12/10

Virtua West Jersey Replacement Hospital

Voorhees NJ

THESIS PROPOSAL

Proposal | Justin Prior | Mechanical

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Executive Summary

The report is intended to describe the design changes being studied throughout next semester. This report includes an overall design summary from Tech Reports 1 and 2. Also included is the main design change being studied, as well as two breadths that I would like to study on the side. A schedule is also included that lays out the work schedule for next semester.

The main design change I would like to make is the use of a geothermal heat pump. Much research was done to determine the correct system to use and if it was indeed even a real possibility. The design that looks the best is a one well system. It is not known yet whether a heat pump, or a turbine will be used to generate electricity. While researching the topic an actual example was found in the same location. The Stockton College of New Jersey successfully installed a geothermal system on a somewhat large scale. While the geothermal system I am proposing will be larger than this system, it was important to see a real life example of this system working in the area.

In addition to geothermal, a redesign of the airflow will be conducted. This is because the design airflows went above code, and many spaces have much more outdoor air than required. This could be a potential energy savings idea, since the system will not require nearly as much outdoor air.

Also included in the report are two breadth proposals. The building has a large glass façade that lets in a lot of solar radiation heating the spaces. The installation of solar panels on the façade will make the solar panels act as solar shading as well for the spaces exposed to the sun. An orientation study will be done as well to see the ideal orientation for maximum solar energy being absorbed by the solar panels.

Due to the solar shading, the daylight in the patient rooms will be reduced. A daylight study will be performed to see how much daylight is lost, and if it has to be made up in artificial lighting. A structural study will also be performed for loads that the solar panels are putting on the columns. Wind loads will be important since it will push up on the solar panels.

System Description

The Virtua West Jersey Replacement Hospital is comprised of three main units. They include the hospital bed tower, the ancillary building comprised of offices and surgery rooms, and a central spine that runs through connecting the bed tower and ancillary building. The mechanical system was separated to condition these spaces separately based on the individual needs. The bedroom tower is mainly patient rooms and offices. These do not require the same indoor air quality as the ancillary building does. The ancillary building requires a much higher overall indoor air quality due to the operating and medical rooms.

The hospital consists of three 1,000 ton centrifugal chillers located in the central utility plant behind the ancillary portion of the building. Located on the roof of the building are three 9,000 gpm high efficiency cooling towers.

The hospital utilizes a VAV (Variable Air Volume) system throughout the building. There are three sets of AHU's located on the 7th. The first set consists of two AHU's at 50,000 cfm each. This will serve dietary areas and labs. The second set of AHU's also consists of two sets of 50,000 cfm AHU's. These will serve emergency and surgery rooms. The last set consists of six 75,000 cfm units that will serve the 8 story patient bedroom tower. For the computer room there are three computer room air conditioning units (CRAC).

For heating and humidifying the hospital has four steam boilers and six condensing boilers. Two of the steam boilers are 40 BHP, while the other two are 287 BHP. All four are located in the central utility plant. Coupled with the boilers are six shell and tube heat exchangers located in various areas around the building used for hot water heating.

Design Factors

There were various design factors that had to be taken into account for the overall design of the HVAC for the hospital. The buildings location is in Voorhees NJ. This requires more heating days than cooling days. Additionally, the building is located on a large site with very little surrounding it. This could potentially lead to significant heat loss during the winter due to no wind obstructions. An additional design factor was the large amount of glass being used on the building. The building's exterior consists of over 40% glass. Glass was used that had a U value of at least U-30 to help solve this problem. The orientation of the building is also a factor. The front of the building faces directly north, giving the building a north-south orientation. This is not ideal for an effective solar gain design.

Design Conditions

The outdoor and indoor air conditions for Philadelphia, PA were used. This is because there was no available data for the buildings location in Voorhees NJ. However, Philadelphia is very close, making the weather data an accurate representation for the weather in Voorhees. Values were taken from the 2005 ASHRAE Handbook of Fundamentals. Values used were the .4% and 99.6%. The OA Dry Bulb for the summer is 92.7° F, while the OA Wet Bulb is 75.6° F. The OA Dry Bulb for the winter is 11.6° F. The clearness number was .98 as well.

Design Ventilation Requirements

Table 4.6 shows the overall breakdown for the energy consumption by the building annually. The primary heating for the building comprises of mostly natural gas, since the boilers are responsible for this and they run on natural gas. There are several heat exchangers that also operate throughout the building for additional heating that do use electricity, which mainly comprises the "Other" in Table 4.6 under primary heating. The Primary Cooling consists of the various parts of the chillers, and the cooling towers. As seen in the table all of the cooling equipment runs on electricity, with the chiller cooling compressors using the majority of the energy. It is important to note the amount of water used mainly in the cooling towers as well. The supply fans also use a significant amount of electricity as well. This is because they are powerful fans that must push large amounts of air through high MERV rating filters. This equates to a large pressure drop, making it necessary for large, powerful fans to be used.

Energy Consumption Summary						
System		Elec (KWH)	Gas (KBTU)	Water (1000 gal)	Total (KBTU/Yr)	% Total
Primary Heating	Primary Heating	-	292,402,592	-		
	Other	17,721	-	1	292,463	73.70%
Primary Cooling	Cooling Comp.	12,924,327	-	-		
	Tower/Cond Fans	1,859,147	-	88,409		12.70%
	Condenser Pumps	-	-	-	50,455,997	
Auxiliary	Supply Fans	8,851,427	-	-	30,209,902	7.60%
Lighting	Lighting	6,512,327	-	-	22,226,570	6%
Total		**30164949**	**292,402,592**	**88410**	**103,184,932**	**100%**

Table 4.6 Energy Consumption

Proposed Alternative Systems

Geothermal Heat Pump

One of the major ways I believe energy can be saved for the Virtua West Jersey Replacement Hospital is to incorporate a Geothermal Heat Pump system with the current system to provide renewable energy. This could potentially greatly reduce the cost energy for the hospital. Before tackling this option it is important to see if it is a viable idea for both the location and type of building.

Geothermal plants are being built across the United States, however, they are mainly on the West Coast due to the temperature of the ground being significantly warmer there. The development of new types of power plants, and improvements in drilling and extraction technology have made geothermal heat pumps a viable option in around 80% of the country. Today there are currently 77 geothermal power plants that can produce up to 25 MW. This number shows that geothermal energy is on the rise, and is capable of supporting a large building with high energy demand.

There are four types of geothermal heat pumps currently being used today. The Flash Power Plant uses geothermal heated water under pressure that is separated in a surface vessel into steam and hot water. The steam is then delivered to a turbine, which powers a generator. The water is then injected back into the reservoir in the ground. Figure 5.1 shows how this system works.

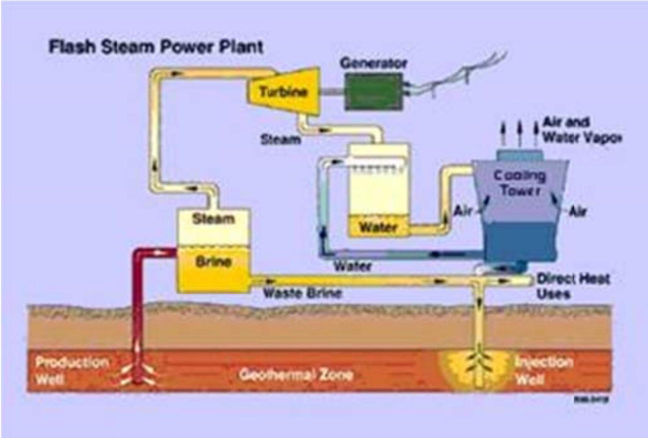

Figure 5.1 Flash Power Plant

The second type of system is a Dry Steam Power Plant. This system, shown in Figure 5.2, uses steam produced directly from the geothermal reservoir to run the turbine that powers the generator. No separation is necessary because the wells only produce steam.

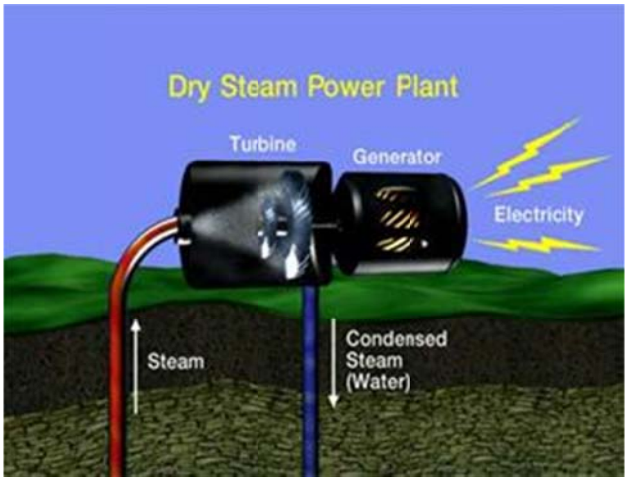

Figure 5.2 Dry Steam Power Plant

The third type of geothermal system is a Binary Power Plant. This type of plant allows for geothermal use for resources with a lower temperature. These plants use a Rankin Cycle system where the geothermal water heats another liquid, for example isobutene or pentaflouropropane, that boils at a lower temperature than the water. The two liquids are kept separate from each other through the use of a heat exchanger, which transfers the heat energy from the geothermal water to the liquid. Using the force of the expanding vapor, similar to steam, the turbine turns to produce electricity. Figure 5.3 shows an example of a Binary Power Plant.

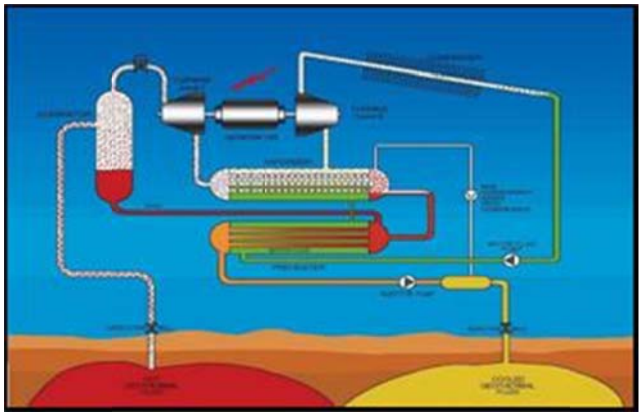

Figure 5.3 Binary Power Plant

The final type of system is a Flash/Binary Combined Cycle. This type of plant uses a combination of the binary and flash technology. A portion of the geothermal water which turns to steam under reduced pressure is first converted to electricity with a backpressure steam turbine. The low pressure steam exiting the backpressure turbine is condensed in a binary system. Figure 5.4 shows a schematic for a flash/binary combined cycle.

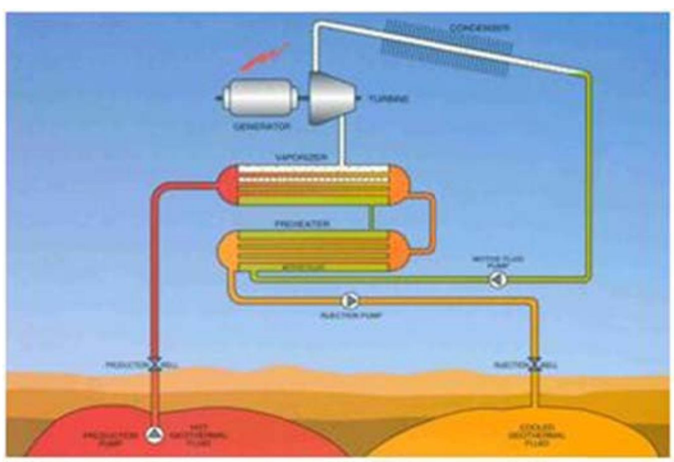

Figure 5.4 Flash/Binary Combined Cycle

In addition to the four types of geothermal plants, there are two main types of wells to use. The first, shown in Figure 5.5, is a two well system. This works by fracturing the rock to improve flow from the ground. Fluid can flow through the interconnected fractures, allowing heat extraction.

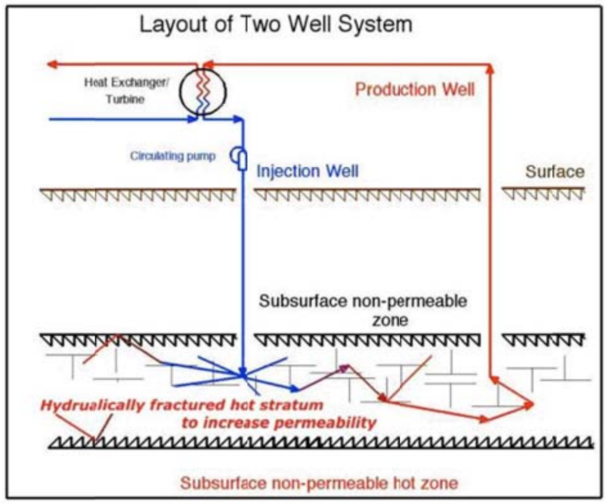

Figure 5.5 Two Well System

The problem with this type of well system is that fracturing can cause the ground to be unstable. In addition to this maintenance costs are escalated due to the contaminants and minerals in the fluid. This is because over time they will corrode the pipes that the fluid is pumped through.

The second type of model is a one well system shown in Figure 5.6. In this model the heat extraction is independent of the heat reservoirs fluid content. A high pressure fluid is sealed from all direct contact with the ground. The fluid would acquire heat by conduction from the hot rock below. This fluid could then turn to steam powering a turbine located above. The cooler water then is pumped back to the subterranean rock to be reheated by the rock. This system does not have the disadvantages of the two well system, and is capable of producing a large amount of megawatts.

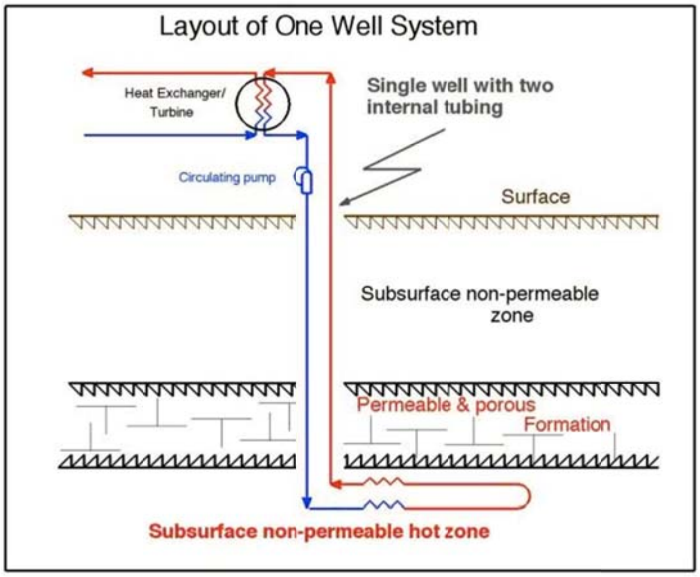

Figure 5.6 One Well System

While geothermal power requires no fuel, the capital cost can be very high. Drilling can potentially account for over half of the cost, and the further the drilling the more expensive it is. For example, a 4.5 MW well in Nevada cost $10 million to drill alone. While the Virtua Hospital will most likely not be able to reproduce this amount of energy due to its location, it shows that first cost is a significant factor in the decision whether to incorporate the system. Overall systems tend to cost above $4 million per MW, which is around $1150 to $3000 per kW. Costs can greatly vary depending on the site. The usual lifetime of a plant is also around 30-45 years.

While the first cost of building a geothermal plant can be high, the operating costs compared to that of other plants is fairly low. A geothermal plant cost around $.04/kWh to operate and maintain. A hydropower plant cost around $.07/kWh, while a nuclear plant can cost up to $1.9/kWh. As Figure 5.7 shows, geothermal energy also has a high capacity factor compared to other renewable sources. The capacity factor is the total energy produced/energy produced at full capacity. In addition, geothermal heat pumps are reliable, and do not depend on the weather like many other renewable sources. Since the wells are all underground, the land usage is minimal as well.

Renewable Energy Sources	Capacity Factor (%)	Reliability of Supply	Environmental Impact	Main Application
Geothermal	85-95	Continuous & reliable	Minimal land usage	Electricity generation
Bio-mass	83	Reliable	Minimal (non-combustible material handling)	Transportation, heating
Hydro	30-35	Intermittent dependent on weather	Impacts due to dam construction	Electricity generation
Wind	25-40	Intermittent dependent on weather	Unsightly for large-scale generation	Electricity generation (limited)
Solar	24-33	Intermittent dependent on weather	Unsightly for large-scale generation	Electricity generation (limited)

Figure 5.7 Renewable Energy Summary

Upon further research of the topic, a specific example for geothermal use was found which can help determine whether this is indeed a viable option to study. The Stockton College of New Jersey installed a geothermal heat pump system to serve several of the academic buildings on its campus. Construction began in 1993 and was completed in 1994. The system was a closed loop (one well) system. A well field was created consisting of 400 wells, each 425 ft deep. These were all installed under a 4 acre parking lot. U–tubes of 1 ¼ inch diameter pipes were used, with each well carrying up to 4000 gallons per minute of water to supply the heat pumps. The system operates during both cooling and heating seasons. Heat is extracted from the ground during the heating season, and unwanted heat is dumped back into the ground during the cooling season. The annual temperature of the supply coming from the well fields is around 65°FThe system in place currently cools and heats 400,000 sq. ft of academic buildings. The total cooling capacity of the geothermal HVAC system is 1681 tons.

The geothermal system had a total installation cost of $4,964,594. However, the electric utility company offered a rebate of $800 per installed ton, creating a total rebate of $960,000. The utility company is Atlantic Electric Company, which is the same utility company being used for the Virtua West Jersey Replacement Hospital. Before the geothermal retrofit, the Stockton College was spending around $940,000 on electricity per year. The geothermal system ended up saving $126,000 per year, creating a 30 year payback period. A one well system tends to have a lifetime of around 40-45 years since the contaminants from the earth do not enter the water. Figure 5.8 shows a schematic of how the geothermal wells for the Stockton College of New Jersey Operate.

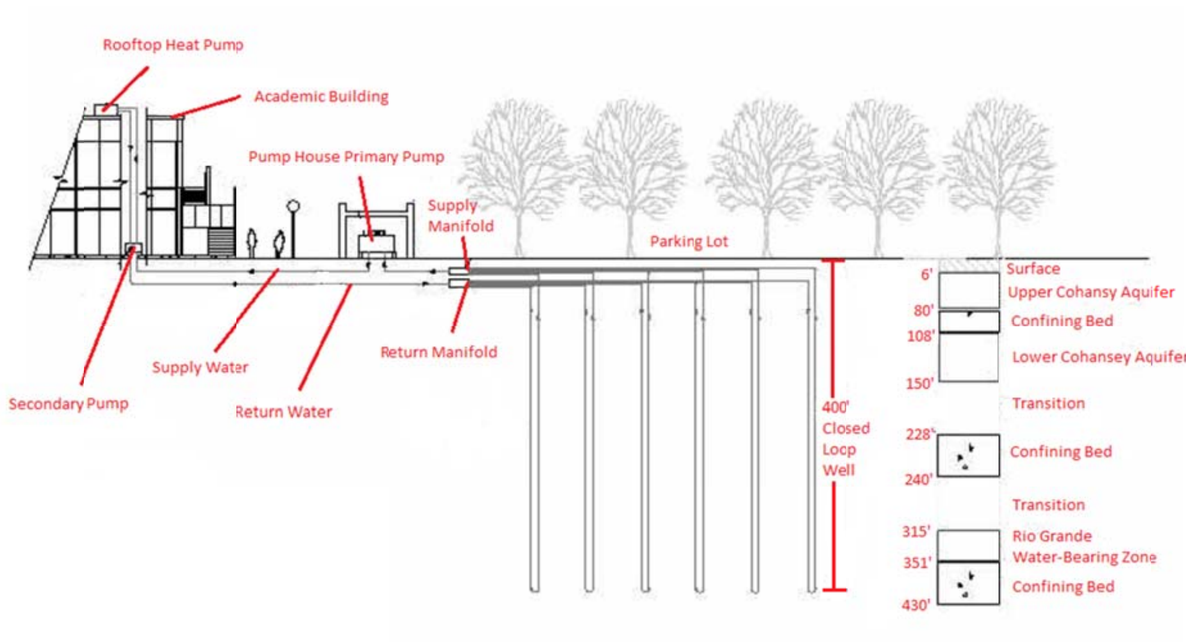

Figure 5.8 Stockton College Geothermal Schematic

The reason for researching this particular project was not only the size of it, but the location. The Virtua West Jersey Replacement Hospital is located 30 miles away from the Stockton College of New Jersey. Due to the similar location and the seemingly successful implementation of the geothermal heat pump in Stockton, I feel that a geothermal design would be a very compelling and realistic option to study. Figure 5.9 shows a distribution of ground temperatures throughout the United States. While the depth in this figure is 33,000 ft, it shows that the temperatures are consistent through New Jersey, and that digging deeper is an option to increase the heat gain from the rock.

One key advantage to the Virtua West Jersey Hospital is the large site that it sits on. The 120 acre site provides a substantial amount of room for geothermal wells to be placed. Figure 5.10 shows a site plan for the building. The hospital is shaded orange, and it is important to note the vast expanse of parking lots located behind the building. This could be a potential site to place the wells, due to the close proximity of parking lot to the central utility plant located behind the hospital. This is important because not only is the majority of the mechanical equipment stored here, but because there is a significant amount of empty space in the plant. This is because space was created in case future expansion was needed, and additional space may be needed in the future. However, the current empty space could house all of the equipment needed for the geothermal wells. This includes the pumps, heat exchangers, and potentially a steam turbine.

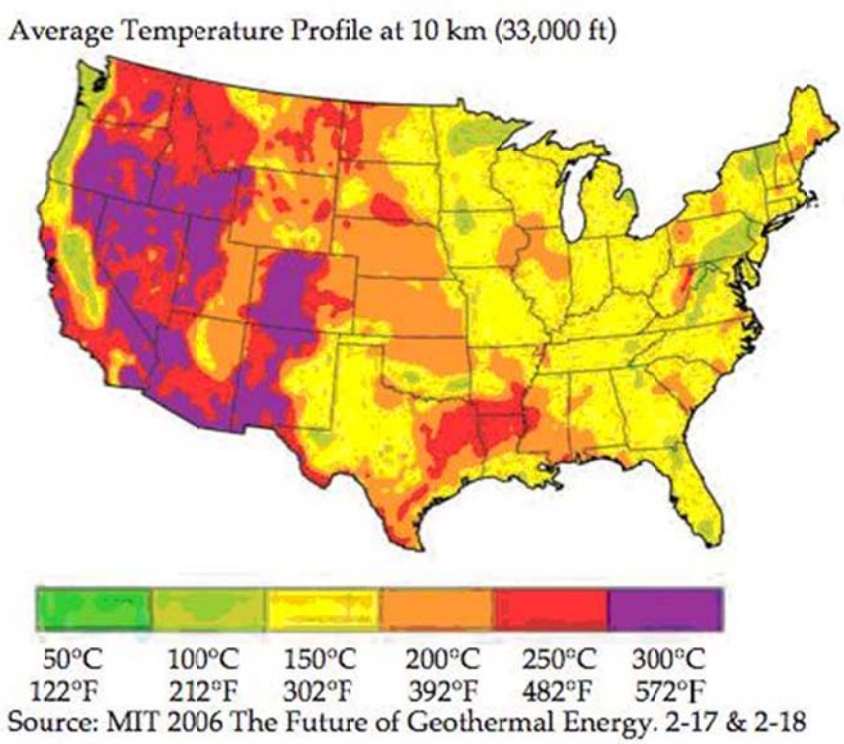

Figure 5.9 Ground Temperature Profile

Figure 5.10 Virtua West Jersey Replacement Hospital Site Plan

Airflow Redesign

Another area for a potential to save energy is to redesign the outdoor airflow requirements done in the Tech 1 report to comply with ASHRAE St 62.1-2004. When the building was designed, IMC 2003 and AIA 2001 were used to determine OA rates. However, when studying the design outdoor air rates, it was clear that the design rates were significantly larger than that required. Many spaces in the building seem to have been over ventilated. Certain spaces do have a very high outdoor air fraction, such as operating rooms and various other medical rooms. However, there are many other office and patient areas that have an extremely high outdoor air rate.

Many of the offices in the hospital are 100% outdoor air. For example, of the 82 offices located on AHU Set 1 and AHU Set 2, 65 of the offices are 100% outdoor air. This number does not include AHU Set 3, which also has a significant amount of offices on it. Many other spaces throughout the building also have high outdoor air rates, which fall under the office criteria for ASHRAE St 62.1. I feel there could be energy savings if the air rates were redesigned under the ASHRAE St 62.1-2004.

Breadth Topics

Electric/Lighting PV Panel Study

One potential area of study is to incorporate Photovoltaic Solar Panels into the design of the building. An interesting way to do this is to incorporate the solar panels into the front façade of the building. The front of the building is completely covered in glass as seen in Figure 6.1, allowing for a lot of solar radiation to enter through the glass. A louver design will help limit the light and solar radiation entering the room. A way to incorporate solar panels into the design is to make the solar panels the actual louvers. This idea can be seen in Figures 6.2 and 6.3. A study will also be done on the building orientation to determine the best orientation for the building to sit for the maximum solar gain for the panels, as well as an energy analysis. Initial costs of the solar panel system as well as the payback period will be analyzed to determine whether it is a viable option. This is an interesting option for me to study since they have been discussed a lot in classes, but I am still skeptical as to whether they are a realistic option.

PV panels will be placed on the roof to collect solar energy for potential savings on electrical costs. A study will be done to see how much electricity the PV panel system can produce, and what components can be placed on them. A single line diagram and schematics will be provided to show wire sizes and the equipment being used. With a large amount of electrical energy being used in the hospital, there is a large potential for energy savings using PV panels.

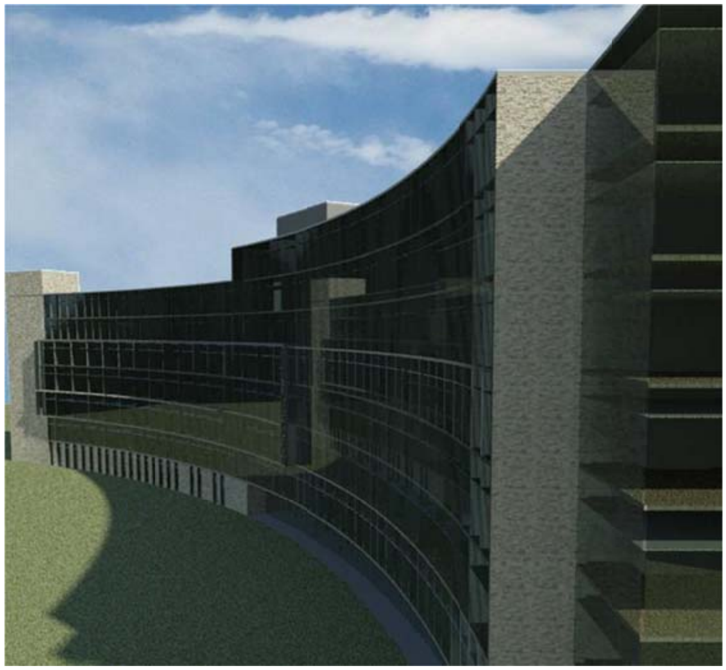

Figure 6.1 Current Façade Design

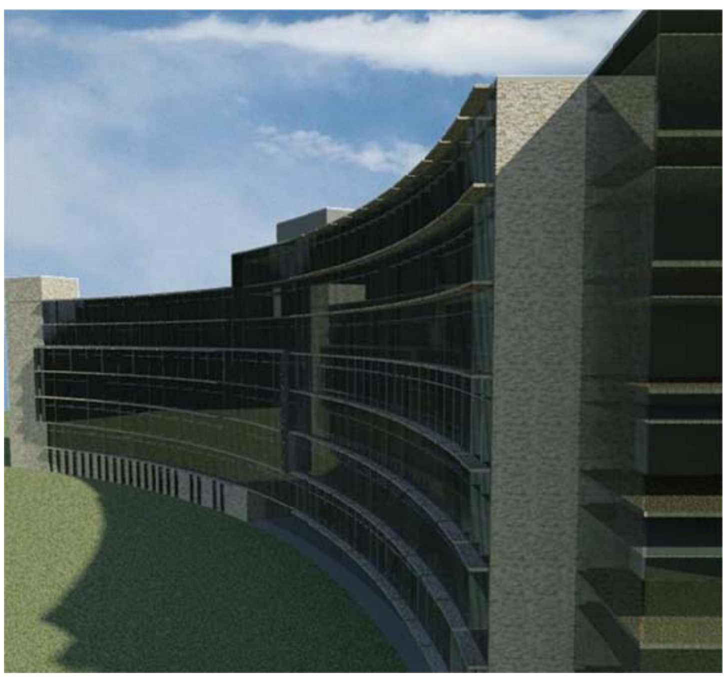

Figure 6.2 Proposed Façade Design

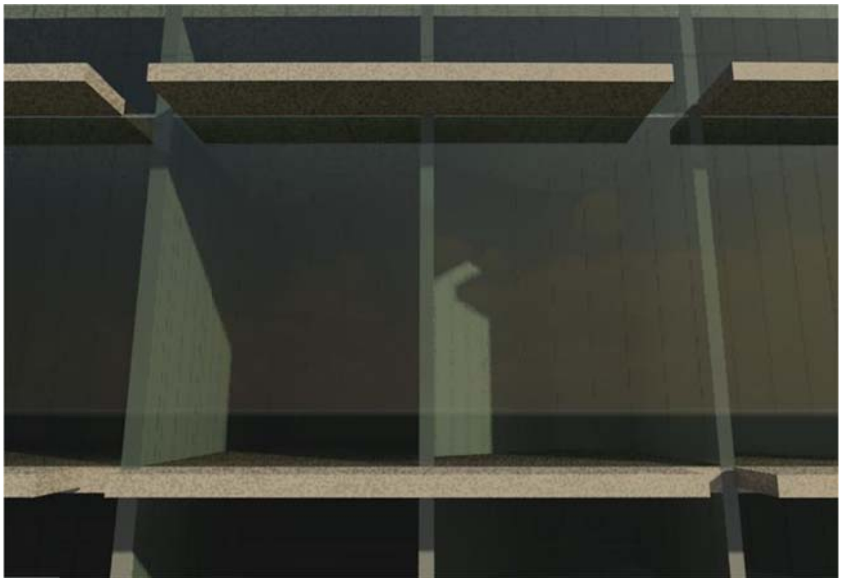

Figure 6.3 Proposed Façade Design

PV Structural Study

The structural impact of the solar panels is also important to study. This is because they will be adding additional loads to the columns. A structural analysis will be performed on the columns that support the roof of the hospital to determine the potential structural impact due to the PV panels. Several loads will be considered, and the columns will be resized if needed. Since there will be a significant amount of PV panels on the roof, there is a large potential that columns will need to be resized.

Modeling Tools and Methods

Various programs will be used to help conduct the research for my thesis. These programs will include mainly Trane Trace and Microsoft Excel. Both these programs will be used to show whether the options I have chosen to study are technically and economically realistic. Conclusions drawn from these programs will discussed in future reports.

Trane Trace is a modeling program used to create energy models for various types of buildings in different areas. Many different systems and types of spaces can be modeled in this program. Many economic conditions can also be entered. Overall results include energy use, internal and external loads, and costs of the building be modeled.

Microsoft Excel will be a very helpful program to help organize and study various topics, but specifically the geothermal heat pumps. Trane Trace is limited in this option, so calculations will have to done separately. This also applies to the PV solar panels. A portion of the study will have to be done through Excel spreadsheets.

References

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The Possibility of Large Scale Geothermal Power Plants, Ghahremani Fathali, Perspectives on Global Issues, 2010

Economics, Geothermal, Renewable Energy Policy Project, 2006 http://www.repp.org/geothermal/geothermal_brief_economics.html

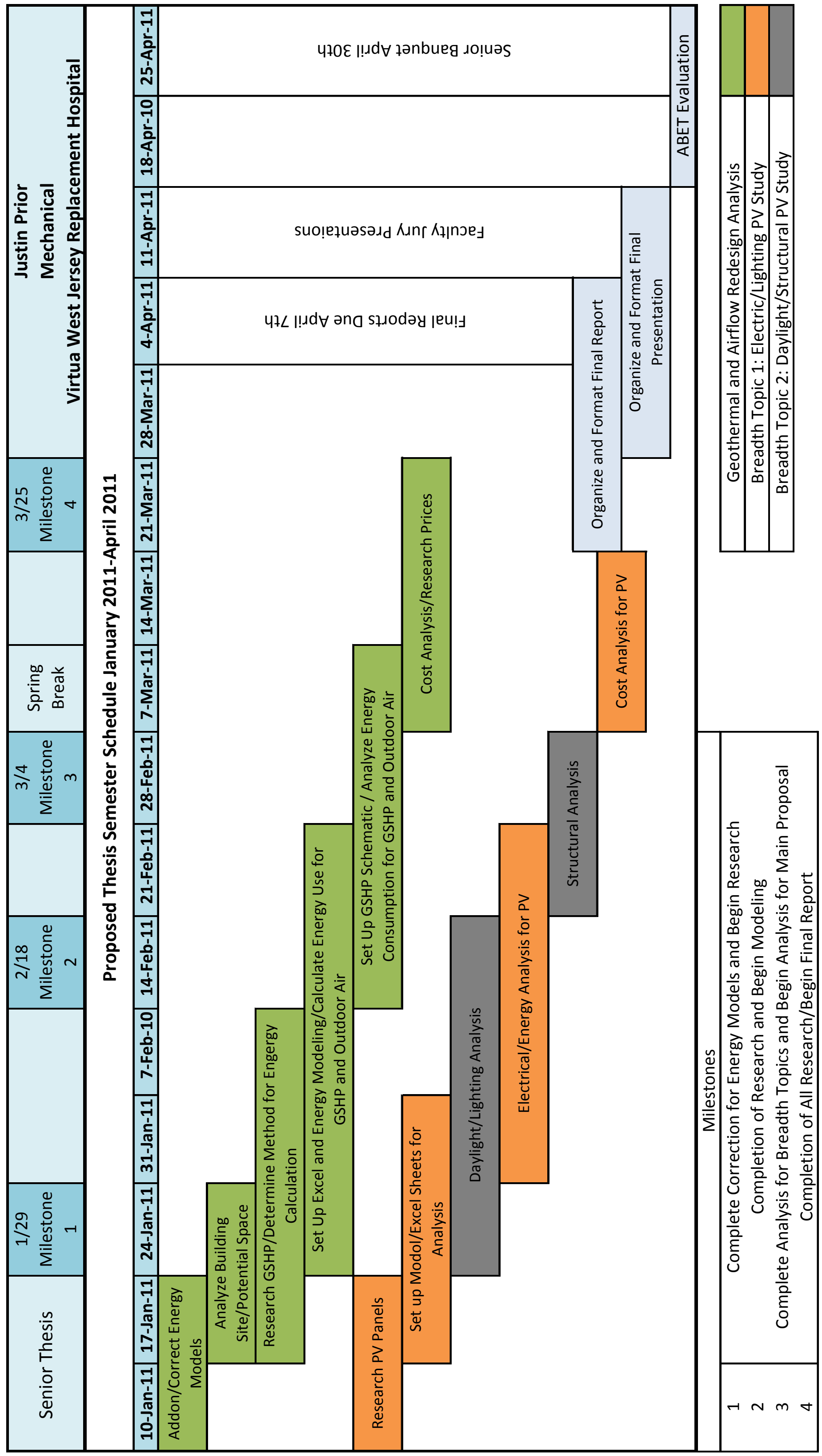
ASHRAE St 62.1-2004

ASHRAE St 90.1-2004

Bill Swanson – Turner Construction Company

Scott Lindvall – HGA Architects & Engineers

Dr. Stephen Treado


Senior Thesis
Justin Prior
Mechanical
Virtua West Jersey Replacement Hospital
1/29 Milestone 1
2/18 Milestone 2
3/4 Milestone 3
Spring Break
3/25 Milestone 4
Proposed Thesis Semester Schedule January 2011-April 2011
10-Jan-11
17-Jan-11
24-Jan-11
31-Jan-11
7-Feb-10
14-Feb-11
21-Feb-11
28-Feb-11
7-Mar-11
14-Mar-11
21-Mar-11
28-Mar-11
4-Apr-11
11-Apr-11
18-Apr-10
25-Apr-11
Addon/Correct Energy Models
Analyze Building Site/Potential Space
Research GSHP/Determine Method for Engergy Calculation
Set Up Excel and Energy Modeling/Calculate Energy Use for GSHP and Outdoor Air
Set Up GSHP Schematic / Analyze Energy Consumption for GSHP and Outdoor Air
Cost Analysis/Research Prices
Research PV Panels
Set up Modol/Excel Sheets for Analysis
Daylight/Lighting Analysis
Electrical/Energy Analysis for PV
Structural Analysis
Cost Analysis for PV
Organize and Format Final Report
Organize and Format Final Presentation
ABET Evaluation
Final Reports Due April 7th
Faculty Jury Presentations
Senior Banquet April 30th
Milestones
1 Complete Correction for Energy Models and Begin Research
2 Completion of Research and Begin Modeling
3 Complete Analysis for Breadth Topics and Begin Analysis for Main Proposal
4 Completion of All Research/Begin Final Report
Geothermal and Airflow Redesign Analysis
Breadth Topic 1: Electric/Lighting PV Study
Breadth Topic 2: Daylight/Structural PV Study