. Gorman, B.A. The architects and Mechanical Engineer are working under the administration and trying to fulfill the requirements that the administration ask them. We will be in close contact with them.

GMB Architects and Engineers have chosen to partner with us and help us find more cost competitive components for our project. They also are helping us understand geothermal better. We will be conversing with GMB throughout next semester.

Team 4, Cleanly Cooling Calvin, is partnering with GMB- Architects and Engineers to install a geothermal system for two suites in the new dorm wing. Team four is working under Cascade Architects and Mechanical Engineers. Team 4 reports to the College administration and to our engineering advisor.

4. CHRISTIAN PERSPECTIVES / DESIGN NORMS

4.1. Stewardship

The Stewardship Design norm includes both Environmental and Financial Stewardship. We believe this is the most important design norm for our project.

4.1.1 Environmental

As Christians we are called to be good stewards of God's creation. We are dedicated to the efficient and effective use of resources. Geothermal is one of the leading green technologies for HVAC. Geo-thermal heating and cooling decreases energy needs and reduces environmental impact.

4.1.2 Financial

We believe that geo-thermal is a good choice financially. Although geothermal has a higher upfront cost, our calculations show that the system would pay itself off in operating cost in about 11 years. After 11 years, geothermal has the potential to save Calvin college money each year. Geothermal can cut utility bills by 25 to 50 percent.[1]

4.2. Transparency

Another one of our main design norms is transparency. The system should be easy to operate and understand. We plan on strategically placing our thermocouples so that they will be accessible for repair and write a user manual. In addition, our geothermal system is going to be educational. The traditional and geothermal HVAC systems in the dorm will be compared using labVIEW on a kiosk. This will help students to understand more about geothermal and how their actions can reduce power consumption.

4.3 Integrity

Our geothermal heating and cooling system must be reliable and well designed. We have an obligation to the utility and maintenance workers to make sure that our design does not need a lot of maintenance. In addition, we have an obligation to the students living in the geo-thermal suites to insure that they will be comfortable and have a system that they can rely on.

5. SCHEDULE

A schedule of the progress and future work of our project is included in appendix 1. The green shaded bars represent all the work that has been completed thus far. The blue shaded bars represent the work to be done beginning January 3 that needs to be done to bring this project to completion. This work includes:

- Ordering/receiving instrumentation
- Integration of instrumentation and testing

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[1]http://www.ceat.okstate.edu/information/ceat_sp/ceat_sp_files/UNIT%20IGSHPA%20Strategic%20Plan%20051304.pdf

- LABview program design
- Interactive presentation development
- Residence hall addition construction
- Geothermal well boring and testing
- Geothermal well instrumentation installation
- Existing dorm instrumentation installation
- New residence hall addition suite instrumentation installation
- Kiosk construction
- Instrumentation network and data archiving development

As the residence hall addition construction schedule has not yet been determined, certain aspects of this schedule are only tentative. For example, the instrumentation installation in the new residence hall suites is highly dependent on the schedule and phase of the construction process. Also, all of the tasks presented are team 4's responsibility except construction of the new residence hall. This task was only included in the schedule to give reference to team 4's task that are dependent on it.

6. DESIGN PROCESS (i.e. Alternative solutions)

6.1. Geothermal Heat Pump System[2]

One heating and cooling system that is being considered for this design project is a geothermal (also called ground-source) heat pump system. This type of system, depending on how it is operating, can be used for heating and cooling. This system is comprised of two major components; Heat pumps and the geothermal heat exchanger. Heat is either pumped to, or extracted from an indoor environment by the heat pump and taken from, or transported to the ground by the geothermal heat exchanger. During a heating cycle the ground is used as a heat source to heat the indoor environment. During a cooling cycle the ground is used as a heat sink for heat rejection of the indoor space. This system is more efficient than any other system because it uses the free energy in the ground to warm or cool an indoor space.

As a part of our design project we have considered several configurations of a geothermal heat pump system, striving to find the best match for the Kalsbeek Huizenga (KH) residence hall addition. These options are explained below.

6.1.1. Heat Pump

One option to provide heating and cooling for the new residence hall addition was heat pumps. Heat pumps operate, much like a refrigerator, on a vapor compression cycle. However there are two main things that separate them from refrigerators. First, depending on the cycle a heat pump

[2] All information presented in this section was gathered from ASHREA 2003 Handbook.

can provide heating or cooling. Second, it draws or rejects to something outside of the conditioned space. This can be boiler/chiller supplies, or a ground source heat exchanger.

6.1.1.1. Large Central Heat Pump Design

The first proposed design for the KH addition was centralized heat pump system. This would use a couple large scale heat pumps to provide heating and cooling for the whole addition. These large heat pumps would be tied in to a major ground source heat exchanger. This design would lend itself to easy operation and maintenance.

6.1.1.2. Multiple Small Heat Pump Design

Another proposed case is to provide a small heat pump for every suite in the new addition. Each small heat pump would heat and cool their respective suite. These heat pumps would also be tied in to a large scale ground source heat exchanger. This system would lend itself to individual temperature control of each suite, and a more efficient use of energy.

6.1.1.3. Single Small Heat Pump for Demonstration

This design would also use multiple small heat exchangers for each suite. However, the bulk of the heat exchangers would be tied into the boiler and chiller loops, and one suite would use a ground source heat exchanger. This would be a more economical version because the boiler loop is already in place at the new dorm site.

6.1.2. Ground Source Heat Exchangers

The ground source heat exchanger, also known as the ground loop, is used to transfer or extract heat from the ground. There are many different configurations that can be used for this type of system, each having it own benefits and drawbacks. Several different alternatives were considered for this design project, and are outlined below.

6.1.2.1. Open Ground Loop

Types of ground loops are first split into two different categories, open or closed. An open ground loop draws water directly from a well, lake, or pond and transports it directly to a heat pump, where heat is extracted or rejected to the water. The water is then dumped back to the same source but in a different location.

There are a couple of problems with an open ground loop. First, it requires a filtration system to remove sand, algae, fish, etc. before the water enters the heat pump. Second, if the water source is too small thermal pollution is a problem. This means if your heating and/or cooling loads are too great the water source will either heat up or cool down too much to the point where it renders the heat pump in operable.

6.1.2.2. Closed Ground Loop

On the contrary a closed loop is one where the fluid inside the ground source heat exchanger (usually water with anti-freeze) never directly interacts with the ground. This type of ground loop is the most widely used. The working fluid is just cycled through ground loop and heat pump. The following ground loops are all closed.

6.1.2.3. Horizontal Ground Loop

Closed ground loops can be classified in to two categories, horizontal and vertical. A horizontal ground loop is where the pipe used in the heat exchanger run parallel with the surface of the ground. As explained by Stephen Hamstra, a geothermal heat pump system expert, a horizontal ground loop is less expensive to install however they require a greater amount of land and are less thermally efficient when compared to other type of systems. As outlined below, there are three main types of horizontal ground loop systems.

6.1.2.3.1. Standard Horizontal Loop

This type of field of horizontal field is the most common. The pipes that comprise the heat exchanger are laid out in straight lines just below the frost line. However, this configuration requires a large amount of land to provide adequate heat transfer and to avoid thermal pollution. If there is a large amount of land available for the ground loop this option is the most cost effective.

6.1.2.3.2. Horizontal Spiral (slinky) Loop

As seen in the picture below, the horizontal, 'slinky', ground loop is a ground source heat exchanger where the pipes are in coils versus in straight lines. A slinky ground loop would be used in area where there is not enough space to install a true horizontal ground loop. The problem with this design is the high potential of thermal pollution because it is dissipating the same amount of energy in a smaller area.


Photograph from Mark Johnson shared in the public domain
Figure 2: Slinky Ground Loop

6.1.2.3.3 Pond Loop

A pond loop is very similar to a spiral ground loop but sunk in a pond versus in the ground (see picture below). When a pond or small body of water is assessable, this is a very economical system due to the hardly any excavation would be required to install it. These types of loops are usually used in small residential cases.


Photograph of Mark Johnson shared in the public domain
Figure 3: Pond Loop

6.1.2.4. Vertical Loop

Vertical loops are created by running pipes vertically into the ground. The bore sizes are 6"-12" typically and 150' to 400' deep. More heating and cooling capacity is achieved with deeper bores. A significant benefit to this system is a large heating and cooling capacity can be obtained in a relatively small amount of land space. According to Stephen Hamstra this type of ground loop is also the most thermally efficient. The only drawback to this system is that the installation is expensive due to the boring required.

6.1.2.5. Sizing

The size of the ground loop/field is directly dependent on the amount of space that is to be heated or cooled. Also the size of the ground loop will vary depending if the building it is heating/cooling is cooling or heating dominated. The smallest bore field for a given building will be if the heating and cooling loads are equal. According to HVAC engineers at GMB, Michigan has the most ideal climate for a geothermal heat pump system. This is because Michigan has fairly equal heating and cooling seasons.

6.2. Traditional Solution (Boilers and Chillers)[3]

A second heating and cooling system being considered for this design project is a series of boilers and chillers. During the winter, boilers will provide heated water to fin tube radiators which will distribute heated air in each dorm room. During the summer, chillers will provide cooled water to heat pumps which will produce chilled air to be distributed around each suite.

6.2.1. Current boiler/chiller system

The current boiler system installed in all existing dorms is a series of boilers which provide heated water distributed to all the dorms through underground pipes. The heated water is fed in each dorm wing through a loop which connects to a fin tube radiator which produces heated air. The fin tube radiator is located on the outer wall in each dorm room. Current complaints about this system are about too much heat in rooms at the beginning of the loop and not enough heat in rooms at the end of the loop. This happens because the radiators are connected in series rather than parallel. No chilled air is produced for cooling the buildings.

6.2.2. Updated boiler/chiller system

The updated boiler system will consist of an expansion of the current underground heated water piping systems into the new dorm wing. This heated water will be distributed to compact fin tube radiators similar to the current model. The radiators will be connected in parallel so that each unit can have personal control of the temperature. This will create fewer problems with too

[3] Information received by Paul Pennock of the Physical Plant and GMB Architects and Engineers.

much or too little heat at the ends of the halls. A chiller will also be used to chill water. This chilled water will be distributed to a heat pump in each suite which will produce chilled air to be distributed around the suite.

6.2.3. Boiler System

The current boiler systems for the four dorms north of Campus Drive are located on the north side of the Knollcrest dining. This system will be sufficient enough to cover the extra heating load required by the new dorm wing.

6.2.4. Boiler Pipe Network

The boiler pipe network is located in pipes underground. These pipes go from the boiler system to each of the dorms. The Physical Plant maintains these pipe networks.

6.2.5. Chiller System and Pipe Network

No system of chilled water loops exists yet around the dorms on campus. In order to provide chilled water to the dorm wing heat pump, a new chiller would be installed for the new dorm wing. This chiller would be hidden on the roof of the dorm wing. There are future plans to expand the underground piping network to provide chilled water loops to each of the dorms from a system of chillers.

6.2.6. Heat Pump

The chiller system in the new dorm wing will use individual heat pumps in each suite. They will be located in a maintenance closet in the shared bathroom. The heat pump selected is the Trane GETB vertical stack water source heat pump.

6.3 Design Decision

The administration has had a continual interest in our project and the education it could provide students on campus, and are dedicated to seeing it go forward. However, due to budget constraints this project is continuing as a small scale demonstration (a pilot project). The final design decision is to have two suites heated and cooled by geothermal in the new residence hall addition (see appendix 4).

6.3.1 Heat Pumps

With the help of GMB engineers, we have decided that one 1½ ton heat pump unit for each geothermal suite would be adequate to provide heating and cooling for the space. These heat pumps will use 2 two speed variable compressors for more efficiency. We are waiting on selecting specific heat pump units given that we could receive donated ones.

6.3.2 Well Field

Using EES (engineering equation solver), a mathematical model has been developed to calculate the needed well size to provide adequate heat rejection/sink for the heat pumps at maximum load. Maximum load occurs during the hottest/coldest part of the summer or winter respectively. In other words, the full 3 tons of heat and cooling potential needs to be supplied to the heat pumps at those times of year. The results are as displayed in the following figures.

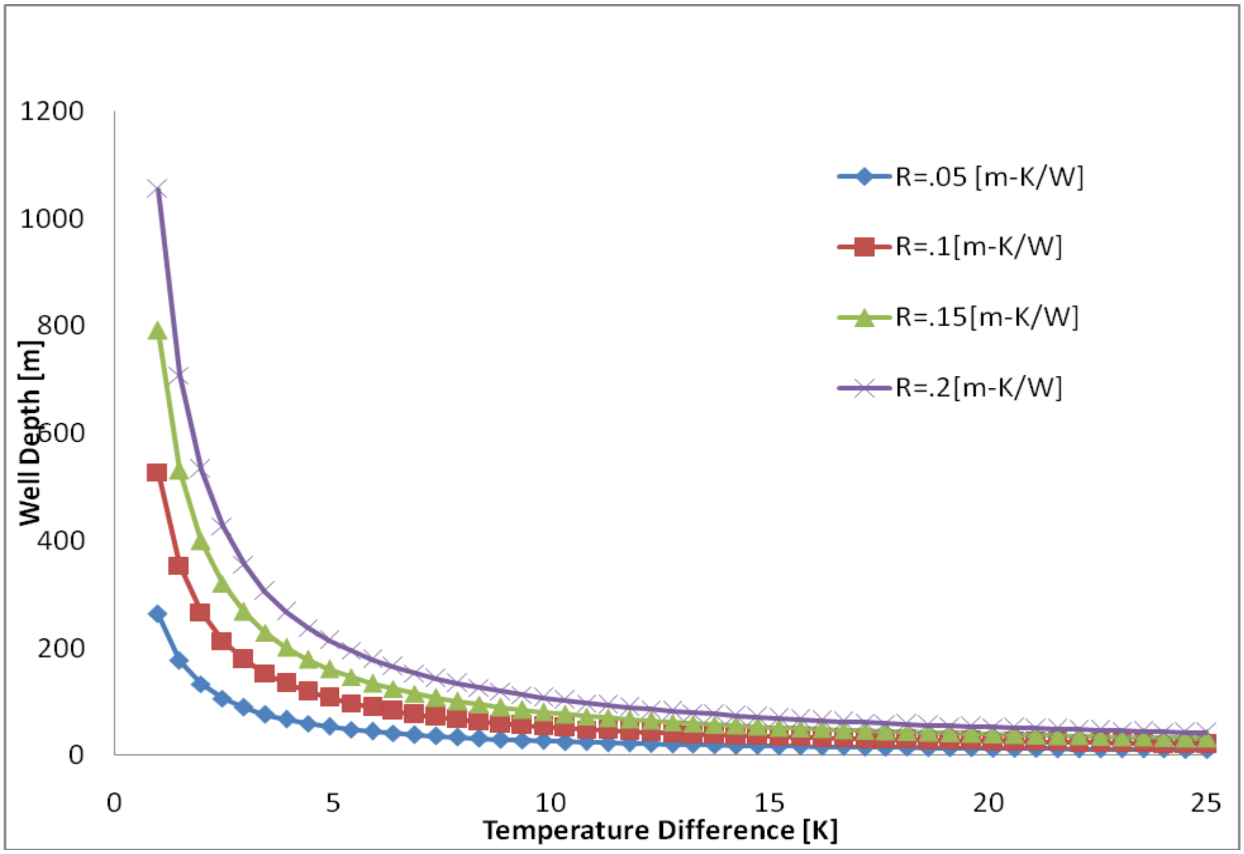

Figure 4: Geothermal Well Depth as a Function of Temperature Difference with lines of Constant Thermal Resistance

Figure 4 displays well depth dependent on the temperature difference between water entering the ground loop and ground temperature, with lines of constant effective thermal ground resistance. Thermal conductivity has not been calculated for Calvin's soil before, in an effort to determine the best possible well size the following graph was developed.

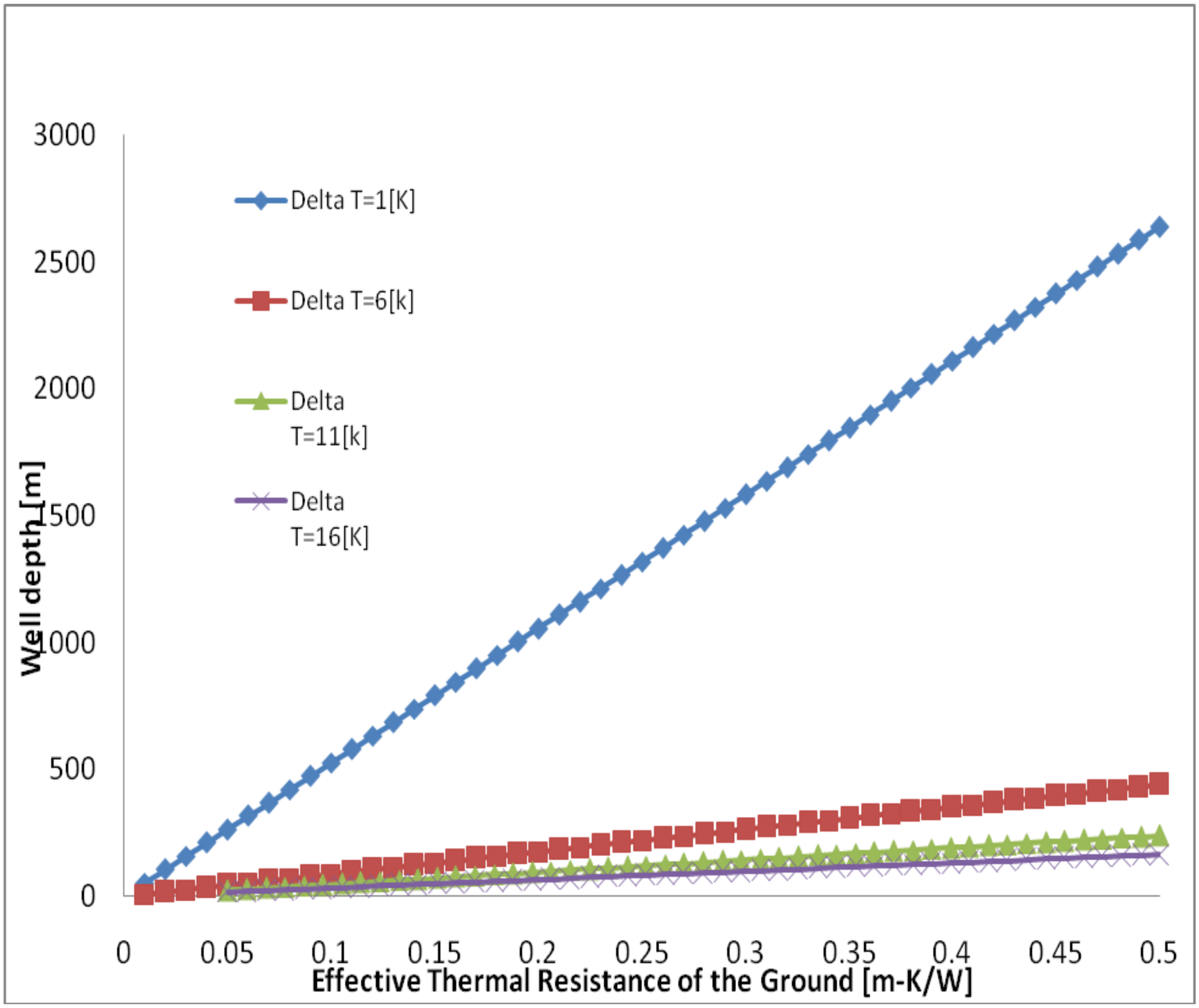

Figure 5: Geothermal Well Depth as a Function of Ground Thermal Resistance With Lines of Constant Delta T

To fully account for the inaccuracy in the thermal resistance it was determined that a well depth of 400 ft will more than account for the maximum heating and cooling loads. See appendix 2 for EES calculations.

7. Educational System Design

A major part of this senior design project is making the demonstration geothermal heat pump system educational. This component of the project has taken two forms. First is an informational kiosk near the installation of the project. Second, an instrumentation package list has been put together that would measure significant data within the system.

7.1. Informational Kiosk

The informational kiosk would be comprised of a computer with a touch screen monitor displaying an intuitive interactive presentation about various aspects of this project. Figure 5 below diagrams what will be displayed in the interactive presentation and how a user would navigate the presentation. When not in use, the program would automatically default to the master screen. Also, each page would have the option to return to the master page.

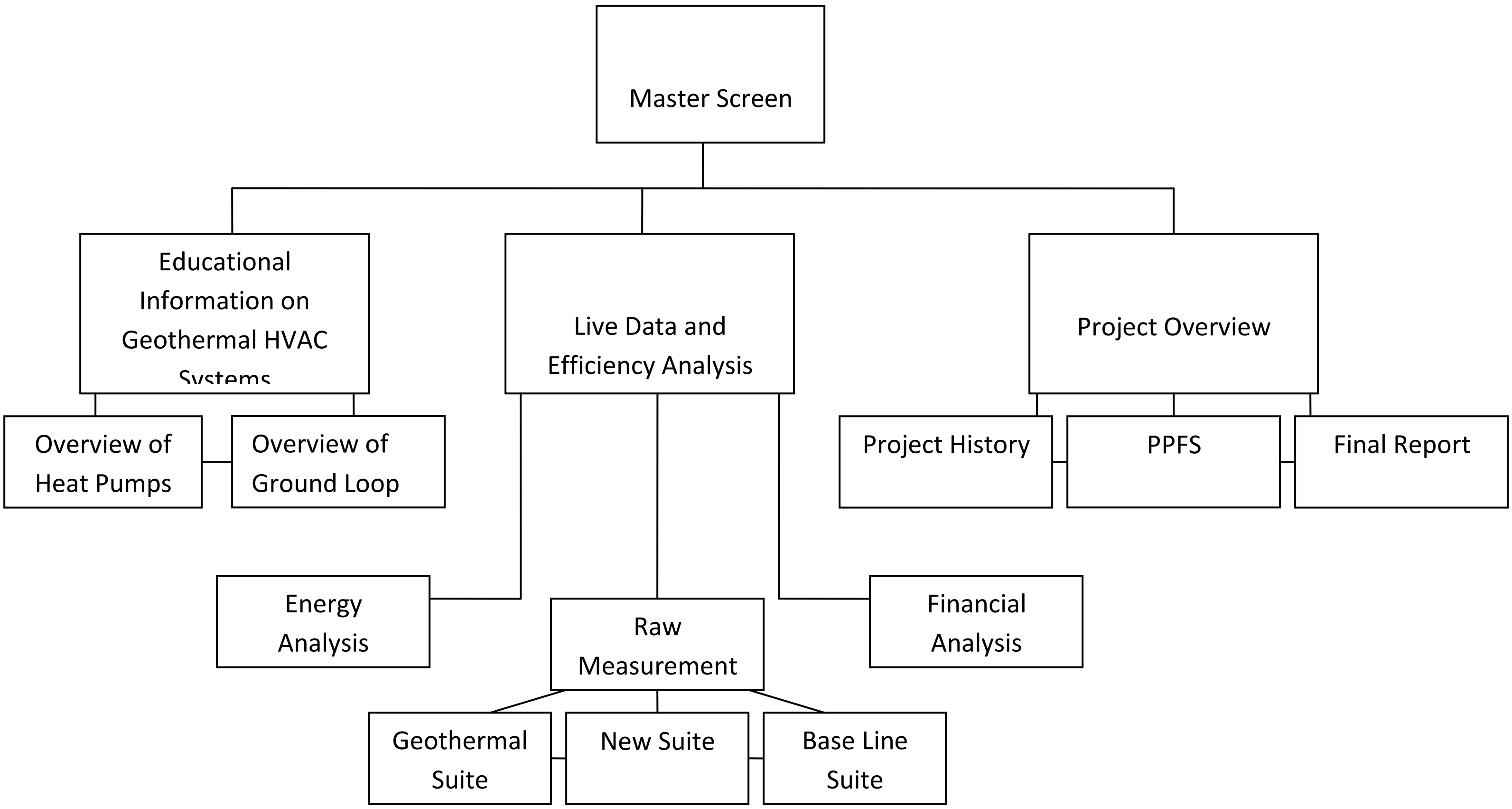

Figure 5: Block Diagram of Educational Software Layout

7.1.1. Educational Information on Geothermal HVAC Systems

This page of the interactive presentation will explain the basic principles of how a geothermal heat pump system operates. It will included two diagrams of a geothermal heat pump system operating where heat is being rejected to the ground and heat being taken from the ground (cooling and heating cycles respectively). This page will also lead to two separate pages that are specifically concentrated on heat pumps and the ground loop.

7.1.1.1. Heat Pumps

This page will display general information about the vapor compression cycle in a heat pump and how it changes depending on the heating or cooling cycle. This page will go through the different design option that was considered during the design process for the KH residence hall addition. Also, a user will be able to connect to the page displaying real-time data on the operating heat pump.

7.1.1.2. Ground Loop

General information about the thermodynamics of group loops will be presented on this page. Information about various ground loop design, their respective benefits and drawbacks will be given on this page. This information will be very similar to information presented in section 6.1.2 of this PPFS. Last, user will be able to connect to the page displaying real-time data on the demonstration ground loop.

7.1.2. Live Data and Efficiency Analysis

In this section of the interactive presentation on the informational kiosk a user will be able to view real time data on three separate Calvin College residence hall suite gathered by an instrumentation package presented in section 7.2. This information will be presented in three separate forms; raw data, energy analysis, and a financial analysis.

7.1.2.1. Raw Measurements

This section will be comprised of three separate diagrams. Each diagram will be a basic model of a Calvin suite and it's supporting HVAC and energy systems. The real-time data will be shown in the model by where they are measured in the respective suite. This way a user will be able to easily understand where the measurements are being taken and what they mean.

7.1.2.2. Energy Analysis

This section will use the real-time data to make a comparison of the energy use in each suite. It will simplify the information so that the user will be able to tell which suite is the most energy efficient and by how much.

7.1.2.3. Financial Analysis

This section will also use the real time data to show how much money the most energy efficient suite is saving. Also, this page will display a break even analysis of the building if it would have been built using all geothermal based.

7.1.3. Project Overview

In this section of the interactive presentation an overview of this project will be presented. It will contain three separate pages about the history of the project, the PPFS, and the final report.

7.1.3.1. History of Project

This page will contain a Gantt chart for the entire project, outlining major milestones in the project.

7.1.3.2. PPFS

This section will also have a PDF copy of this report.

7.1.3.3. Final Report

Once the final report is complete a PDF copy will be included on this interactive software. This will be included for people who wish to obtain a deeper understanding of the project and geothermal heat pumps systems.

7.2. Data Acquisition Package

As mentioned before, part of the educational aspect of this project is an instrumentation package. This instrumentation package would be comprised of measurements taken on three separate suites. The base line suite will be a current residence hall suite (The least energy efficient suite). The second suite that will be monitored is one of the new residence hall addition's suite that does not use geothermal system. The last suite will be a one that uses the demonstration geothermal heat pump system. Temperature and power usage, and occupancy will be measured in each suite.

7.2.1. Temperature Measurement

Various temperature measurements will be taken in each suite. A preliminary list desired temperature measurements are as follows: Ambient room temperature, outside air temperature, temperature through the external wall, temperature on the interior and exterior of the windows. Temperature measurements various statepoints in heat pump.

7.2.2. Power Measurement

Another measurement that is desired in each suite is power use. This manly entails, but is not limited to, outlets and lights. It will also be important to monitor the power consumption of the heat pump in the geothermal suite.

7.2.3. Ground Loop

Various measurements will also be taken on the ground loop for the geothermal heat pumps. This will include soil temperatures, temperatures in and out of the working fluid, flow rate in the ground loop, and power consumptions of the pump(s) for circulation of the fluid.

8. RESOURCES

8.1. Calvin's Administration

Vice President DeVries, Vice President Hoogstra, Dean Witte, Phil Beezhold, and Sam Wanner have all been very beneficial in our project. Vice President DeVries has encouraged us to pursue this project from the beginning and has supported us through each of our obstacles. This administrative staff has worked hand in hand with us as we design the Geothermal system to be installed in the residence hall addition. The administration approved $40,000 from the dorm to be designated to our project.

8.2. GMB

GMB is a full service Architect and Engineering firm located in downtown Holland. Jim Vanderveen and Steve Hamstra, two GMB employees, have provided much educational background about geothermal systems. They have provided much advice and have offered to donate their design expertise.

8.3. RETScreen software

This software was recommended to us by Jordan Hoogendam, a Calvin engineering graduated working in the LEED building design field. RETScreen is a distinctive decision support tool that has been developed through assistance from numerous experts on renewable energy technologies from governments, academia, and industry. This software is used to evaluate life cycle costs, emissions reductions, financial viability, and energy efficiency of efficient energy and renewable energy technologies.

9. BUDGET

9.1. Geothermal system

The primary components of the Geothermal System are the heat pumps and the wells. These costs are explained below.

9.1.1. Heat Pumps

Depending on the design selected, the heat pumps will cost between $2500 and $3500. GMB is optimistic of donated or discounted components and labor assuming local companies will be looking to boost their Public Relations with and education project.

9.1.2. Wells

The cost for the Geothermal Wells includes the costs of all well borings, pipes, and installation. GMB ran a conservative estimate of $10,000 for the Wells. GMB is optimistic of donated or discounted components and labor assuming local companies will be looking to boost their Public Relations with and education project.

9.1.3. Other Costs

The contingency of the geothermal system is $7,000.

9.2. Educational Component

The Costs for the educational components include all instrumentation necessary to collect and process data from the HVAC systems. Table 1 below lists the prices for each component that we believe is needed for the instrumentation package. The total estimates come to approximately $17,500. The contingency for the educational components is $2,000.

Table 1: Instrumentation Components and Costs

Instrumentation List

Part	Qty	Manufacturer	Description	Dscnt %	Price	Total Cost
Kiosk						
Touch Screen	1	Dell	15" Screen	1	$529.00	$529.00
Tower	1	Inspiron	Slim Tower	1	$349.00	$349.00
Meter and Sensors						
Thermocouples	1	Omega	1000'	1	$975.00	$975.00
Flow Meter	2	Omega	Paddlewheel	1	$200.00	$400.00
Fitting	1	Omega	1.25" Galvanized Iron Tee	1	$110.00	$110.00
Occupancy sensor	3	Leviton	Ceiling Sensor	1	$59.95	$179.85
Power Meter	15	CR Magnetics/McMaster-Carr	Power Transducer	1	$188.44	$2,826.60
Internet Connection						
Ethernet Controller module	2	National Instruments	32 MB RAM	0.9	$1,349.00	$2,428.20
Wireless modem module	2			1	$2,049.00	$4,098.00
DAQ						
Thermocouple Input	5	National Instruments	Thermcouple Input	0.9	$498.00	$2,241.00
Power Source	2	National Instruments	Power Source	0.9	$199.00	$358.20
FieldPoint	2	National Instruments	Field Point	0.9	$1,349.00	$2,428.20
Shipping						
shipping	1		From Vendors	1	$1,000.00	$1,000.00
						$17,394.05

Budget	
Total	$40,000.00
Remaining	$22,605.95

10. FEASIBILITY

10.1. System Performance

Geothermal heat pump systems have been installed in many different climates and prove to function properly. However, the overall performance of a geothermal heat pump system is highly dependent on the climate of its installation. According to the engineers at GMB, Michigan has the best suited climate for geothermal heat pump installation. This is because Michigan lies on the 45 parallel and has very balanced heating and cooling seasons. As a result GMB is the world leader in geothermal heat pump installations.

10.2. Financial Performance

The financial performance of a geothermal heat pump system is dependent on existing infrastructure. The KH residence hall addition was analyzed in two different ways; as if it were a standalone building, and as it is, an addition. The method use and results are outlined below. Both analyses compare two different designs for one building, one with a traditional HVAC system, and one with a geothermal system.

10.2.1. Stand Alone System

This method of analysis assumes is being built in satellite position and requires all utilities. That is, the building requires a full HVAC system. The software that was used to help complete this analysis was RETscreen. This software was recommended by Jordan Hogendam. He uses this software to determine the financial feasibility of buildings he is designing. With RETscreen, one is able specify information on the geographical area of the proposed building and building characteristics. This information includes climate, soil type, gas and electricity prices, building size, occupancy rates, and etc. For the analysis a base case is defined. The base case that was used was a building with the exact characteristics of the KH Residence hall addition using a traditional HVAC system. Then the new case was the same building with a geothermal HVAC system. The results are show graphically in figure 6.

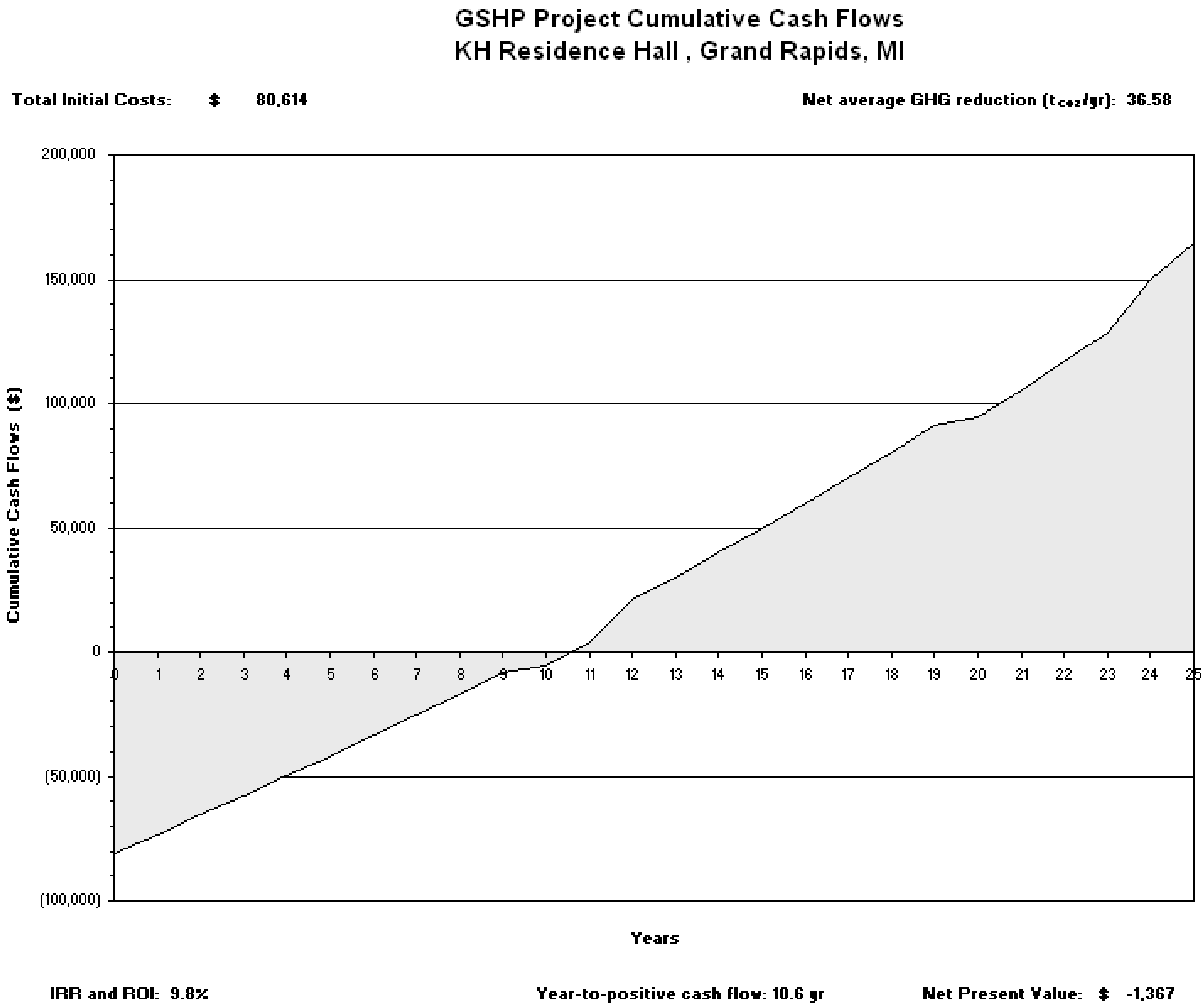

Figure 6: Break Even Analysis of Geothermal HVAC System

The Building with a geothermal HVAC system is estimated to break even with the base case building in **10.8 years,** with a return on investment of **12.1%.** See appendix 3 for the entire RETScreen spread sheet analysis.

10.2.2. KH Residence Hall Addition

Due to the fact that this building is an addition to a current residence hall, the cost for traditional HVAC infrastructure has already been incurred by the existing building. As a result, when compared to this, a geothermal HVAC system does not financially perform as well as a standalone system.

11. FUTURE WORK

11.1. Purchase educational components

In the future we plan on purchasing the educational components of the system. We have put together a tentative list of the components we will need. We plan on working with GMB and Professor Heun to cut the costs of these components. Table 1 above shows the components needed.

11.2. HVAC design Calculations

Once the final dorm design has be specified, GMB engineers have offered to educate us on how to design an HVAC system using geothermal heat pumps, specifically for the KH residence hall addition. With this knowledge we plan on design the HAVC system in the geothermal suites and the present our design to GMB for verification.

11.3. Installation of educational components on newly constructed systems

Once the instrumentation and other educational components have been purchased, they will need to be installed in the appropriate locations. The instrumentation in an old dorm could be installed during any academic break or during a time when residents permit entrance. The instrumentation in the new dorm wing will be installed as the wing is constructed.

In the event of the dorm construction continuing beyond the end of the Spring 2008 semester, the educational components will need to be installed on the system while it is being constructed. This would include any instrumentation that cannot be installed prior to the end of the Spring 2008 semester due to the construction timeline.

The educational kiosk will be the last piece installed. Once the dorm wing is finished, the kiosk can be installed and connected to the instrumentation system.

11.4. Educational software architecture

Once our instrumentation equipment list is finalized and purchased, we will finalize our design of the educational software for the kiosk. The general form of this software will be as outlined in section 7.1. We plan on developing calculations for energy and financial analysis, that will be displayed in the respective section of the presentation, using the real time and archived data from the instrumentation package.

12. CONCLUSION

Our project consists of a small scale geothermal demonstration system in the new KH residence hall addition. This demonstration includes a Geothermal HVAC system with a comprehensive instrumentation package designed to take real time data and perform energy and financial analysis. This educational component will also compare the geothermal system to other HVAC systems. The next steps of our project include purchasing and ordering our instrumentation package, testing and implementing our instrumentation package, and installation of the instrumentation package in the new residence hall and an old dorm suit. The administration will begin construction on the new dorm wing, including the geothermal system in January. We will begin work on this the first day of interim. It is our desire to provide a beneficial educational experience to students on campus, specifically the student involved in the living and learning community in the new residence hall through our project.

Appendix 1: Gantt Chart

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Appendix 2: EES Well Depth Calculations

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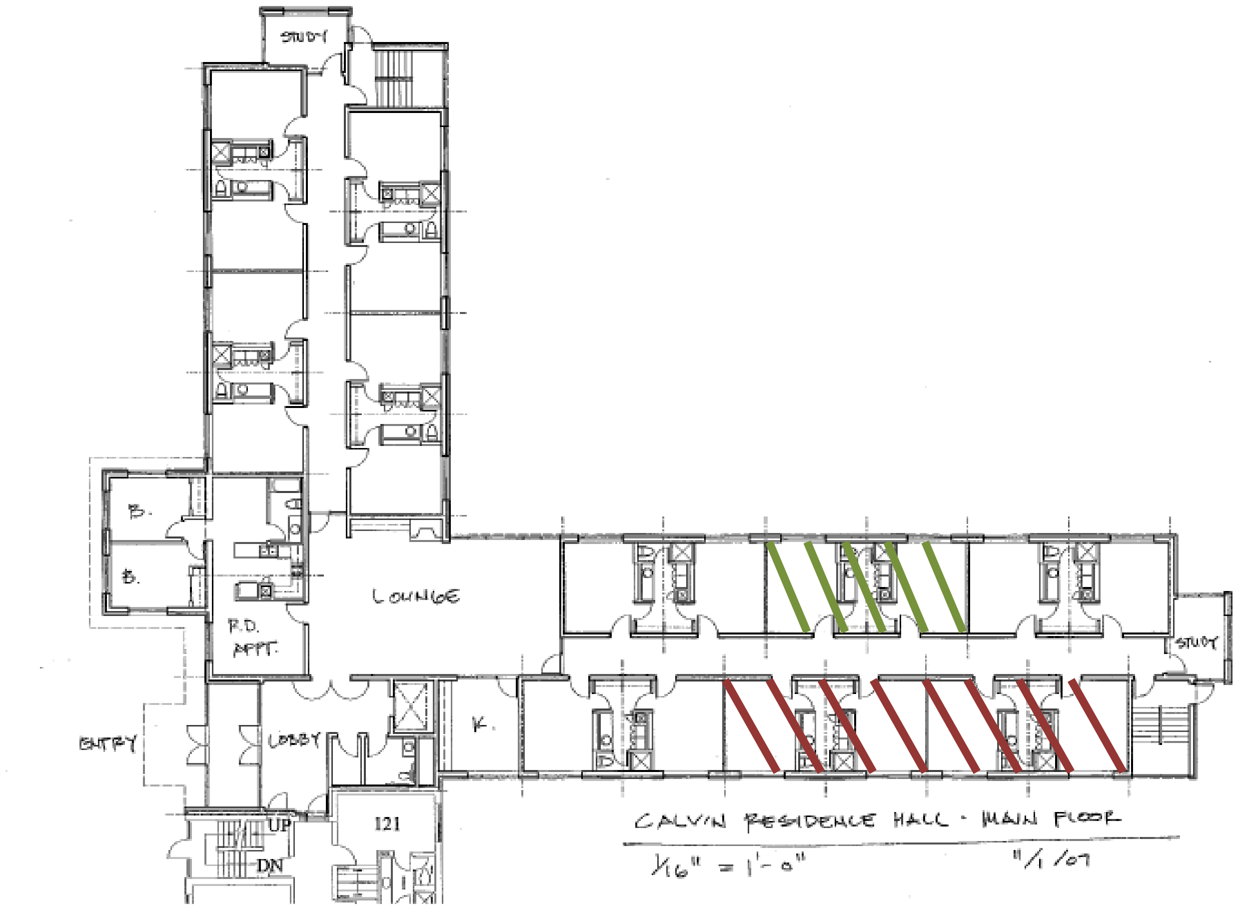
Appendix 3: RETScreen Economic Feasibility Calculations

Appendix 4: KH Residence Hall Addition Floor Plan



Geothermal Heat Pump Suites
2nd Case DAQ Suite

Potential Well Field Site