ZERO ENERGY HOME

Introduction to Engineering Design

Section #207

EDSGN 100

Design Project #1 Report

The Super Alphas

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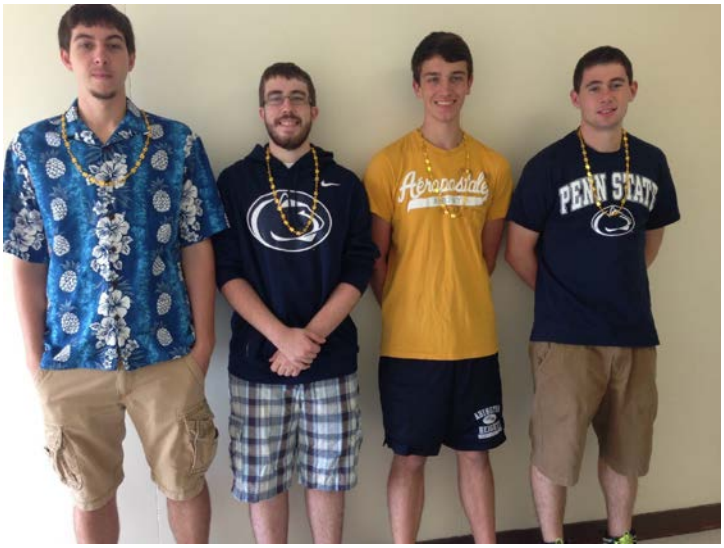

Submitted to

Wallace M. Catanach, III, PE

Date: 8/14/14

Executive Summary

An individual has a need for their home to produce at least as much energy as it consumes. Over the past century and a half, mankind has been depleting far more non-renewable resources than the world can replenish. These non-renewable resources, in many cases, cause pollution when used. The objective of this project is to produce a home that uses energy sources that are not detrimental to the environment. In doing so, the home will be self-sustainable and will be able to supply excess energy to the grid. This house will meet the needs of a typical family of four. The house production cost will not exceed $140,000. Finally, the house will have a photo-voltaic system of a minimum of 4.76 kW.

In establishing our design, multiple options were considered. Initial customer and energy surveys were conducted. By surveying possible customers as well as researching many pre-existing Zero Energy Homes, we were able to brainstorm many ideas for possible inclusions in our design. This research influenced the main concepts of our design. After ranking the customer needs and compiling a selection matrix table, the three layouts were scored according to compliance to the desired specifications. Two of the designs were based on a 1.5 story layout while the other was based on a larger, one story home. Based on the results of the concept scoring exercise, our initial selection will be the one story home design. This home will use a photovoltaic system, a solar heater, an electric geothermal heat pump, and a high R-value insulation.

The construction of the prototype design is accompanied by several risks. The highest risk of this project is the possibility of the ground collapsing during the installation of the geothermal system. This risk will be minimized by utilizing a ground penetrating radar, or GPR

for short. The GPR will analyze the ground quality prior to the drilling and construction of the home. A project plan will be updated every Monday and Wednesday (EDSGN class) to ensure steady progress is being made. Using the Zero Energy Home Calculator, provided by our instructor, the home's predicted budget and energy usage were accurately calculated. The final design will be delivered to our client on August 14th, 2014.

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1.0 Abstract:

Our society has recently taken a large interest in zero energy homes and renewable resources. These homes are self-sustainable and energy efficient due to the utilization of renewable technologies. Common types of energy include solar, geothermal and wind technology. A zero energy home produces as much energy as it uses for a net zero energy consumption. The purpose of our engineering project was to design and construct a physical model of our zero energy home concept. The home is approximately 700 square feet and will retain a cost under 140,000 dollars. The family will be provided with two bedrooms, one bathroom, kitchen, living room, laundry, and a large closet. Developing our house concept was difficult, but we were able to conclude on an exceptional design.

2.0 Introduction:

As our environmental footprint increased, society took a larger interest in renewable energy sources. A zero energy home is a relatively new technology that has the ability to save the planet. Our client has employed us to research and design an efficient zero energy home. We started this task by developing an organized schedule of our project plan. Utilizing the eight step engineering method we designed our house. We continued by researching zero energy technologies, producing sample cost models, and defining the customer’s needs. We designed three houses and compared them with a concept selection matrix. The matrix allowed us to select the most important design features and we selected the best house. Afterwards we began producing virtual and physical models of our zero energy home.

3.0 Mission Statement:

1. Mission Statement:
    a. Zero Energy Home Project
2. Product Description:
    a. Zero energy
    b. Comfortable for occupants
    c. Can suit a family of four
3. Benefit Proposition:
    a. Requires zero energy to be drawn from the electrical grid to operate
4. Key Business Goals:
    a. Decrease operational costs
    b. Make money for occupants
    c. On the market by August 14, 2014
5. Primary Market:
    a. Family looking to have less of a negative impact on the environment
6. Secondary Market:
    a. Family looking to make money off of living in their house
7. Assumptions:
    a. Minimum 4.5 kW PV-System, at least 700 sqf, at least 70 sqf aperture on south wall
8. Stakeholders:
    a. Potential occupants, real estate representatives, legal department, construction company, designing engineers

4.0 Customer Needs Analysis:

When dealing with the customer needs, a few aspects must be taken into account. First, what the customer truly needs is primary. Sometimes though, a specific customer statement is not able to meet at 100% efficiency, so a workable need must be created to address this, even though it will not be perfect. Another aspect to consider is that not all customer statements can be translated into needs. It is important to not make too many needs where they are not required, as this can overcomplicate the entire design process. In the following section, every aspect of the preliminary brainstorming and house design that we performed can be found. Through these operations, we all sifted through various concepts and ideas to streamline our design. This process gave us a few possible house designs which we compared and chose the best out of the group.

4.1 Customer Requirements:

1. Produce enough energy to operate the house for a year.
2. Have extra energy to charge an electric vehicle.
3. Produce excess energy to be able to add to grid.
4. Home is located in and operates efficiently in Pennsylvania.
5. Produce a model of this zero energy home in SolidWorks.
6. ZEH design meets needs of typical family of four.
7. House uses green technologies to be self-sufficient.
8. House is visually stimulating.

9. ZEH will not have a large environmental footprint.
10. House will not deplete nonrenewable resources.

4.2 Hierarchy of Customer Needs:

In order to properly analyze the customer's needs, a table was created to describe the importance of the needs. In this table the data is ranked from 1 to 5. 1 is the lowest and least important need. While 5 represents the highest and most significant needs. The importance factor is based on how relevant it is to completing the mission statement.

Need	**Importance**
Solar Panels on Roof	5
1 Story House	5
Geothermal Heating	5
2 Bedrooms	5
Lots of trees in yard	5
Hardwood Floors	4
Small Wind Turbine	3
Closets for Storage	3
Energy Efficient Lights	3

Good Use of Natural Light	3
2 Bathrooms	3
Fireplace	3
Great Insulation	3
Bright/White Walls	2
Solar Panel in Yard	2
Brick Exterior	2
Composting	2
Large Garden	2
Hybrid Vehicle	2
2 Car Garage	1
Modern Furniture	1
3 Bedrooms	1
Tiled Pane Exterior	1
Made of Wood	1
High Ceilings	1

Stainless Steel Appliances	1
2 Story House	1

4.3 Target Specifications:

Stories	1.5
Square Footage	750
Number of Bedrooms	2
Wall Construction	Double 2x4 10” foam
Ceiling Insulation	R-60
Window Type	Triple Low-E
North Wall area	1064 sqf
East Wall area	619 sqf
South Wall area	1064 sqf
West Wall area	619 sqf
North Window area	144 sqf
East Window area	21 sqf
South Window area	52 sqf

West Window area	0 sqf
Photovoltaic System	4.63
Heat Thermostat Setting	70
Cool thermostat Setting	75

5.0 External Research:

As part of our group's research, we wanted to cover as many aspects of knowledge about zero energy houses as possible. As part of this, we began our research through a homework assignment in class. Our professor asked that each group member research two pre-existing zero energy houses and record many different facts about them. Through this assignment, we each gained some understanding of the principles of zero energy design and what it takes for a house to be considered zero energy. To further our understanding of how these houses were designed, built, and operated, we wanted to expand our research into some literature. Through a few searches on an internet database, we uncovered many great sources to draw information from. Mitchell Leckner performed the same task that we did, but in greater detail. By looking at this example house, we gained an even greater understanding of what goes into a zero energy house to make it have a net zero energy use or less. S. Rosta wrote about a monitoring of two identical homes in Nevada to compare the effectiveness of zero energy houses. From this research, out group gained a vast understanding of what it takes to design, construct and operate a zero energy house. Our research aided us greatly and gave us an understanding of just what goes into building a home that has no electrical operation cost because it is able to supply its own energy.

From our external research, our group learned what we needed to know to be able to design our own zero energy house. In the following sections, records of research that the group did involving existing houses, patents, and renewable energy resources can be found, in addition to other information. This information combined to give us an understanding of just what it would take to fully design our own zero energy house that was both comfortable and effective in reducing the ecological footprint.

5.1 Patent Research:

Currently there are many existing patents for both the design of the zero energy home and the technologies that exist in most of them. One such patent in the last two years developed a new material that more effectively stored thermal energy than previously used materials in zero energy homes (patent number US8091613). Another patent issued a few years ago licensed designed an engine-like mechanism to improve the efficiency of heating in homes relying on thermal energy to serve needs such as water heating (patent number US8224495.) Another patent, patent number US 20120261091 A1, is for an underground pipe system to be installed beneath a low or zero energy home by engineer and physicist Edmond D. Krecke. The system works by storing warm air in the piping during the summer and cold air during the winter. During the summer, the cooler air is released into the house and during the winter the warmer stored air is released into the home to provide an optimal indoor temperature.

5.2 Benchmarking:

As part of our group's benchmarking, we felt that we should learn more about our competition. To us, our competition were the other design groups in our class. We went around and asked

each group a few questions to get a general sense of what their houses would be like. Most groups were using a photovoltaic system as their main source of power. Most also had two bedrooms and were one floor. This was mainly due to the $140,000 cap that was placed on each group. Each group did have slightly different PV system limits, but most seemed to be situated around 4 kW. We also researched existing zero energy homes with the purpose of comparing them to our own design. We wanted to do this to be able to understand the standards for the industry and realize how effective our designs would be.

5.2.1 Existing Structures:

Seattle, Washington

This house in Seattle, Washington is well suited to be a zero energy home for its occupants. It is relatively medium-sized at 1915 sqf and it has a maximum occupation of four people. It has a photovoltaic system of 6.4 kW with R-26 wall insulation and R-42 ceiling insulation. It can get cold in Washington, so the house must be well suited to shield the occupants from the freezing weather. At the end of the year, this house will have made money for the owner, s it produces a surplus of energy that can be returned to the electric company. This house serves as a great example of how a home can be simple, yet still provide comfort to the occupants, all while having a minimal impact on the environment.

Location	Seattle, Washington
House Size	1915 sqf
Number of Floors	2

URL of where Info is Found	http://www.greenbuildingadvisor.com/homes/net-zero-energy-house-125-square-foot
Number of Occupants	4
Number of Bedrooms	3
Type of Heating System	Heat Pump
Main Heating Fuel	Electricity
Size of Photovoltaic System	6.4 kW
Solar Water Heater	No
R-Value of Wall Insulation	R-26
R-value of Ceiling Insulation	R-42
Ventilation Air Heat Recovery	Yes
Predicted Measured Annual Energy Use	6,064 kWh
Any Other Pertinent Info	At the end of the year, there will be a 1,429 kWh surplus.

Holderness, New Hampshire

This house, located in Holderness, New Hampshire, serves as another great example of standard zero energy home design. This house has a greater square footage than the previous one, but it is only one floor. It can get extremely cold in New Hampshire, so the house must be well equipped to deal with the harsh temperatures. This house has a water furnace as well as a woodstove. Wood Stoves are extremely efficient and can heat a room very well, but they require a large amount of wood to burn before it can do such things. This house can fit a maximum of four occupants and has a 7.5 kW photovoltaic system. This house also has R-52 wall insulation and R-73 ceiling insulation. This zero energy house is a perfect example of how a smaller house can still provide the necessities to all of its occupants while having a small impact on the environment due to its net zero energy use.

Location	Holderness, New Hampshire

House Size	3400 sqf
Number of Floors	1
URL of where Info is Found	http://www.greenbuildingadvisor.com/homes/true-net-zero-gut-rehab-new-england-style
Number of Occupants	4
Number of Bedrooms	3
Type of Heating System	Heat Pump
Main Heating Fuel	Water Furnace supplemented by a Woodstove
Size of Photovoltaic System	7.5 kW
Solar Water Heater	Yes
R-Value of Wall Insulation	R-52
R-value of Ceiling Insulation	R-73
Ventilation Air Heat Recovery	No
Predicted Measured Annual Energy Use	5,068 kWh
Any Other Pertinent Info	None

5.2.2 Existing Renewable Energy Sources:

http://www.greenchoices.org/green-living/energy/greener-and-cheaper-ways-to-heat-your-home

Geothermal heat pumps can be used to heat a home by harnessing natural sources of heat from the Earth. These pumps fluxuate the pressure of a coolant inside the pipes to heat or cool the surrounding air. A well is needed for geothermal heating and they are powered by electricity so this type of heating has a large cost not only to install but also to keep running. On the plus side though, geothermal heat pumps are very efficient and have fewer emissions into the environment. Biomass boilers can be used to heat a home by burning biomass pellets that are made of plant waste material which is a renewable resource. When burned, the biomass emits only the amount of carbon dioxide that it absorbed during growth. Biomass material can also be mixed with some fossil fuels that are used in home to cut down on the carbon monoxide emissions. Passive solar water heaters are also available, but are not effective water heaters by themselves because they rely heavily on how much direct sunlight they receive. The most common source of electricity for zero energy homes is a photovoltaic system, which works in conjunction with solar panels to power the home on the sun's energy. Currently solar energy accounts for less than one percent of

all electricity generated in the US. That is because of the overwhelming cost of the photovoltaic arrays. Along with the cost, today's solar panel are not as efficient as they could be so the return on the initial investment would take a long time. Although, solar panels are the way to go if used in a place where there are long daylight hours and at a high solar angle. Wind power is becoming an increasingly popular option for renewable energy in the US. The wind energy collected today is around one percent of the total energy produced, but has a promising future to expand on that number. Wind energy is harnessed by a large turbine with either two or three blades, high off of the ground. The optimal place for these turbines are in areas with fast winds and low turbulence. There are some setbacks of wind energy though one is the environmental impact they are having. Some species of migratory birds and bats are flying into the turbines and dying but studies have proven that this number is still far fewer than the number that fly into buildings. Another issue is the noise the turbines make but through world class engineering that noise has been greatly reduced. The most common source of renewable energy in the US today is hydropower, which makes up seven percent of the energy produced. Hydropower uses water to generate electricity. Dams are formed on rivers to store water than the water is allowed to flow out at a controlled rate to turn a turbine which in turn spins a generator to produce electricity. Small, or better known as micro-hydroelectric power systems, can be used to power entire homes and farms. The downside is that the hydropower systems are limited to areas with water sources and most of the time these areas conflict with recreational, tourism, industry, and human developments. Also the dams built on the rivers can alter fish migration and cause flooding upstream. There are solutions though such as fish ladders and the dams can control destructive flooding downstream. Not only does this system produce large amounts of electricity it is also one of the least expensive. Although any of these technologies can be used to power, heat, or cool the home most zero energy homes

require a lot of insulation and windows in order to use the least amount of energy. Having a lot of windows is important because if angled correctly they can allow a relatively large amount of sunlight to enter the house and passively heat it. Thick insulation is useful in keeping heat or air conditioning within the home so less energy is used to maintain the internal temperature of the house. Another mechanism that can be used to make a home consume less energy is an electric heat pump. Unlike an air conditioning unit an electric heat pump transfers heat in and outside of a house instead of using energy to heat or cool a home as air conditioners and heaters use. According to the U.S. Department of Energy, a heat pump uses about a quarter of the amount of energy an air conditioning unit uses. This product works best when paired with another technology that regulates the heating of a building such as a solar collector, according to the inventor.

http://energy.gov/energysaver/articles/heat-pump-systems

http://www.google.com/patents/US20120261091

www.nationalatlas.gov/articles/people/a_energy.html

5.3 Production Dissection:

There are eighteen solar panels on the roof of our home. These solar panels amount to a 4.76 Photovoltaic system. The energy captured by the solar panels will be put to use in the house and excess will be sent back to the grid. Direct sunlight is collected with the solar panels; but with the home's aperture, on the south wall, passive sunlight will also be put to use. Passive solar heat is utilized by having a large aperture that allows vast amounts of sunlight to enter the home. Then the sunlight hits and heats a slab on the floor of the home that will absorb heat in the day and give it off at night. The house will be heated and cooled with a geothermal system that runs

in a vertical loop. A vertical loop will be used because it is easier to install on small parcels of land, much like what our home is on.

5.4 Global Marketplace

The US is currently ahead of the competition when it comes to zero energy home production. Although with the cost of solar panels lowering every day, more and more zero energy homes can start popping up all over the world. Eventually the type of house we are designing can be mass produced because it not only accommodates a family of four it also is small enough to be built quickly and shipped. If these homes are massed produced they will become available to some of the poor countries such as Zimbabwe. Zimbabwe was the example because they cannot currently afford zero energy homes but they have the ideal setting for max sun absorption. Zero energy homes in poor countries can not only increase the way of living for most of the people, the excess energy can be sold to neighboring countries. The US should invest in more zero energy home research so that we can be the country that sparks the revolution, not to mention the possibility of a high return on that investment to help with our large debt.

5.5 The Effect of Location:

The golden rule of real estate is location. The location of a zero energy home determines how affective the home will be at producing energy. An example is a home in a southwestern state where there is plenty of sunlight and few tall trees would produce more solar energy than a home in the backwoods of a northeastern state where there is not as much sunlight and many tall trees that shade homes. Some areas even in colder places such as Pennsylvania sit on geothermal “hot spots” which may require the home to use less energy. Areas with high amounts of snowfall are

not ideal for the use of solar panels because the snow will collect on the panels and need to be continually cleaned off. Zero energy homes in moderate climates of Europe use very thick insulation. This would work for a zero energy home in Pennsylvania since it has a similar climate to this region of Europe. Additionally, the windows of one such home in Brussels were designed so its windows were able to take in as much sunlight as possible. New windows were a common addition to buildings converted to zero energy homes to improve insulation. A home in Midland used solar panel shingles and Styrofoam brand insulation- a thick variety of home insulation.

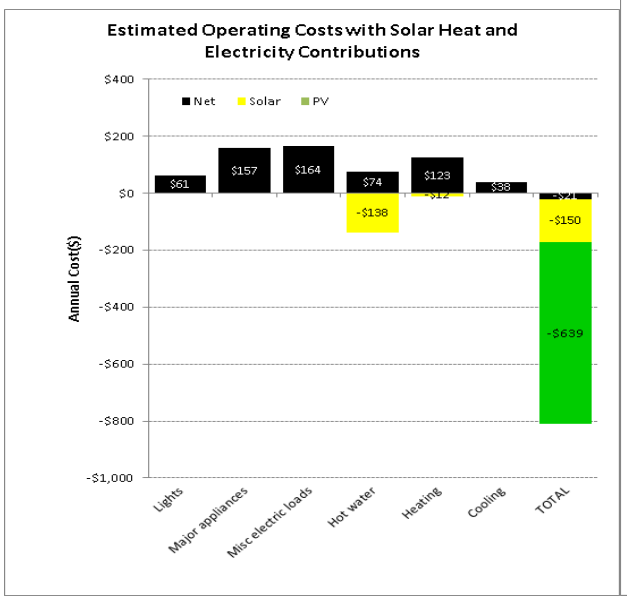
http://www.powerhouseeurope.eu/nearly_zero_taskforces/nzeb_in_coldcontinental_climates/key_resources_and_outputs/

http://www.mlive.com/business/mid-michigan/index.ssf/2011/07/a_real_power_house_but_is_midl.htm

6.0 Concept Generation:

To generate concepts our team split into groups of two and used the zero energy home calculator to design three possible homes.

6.1 Concepts:


Estimated Operating Costs with Solar Heat and Electricity Contributions
Net
Solar
PV
Annual Cost($)
$400
$200
$0
-$200
-$400
-$600
-$800
-$1,000
$61
$157
$164
$74
-$138
$123
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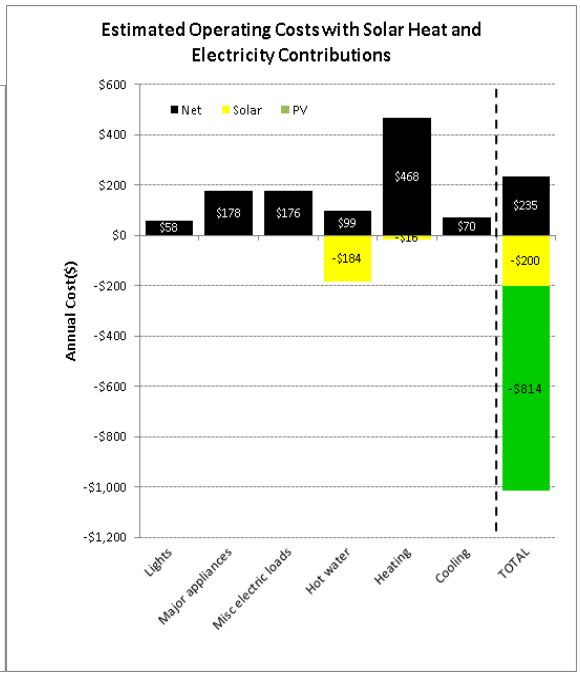
-$150
-$639
Lights
Major appliances
Misc electric loads
Hot water
Heating
Cooling
TOTAL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PV
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-$200
-$400
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$178
$176
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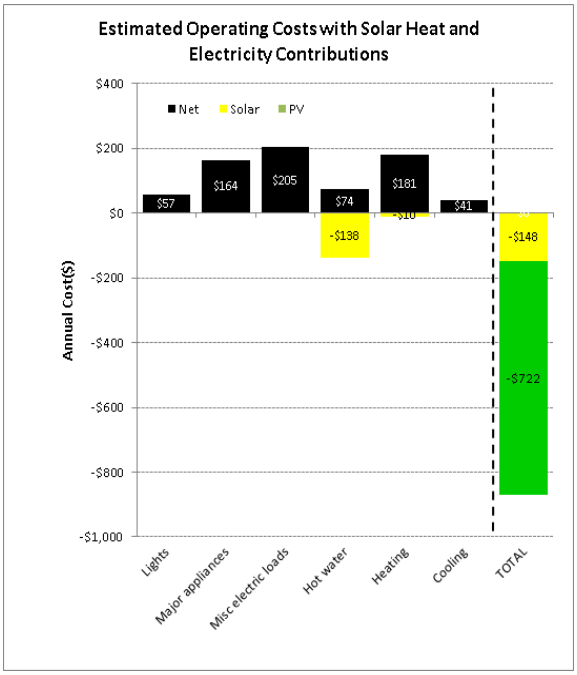
-$814
Lights
Major appliances
Misc electric loads
Hot water
Heating
Cooling
TOTAL


Estimated Operating Costs with Solar Heat and Electricity Contributions
Net
Solar
PV
Annual Cost($)
$400
$200
$0
-$200
-$400
-$600
-$800
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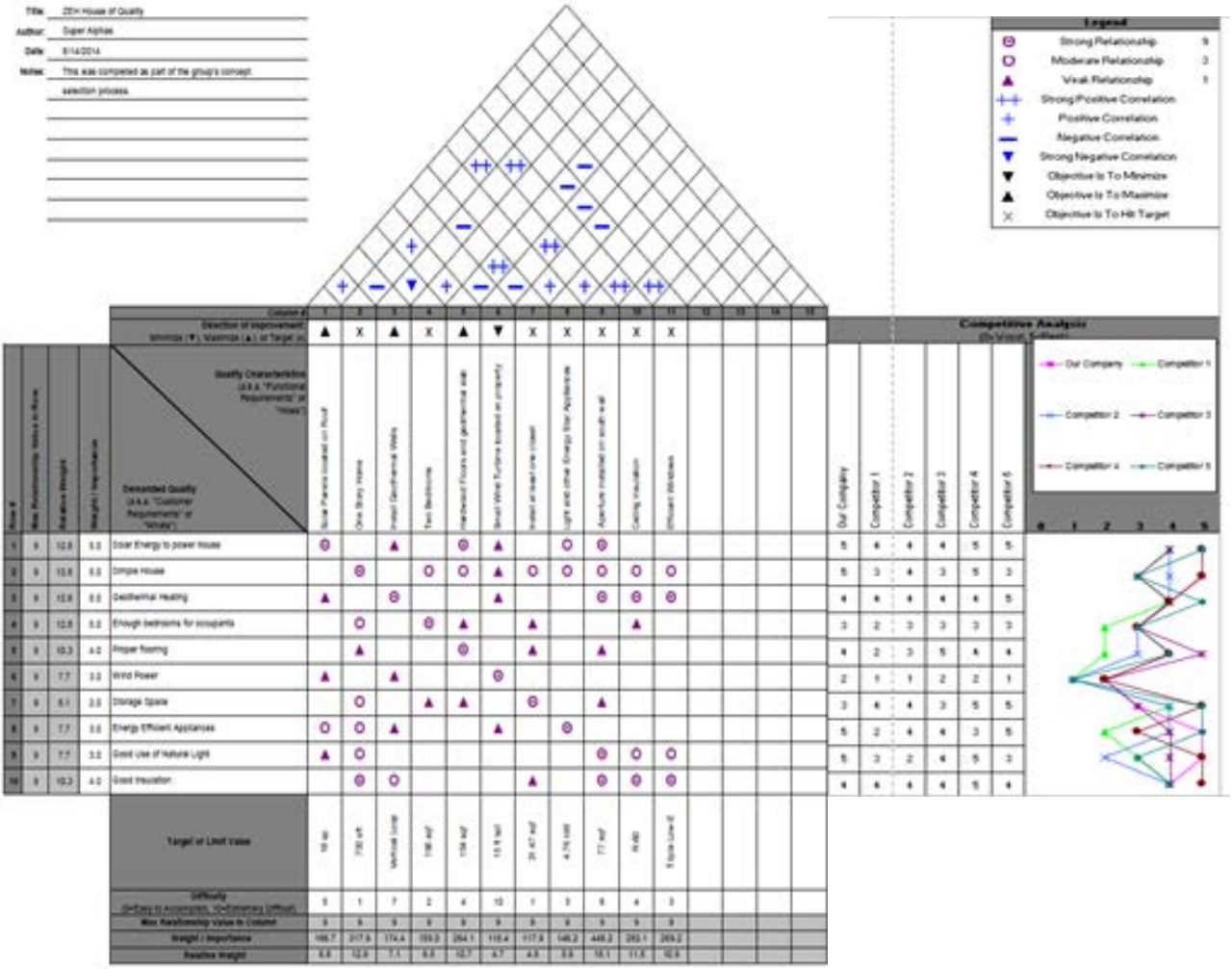
$57
$164
$205
$74
-$138
$181
$41
-$148
-$722
Lights
Major appliances
Misc electric loads
Hot water
Heating
Cooling
TOTAL

7.0 Concept Selection:

We brought all of our needs and metrics together in a house of quality and then chose what to keep in the house.

7.1 House of Quality:



7.2 Concept Screening/Scoring:

As a group we used concept scoring to determine which potential features in our zero energy home were more important than others. Higher numbers for certain aspects to be included in the home denote what our group believe to more important concepts than others. For example, in our concept scoring we gave the concept of having solar panels on a score of five and the concept of having three bedrooms in our home a one, because solar panels on our home is a critical factor out home needs in order to generate as much energy from renewable sources as it takes from the grid. Meanwhile, having three bedrooms in our home received a score of one because having four bedrooms would indicate the house would have to be quite large and exceed our price limit of 140,000 dollars. Additionally, it require much more energy to power than our current design and have a larger environmental impact on our earth making the home relatively counterproductive to our goal. Hence, in our final design solar panels will be included in our home and instead of having four bedrooms in the home it will contain only two for the previously listed reasons. Another design quality we specified as a score of three was having a three bedroom home, since we felt this would best suit a family of four. However, although it was deemed as important, we reduced this design to two bedrooms in our final home since a three bedroom home was not a feasible design in a home of only 700 square feet. This is ultimately why we rated having two bedrooms in our home a five in the concept scoring as we foresaw this issue early on in the design process. Although we could have made the home larger to include an additional bedroom, a larger home design would have exceed our budget. Including geothermal heating in our home design was another design quality that received a score of five for a few reasons. First, geothermal heating is a very effective method to heat a home because no matter what time of year it is the ground temperature at which the geothermal system is located does not go below

fifty degrees fahrenheit. This makes it a better choice than a larger photovoltaic or passive solar heating methods because it is more efficient statistically in the energy it converts to power a home, but is also cheaper than installing a significantly larger photovoltaic on our home. This design quality will be included in our final design for these reasons. One design quality we rated a one for several reasons and did not include in our final design was making our zero energy home a two story house. We ultimately decided to construct a one story zero energy home mainly for aesthetic reasons. This was the cause because our kitchen and living room were connected; creating the only large, open space in the home while all other rooms contain doors (such as the closets and bedrooms). Hence, constructing an upstairs would have required two much smaller floors which would have ultimately led to one floor containing several closed off rooms (bedrooms and closets) with no room for even a small hallway. As a group, we thought this would be inconvenient for the family living there and detract from the interior's aesthetic quality. Another design quality that our group rated a two in our concept scoring process but did include in our final home design was constructing a large garden the future homeowner's property. The only design quality our group gave a scoring of four to will be included in our final zero energy home design is including hardwood floors in the interior. Along with the nice aesthetic quality of hardwood flooring as a group we felt it would be unethical to include flooring containing toxic plastic synthetics, such as phalates, because the manufacturing of these materials is harmful to workers and when replaced could have much more negative impacts on the environment than cutting down a few trees when disposed of. One design we rated a three, which still denotes the feature as important, was installing a small wind turbine on the home's roof to further reduce the amount of electricity the home used from the grid. However, due to the size of our photovoltaic, geothermal system, and insulation our home already produces more energy than it uses meaning

our home could actually put its excess energy back into the grid at the homeowner's profit. Additionally, we did not have the funding to include a wind turbine on the home after all other costs were accounted for in our design of the home. Another design we scored at a three in our concept scoring was including several closets in the home for storage. As a group we decided to include three closets in the final design of our home as our zero energy home does not have a basement that can be used as storage. Another design we rated as a three in our concept scoring was making all light in our home energy efficient light bulbs. While we did not believe they were a vital quality for our home since much of the energy in our home since the energy the home uses comes from renewable energy sources; our team did include these lights because they are cost effective and were just one more way we could reach our goal by making our home use less energy. Another design we rated a three during our concept scoring was making our zero energy home's interior very accessible to natural light. We did include this in our final design by creating a few very large windows in our home and a few smaller windows because with proper orientation and an appropriate roof overhang these can contribute a minimal amount of passive solar heating for the home during winter months. One design as a group we felt would be both feasible and necessary for our zero energy home was designing it to have three bathrooms to best fit a family of four's needs. However, when designing the layout of our home, we realized that a 700 square foot one story home with two bedrooms had only enough space for one bathroom. Hence, our final zero energy home design will include only one bathroom. In terms of heating our home in the winter, since it is located in Philadelphia, Pennsylvania, our group originally decided to include a fireplace within the home given a score of three. However, after analyzing the amount of energy the home could produce and use according to the ZEH calculator we decided a fireplace would not be necessary for heating of the home in winter months. This was

the case largely because as a group we decided to install a geothermal heat pump that will partially heat the home. Additionally, a very minor drawback to installing a fireplace in the home would detract to its already snug 700 square feet. Another feature our group rated a three and ultimately decided to include in our final design was having high quality insulation for our home's walls and ceiling. The ceiling of home will have a very high insulation value of R-60 and the walls are also well insulated with double two by four ten inch thick foam. A few design options our team may have a positive effect on the home's appearance but did not include because the family living there could easily do was to make the walls a light tan color and to include modern furniture in the home. Another product we chose not to include with the home was a hybrid vehicle for cost reasons. When designing the home our team thought it would it would be a nice item to include with the home as the family living in the home we designed will likely be looking to reduce their impact on the environment in more ways than just living in a zero energy home. Adding a hybrid vehicle with the home was scored a two in the concept scoring process. In terms of the home's exterior we chose using brick, originally scored at two, over a tiled pane exterior scored at a one in the concept scoring process. Our group chose brick over tiled pane because tiled pane could be made of plastic synthetics that contain toxins that can harm the environment during extended use while brick does not. Another concept our team considered including with the home's construction was a compost area. We rated this a two because it would lessen the home's inhabitant's environmental impact and most likely reflects their lifestyle. However, our team ultimately decided not to include a compost because it is the family living in the zero energy home's decision to compost or not and if they choose to do so a compost can easily be constructed on their property at a later time. One design feature our team did not include in our design was constructing high ceilings on the home. This was given a

concept score of one because to our team it was nothing more than a visual preference and could not be constructed in the shape of a traditional roof. Another design feature our team concept scored a one but ultimately decided to include was to construct the home out of wood since it is a relatively cheap and strong material most traditional homes are constructed from and the zero energy home our team designed can easily be constructed as any other traditional American home. A design feature our group concept scored a one and did not include was an attached two car garage. We decided not to include a built in two car garage in the final design because it would have severely limited the family's already small living quarters. On final product our team did not include in the home were stainless steel appliances, which were given a concept score of one simply for their appearance. These were replace with energy star appliances to reduce the home's energy usage which are likely available in stainless steel.

8.0 Design:

This zero energy home will be one stories with one bathrooms, two bedrooms, a kitchen, living room, three closets throughout the house, a laundry room, and contain the necessary appliances in all of these rooms. There will be very little maintenance needed to keep this house up and running. Solar panel are usually under warranty for up to thirty years and that is when they need replaced. The only real maintenance would be to replace the batteries on the photovoltaic system. These batteries need replaced periodically every five to six years but most of the time are included in the warranty. Also the panels will need to be cleaned continually because if left uncleansed the degrading factor, already at one to two percent depending on climatic conditions, will increase.

http://bostonsolar.us/boston-solar-energy-blog/bid/68011/Solar-panels-lifetime-productivity-and-maintenance-costs

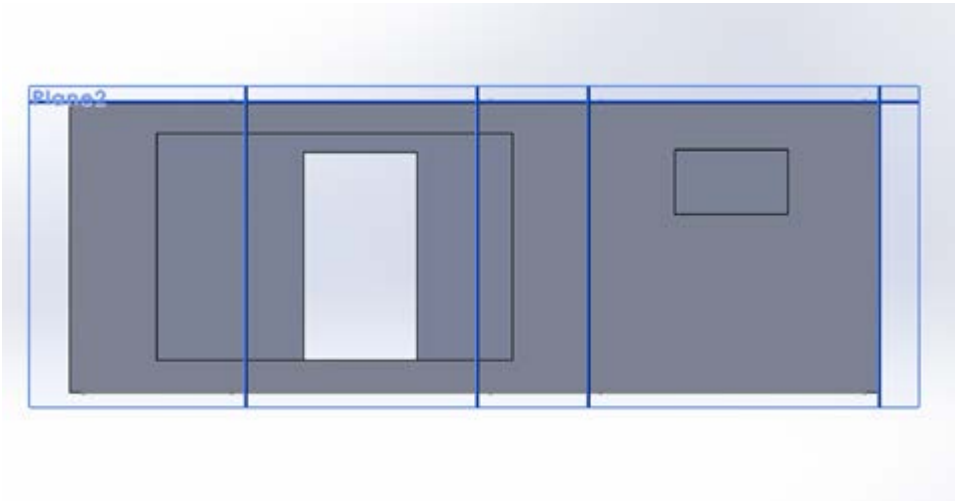
8.1 Final Specifications:

Stories	1
Square Footage	700
Number of Bedrooms	2
Wall Construction	Double 2x4 5” Foam
Ceiling Insulation	R-60
Window Type	Triple Low-E
North Wall area	183 sqf
East Wall area	210 sqf
South Wall area	141 sqf
West Wall area	212 sqf
North Window area	17.5 sqf
East Window area	42 sqf
South Window area	84 sqf

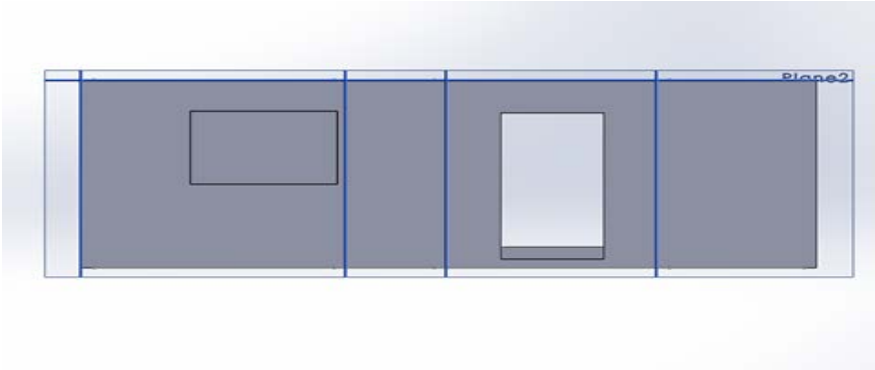
West Window area	40 sqf
Photovoltaic System	4.76
Heat Thermostat Setting	65
Cool thermostat Setting	77

8.2 Final Design:

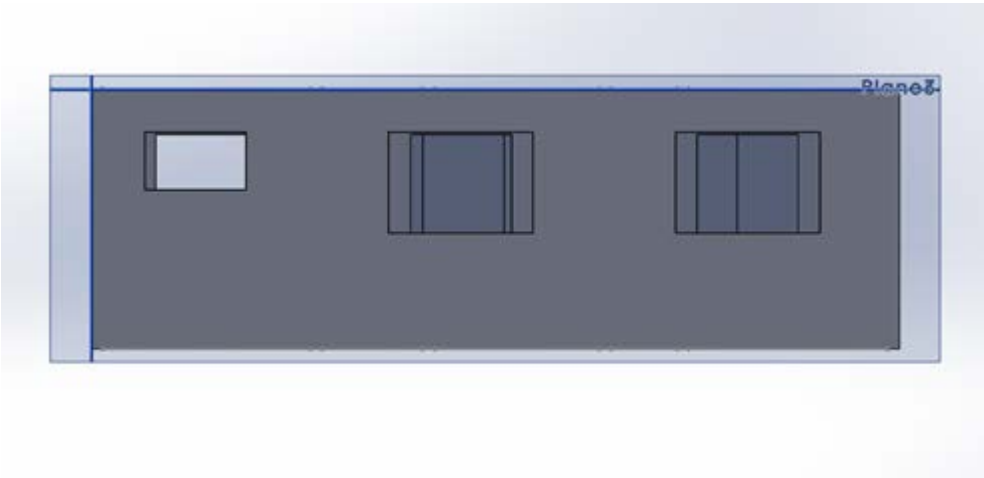
South Wall:



North Wall:

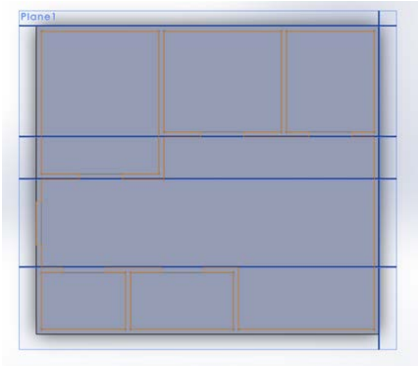


East Wall:

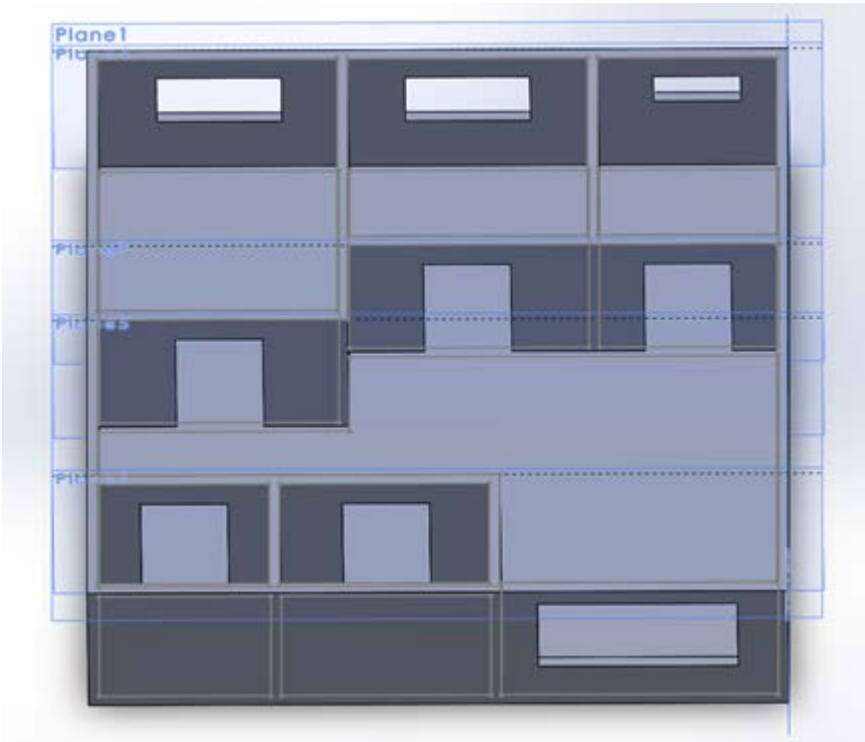


West Wall:

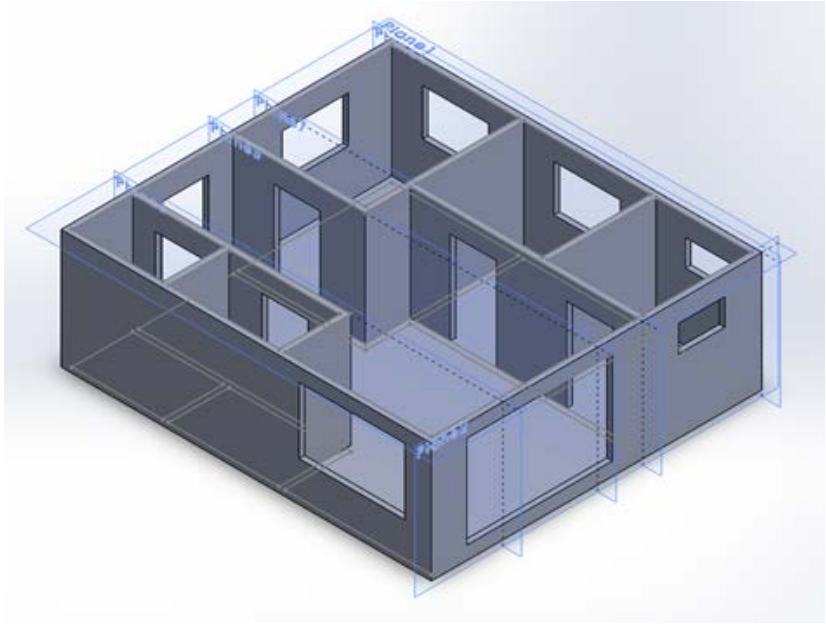
Top View:



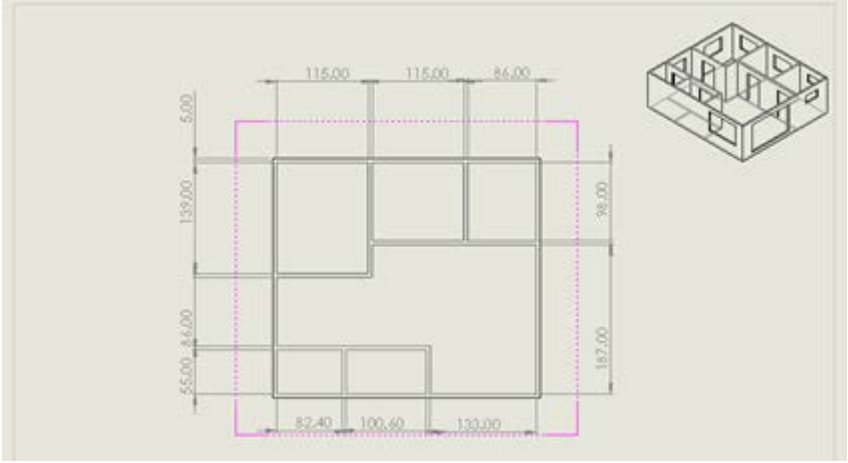
Top View 2:



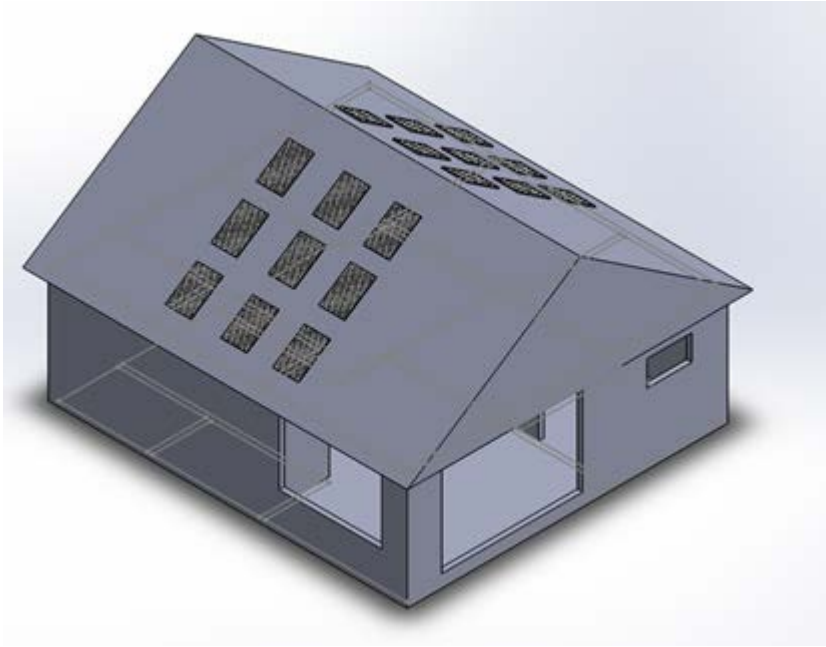
Isometric:



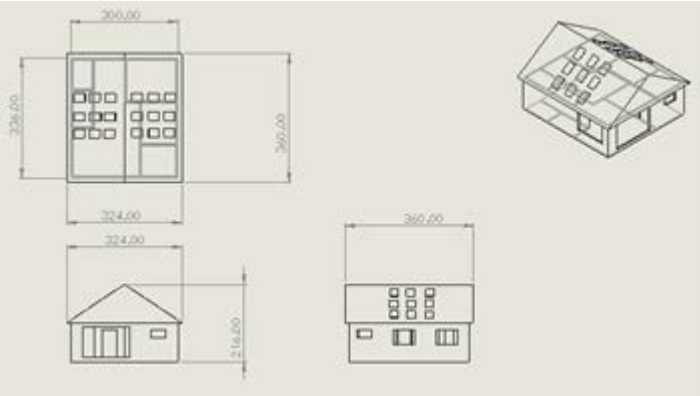
Drawing without Roof:



Isometric with Roof:



Drawing with Roof:



9.0 Conclusions:

Coming into Engineering Design 100, only a few of the group members had had some experience learning about the environment. The first few days of class we began learning about different aspects of our impact as a society on the environment. We discussed different energy sources and how they can reduce our ecological footprint. Since our project was about designing a zero energy home, we learned a large amount about just how to reduce this footprint on the environment through building a house that creates as much, if not more, energy that it needs to operate. A house like this greatly reduces the ecological footprint left behind by the owners.

From the beginning of the project, the group knew that we had to create a simple house. Our budget was only $140,000, so we had to sacrifice many amenities to create a decent enough house to handle a family of four. We decided to create a one-story, 700 square foot house, as this would be a relatively easy home to outfit to be zero energy. We did research on different aspects of zero energy homes, and picked what aspects we thought would best fulfill our vision. We analyzed the customer statements and converted them into needs, then matched them with a value to create metrics. These metrics became a pillar of our progression on the project. We then performed research into things like pre-existing homes and patents on any technology we were considering using for our design. We also investigated what the other groups were doing, as we performed benchmarking to analyze the thought processes of our competitors.

After the preliminary research was completed, the group moved on to the concept selection stage. We analyzed each idea we had created for our house and decided how important we felt each was. We also investigated the correlations between the customer needs and metrics, as well as

each metric to each other, through a House of Quality. This House of Quality gave the group a great visual to use when deciding what to include in our house. This template we used earlier in the class, gave the group the specifications of our house. Once we all settled and agreed on specifications, the group constructed a 3D model of our intended design in SolidWorks. This model included spaces for rooms, as well as a door and windows. The group put emphasis on the aperture, the large window that would allow for the natural heating of the house through the use of sunlight. We then began construction on a physical model, made of cardboard. The cardboard model was decorated with spray paint to allow for some creativity among the group members. This model was constructed on a scale of one foot = ⅛ inch.

Throughout the course of this project, we have gained a large understanding of many aspects of environmental conservation. A zero energy home is a great way to reduce one's ecological footprint as it reduces the amount of resources used from the environment greatly. It provides a house that utilized renewable energy sources to power itself. It is ideas like these that will save our planet for future generations. From geothermal wells to solar heat pumps, we learned so much about different ways to get power without a negative impact. We, as future engineers, will take this knowledge with us to help the environment and all who utilize it.

10.0 References:

The following are references that we used to gain a greater understanding of all aspects of the project. We used both literature and websites to aid in our research and give us the information we needed to complete this project.

10.1 Literature:

Life cycle cost and energy analysis of a Net Zero Energy House with solar combisystem

Leckner, Mitchell (Centre for Building Studies, Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, QC, H3G 1M8, Canada); Zmeureanu, Radu **Source:** *Applied Energy*, v 88, n 1, p 232-241, January 2011

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Rosta, S. (UNLV Center for Energy Research, Las Vegas, NV 89154); Hurt, R.; Boehm, R.; Hale, M.J. **Source:** *International Solar Energy Conference*, v 2006, 2006,*Proceedings of the ASME International Solar Energy Conference - Solar Engineering 2006*

10.2 Websites:

http://www.greenchoices.org/green-living/energy/greener-and-cheaper-ways-to-heat-your-home

http://energy.gov/energysaver/articles/heat-pump-systems

http://www.google.com/patents/US20120261091

www.nationalatlas.gov/articles/people/a_energy.html

http://www.powerhouseeurope.eu/nearly_zero_taskforces/nzeb_in_coldcontinental_climates/key_resources_and_outputs/

http://www.mlive.com/business/mid-michigan/index.ssf/2011/07/a_real_power_house_but_is_midl.htm

http://bostonsolar.us/boston-solar-energy-blog/bid/68011/Solar-panels-lifetime-productivity-and-maintenance-costs