Zero Energy Home

Introduction to Engineering Design

Section 018

EDesign100

Design Project #1

Report

The Allegiant

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Executive Summary

Our Engineering Design team, The Allegiant, is designing a Zero Energy Home under a $160,000 budget. The goal is to create and design a sustainable house that uses zero energy while being cost efficient now and continues to be efficient in the future. Our goal is to create a better quality of life for a family of four while using energy efficient building materials, energy efficient appliances, low cost building techniques, as well as the use of solar panels and geothermal heating and cooling systems. This home will not have any electricity bills leaving the family with money to spend on important items, such as food, that will result with them being satisfied along with having better nutrition.

Zero Energy Home

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1.0 Introduction

Our Engineering Design team is working together to create a Zero Energy Home for a family of four, in Pottsville, Pennsylvania. This family is living with scare resources and is living at the poverty level. Combining many methods of home power and heating with the location, we found that using Pottsville as the location, the cost of building the home is cheaper. Energy is an expensive necessity for home power to nowadays and continues to become more expensive. The goal is to create a Zero Energy Home under a budget that eliminates the extra expenses of power. This will ensure that the family will not have to invest more money than what is necessary to sustain the house while having a better living environment. We also have to create a house that is sustainable. Sustainability is defined as using a method that will not destroy resources and will last a lifetime. To be sustainable, the creation of a Zero Energy Home should not be harmful to the environment or its surroundings. In order to accomplish a sustained home we chose products that will not harm the environment by releasing toxins into the air or creating hazardous waste. We will analyze all materials that we will use in creating the home to make sure that they were in fact sustainable. In this report we will discuss the energy efficient materials that aid in powering the home without the use of conventional public electricity. We then will discuss the energy and cost efficient appliances we decided to put in the house. Adding to our discussion, we will also explain the energy efficient architectural shape of our house that is cost effective as well as regulates temperatures. Finally, we will discuss the alternatives for energy that we used in creating our home. In our conclusion we will discuss and evaluate how well we effectively accomplished our goal.

2.0 Mission Statement

We have been prompted to create and design a Zero Energy Home that is cost efficient for a family of four with a $160,000 budget. Our goal is to give this family a better suitable living environment that will not only benefit them in the long run both financially and health wise, but to also ensure they sustain a happy and fulfilled life. We will make sure to design this home in the highest quality to ensure this family does not have to pay countless bills like they do now.

3.0 Customer Needs Analysis

In our mission statement we addressed our goal of creating a Zero Energy Home. In order to create this home that satisfied the customer's needs, we needed to analyze what was most important to the customer while being energy efficient and staying under the budget. This home had to be energy efficient while being appealing to the customer. In order to do so, we first extracted the design and the appliances needed to create a home. After we analyzed and extracted the products, we finally produced a design that would not only appeal to the customer, but would also be energy and cost efficient.

3.1 Hierarchy of Customer Needs

In order to analyze the customer's needs, we needed to create a list of all the appliances and qualities one looks for in their home. After we created this list, we ranked the appliances and qualities in order of importance from 1 to 5, with 5 being the most important. The importance factor is based on how much the customer actually needs the appliance relative to how much they actually want the appliance. This list is shown in Table 1.

Table 1- Hierarchy of Customer Needs

Need	**Importance**
Sustainable in Pennsylvania	5
Self-Sustainable Energy	5
Uses Renewable Resources	5
Affordable	5
Attractive Design	3
Comfortable	5
At least 2 Bedrooms	5
Laundry Room	4
Utility Room	5
Kitchen	5
Appliances	5
Living Room	4
Insulated Windows	5
Big Television	2
Furniture	5
Landscape uses Passive Energy	3
Trees	3
Fireplace	2

Table 2- Needs Metric Matrix Chart

Need	Matrix	Voltage (v)	Energy Efficient	Energy Star Appliances	Water Consumption	Energy Consumption (kWh/yr)	Feet(ft)	Weight(lbs)	Flow Rate(GPM)	Savings	Yearly Operating Cost
Sustainable in Pennsylvania			x							x	
Self-Sustainable Energy			x							x	
Uses Renewable Resources			x							x	
Affordable			x							x	
Attractive Design			x				x				
Comfortable							x				
At least 2 Bedrooms							x				
Laundry Room			x	x	x	x	x		x		x
Utility Room		x	x	x			x				
Appliances		x	x	x	x	x	x	x	x	x	x
Kitchen				x		x	x		x	x	
Living Room						x	x				
Insulated Windows			x							x	
Big Television			x	x		x		x			
Furniture							x				
Landscape uses passive energy			x							x	
Trees			x							x	
Fireplace							x				x

4.0 External Research

Using our mission statement, we found in order to create a Zero Energy Home we needed to research important matters that would help us acquire our goal. We needed to research which appliances were energy efficient, what zero energy methods would allow the family to power the appliances, and what low cost design would benefit the method. We also researched design techniques and material that would help regulate the temperature on the inside. Lastly, we needed to research which location we wanted to build our house in. Researching these matters we grasped a better understanding of the products and their importance to our home.

4.1 Patent Research

While researching existing Zero Energy Homes, we also investigated patents that had been published relating to Zero Energy Homes or ZEH. The first patent that our research revealed was a Net Zero Energy Building System (US 20110253126 A1) and it was invented by Huiming Yin and Chen C. Julian. They gave a quick summary of what a ZEH was and the goals of a ZEH. They defined a ZEH as a building that consumes less energy than current buildings, with the ultimate goal of having a net energy consumption of zero. This was the goal of our project; we worked to build a ZEH that produced all the power it would need to sustain itself.

Their “net zero energy building system” included solar heating, power and energy storage systems. The four components they focused on for these energy storage systems were roofing panels, electricity generators, an insulated fluid storage tank, and a fluid circulation system that would connect everything together. They had very similar goals, a few being durability, thermal efficiency, sound absorption, and moisture migration. Another patent that we came across was for a low-energy building specifically a ZEH (US 20120261091 A1). This patent was invented by Edmond D. Krecke. His main goal was to aid a ZEH by inventing an alia pipe-in-pipe conduits system. This is basically a system of piping that is run underneath the house and through the walls. It was designed to help the ZEH become more self-sufficient in the area of heating and cooling. However, after further research we came to the conclusion that although our end goals were related to the two patents above we were not in violation of their patents. Our ideas are unique and of our own creation. We researched to learn about ZEHs, how to build one and what to buy in order to obtain our goal, but our design and choices were not based solely off of one house. Nor did we claim to invent our own idea within our design process; we have research to substantiate this entire report.

4.2 Benchmarking

During the benchmarking process we compared our Zero Energy Home to other homes already existing in Pennsylvania. During this process we found what our house is lacking and what we need to improve on. We also found that our house has some stronger points compared to others. In Table 3, the location and picture of the Zero Energy Homes are displayed. In Table 4, different features are being compared between the three energy homes. There are many similarities, but also differences as well. The State College Zero Energy Home found many resources to use inside their home while using four different types of systems, showing to be the most diverse home.

Table 3- Zero Energy Homes in the Benchmarking Process

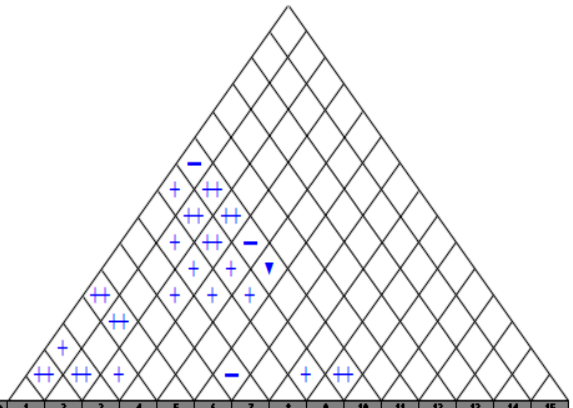
1820 Merriman Way, Pittsburgh	**MorningStar, State College**	**O’Neil Home, Perkiomenville**

Table 4- Benchmarking

Features	1820 Merriman Way, Pittsburgh	Morning Star, State College	O'Neil Home, Perkiomenville
Square Feet	1,800 sq. ft	1,000 sq. ft	2016 sq. ft
Building type	Residential Single Family 2 bedrooms	Competition home Single Family 2 bedrooms	Residential Single Family
PV Panels (photovoltaic)	5.25 kW	5.1 kW	5.25 kW
Green Roof	No	Yes, uses plants in order to reduce heat off the roof.	No
Flooring	Harvested bamboo Stained Concrete Ceramic floors Carpet	Hardwood	Stained Concrete Site-harvested wood floors
Interior	Slide doors Quartz countertops	Thermal Blinds Milk bottle wall Moveable wall	Site-harvested wood vanity, stairs, flooring, and trim Energy Star appliances
Exterior	White reflective roof Overhang Strategic tree placement Insulated Panels Argon-filled and clad wood windows	Exterior Sliding Panels (ESPs) Argon-filled windows Insulated panels Southern Overhang	Insulated Panels Fiber Cement Siding Shingle Roof Clad wood Energy Star windows
Systems	Solar Geothermal	Solar Wind Geothermal Hydrogen	Solar Geothermal
Lighting	LED	DC-LED, Solar Slates, full height vision glass, radio-based lighting control system	Energy Star
Heating and Cooling Systems	Passive Solar, natural ventilation,	Passive Solar, radiant floor, ground source heat pump, natural ventilation	Passive Solar, natural ventilation, radiant floor, Geoexchange

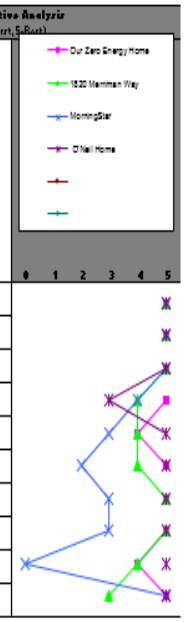
4.2.1 House of Quality

The purpose of a House of Quality is to turn customer needs into targets that should be met in the final design. In order to do this, we first looked at the relationship between the customer needs and the technical requirement and decided if they have a weak or strong relationship. Above the technical requirements we had to decide which requirements should be minimized or maximized to hit the target. The “roof” is a comparison of the technical requirements and if they have a positive or negative correlation with one another. We then compared our customer needs to prior competition from 4.1. Lastly, we found a target value for each requirement. The House of Quality is a way to plan and communicate concepts as well as designs. This type of benchmarking is also a way to identify any parts that need to change.



Legend		
θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Columns #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Competitive Analysis (0-Worst, 5-Best)					
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	X	▲	▼	▼	X	▼	▼	X	▼											
				Quality Characteristics (a.k.a. "Functional Requirements" or "How") / Demanded Quality (a.k.a. "Customer Requirements" or "What's")	Voltage (V)	Energy Efficient	Energy Star Appliances	Water Consumption	Energy Consumption (kWh/yr)	Feet (ft)	Weight (lbs)	Flow Rate (GPM)	Savings ($)	Yearly Operating Cost						Our Zero Energy Home	1520 Merriman Way	MorningStar	O'Neil Home		
1	9	11.6	5.0	Sustainable in Pennsylvania		θ							θ							5	5	5	5		
2	9	11.6	5.0	Self-Sustainable Energy		θ							θ							5	5	5	5		
3	9	11.6	5.0	Uses Renewable Resources		θ							θ							5	5	5	5		
4	9	11.6	5.0	Affordable		θ	▲			θ			θ							5	4	4	3		
5	9	7.0	3.0	Attractive Design		O				θ										4	4	3	5		
6	9	11.6	5.0	Utility Room	θ	θ	O			O			O							5	4	2	5		
7	9	11.6	5.0	Appliances	▲	θ	θ	O	O	▲	O	O	O	θ						5	5	3	5		
8	9	11.6	5.0	Kitchen	O	O	θ	▲	θ	O		O	▲							5	5	3	5		
9	3	4.7	2.0	Big Television		O	O		O		O									4	4	0	5		
10	9	7.0	3.0	Landscape uses passive energy		θ							θ							5	3	5	5		
				Target or Limit Value	Low	0 Energy	7	4.58 Gallons/min	848 (kWh/yr)	1425 sq. ft	7.48 (lbs)	5.15 (GPM)	70%	$80											
				Difficulty (0-Easy to Accomplish, 10-Extremely	2	5	4	8	8	5	8	7	6	6											
				Max Relationship Value in Column	9	9	9	3	9	9	3	3	9	9											
				Weight / Importance	151.2	760.5	269.8	46.5	153.5	248.8	48.8	69.8	493.0	104.7											
				Relative Weight	6.4	32.4	11.5	2.0	6.5	10.6	2.1	3.0	21.0	4.5											



4.3 Product Dissection

We extracted and analyzed the creation of this house thoroughly. First, we prepared a list of appliances that were required in order to live in the home. We did some external research to see how much the products cost, how energy efficient they were and then determined how important they were in the creation of the home. We prepared a separate appliance list and then ordered them in importance to the consumer (Shown in Table 5). The basis of our research for appliances came from Energy Star. Energy Star is a government-backed symbol for energy efficiency. It helps people shop for energy efficient products and saves people hundreds of dollars every year. Their goal is to reduce greenhouse gas emissions from inefficient uses of energy and to make it easier for customers to save money by making it simple to find energy efficient products. The appliances that required a considerable amount of money were put off until the end to see if they could fit in our budget. We saw that some products did the same function. Therefore, we only needed one of these products in our home. We also realized that some of the mechanisms we wanted to use in the creation of our home were way over our budget so we had to eliminate them (Shown in Table 6). The last problem we encountered was that the product was low-cost, but it used too much energy which would contradict our mission statement. Next, we drew a floor plan that was low-cost to build with few cuts and derived a square footage amount under our budget that would allow us to spend money on other items. We then had to research methods of energy so that the family could use the appliances in the home without any bills. We finally decided on how to finish the exterior of the house and building materials that would benefit our methods of energy and regulate the temperature on the inside.

Table 5- Appliance List

Appliance	Cost	Energy Efficient	Importance
Washer/Dryer	$1,599	yes	5
Television	$180.59	yes	2
Oven/stove	$529	no	4
Microwave	$149	no	2
Refrigerator	$829	yes	5
Dishwasher	$599	yes	4

Table 6- Energy Methods

Energy Method	Cost
Solar	$28,615.00
Geothermal	$7,500.00
Wind	Not Available in Pottsville
Hydrogen	Est. to $500,000 Not Available in Pottsville

4.4 Global Marketplace

People all over the world are becoming more educated with Zero Energy Homes and their positive impact on the environment. Zero Energy Homes have become popular all over the globe and more countries are building these houses in effort to help their countries' environment. Zero Energy Homes have proved to decrease technology costs. Countries such as India, Belgium and Germany have all built Zero Energy Homes. Canada has also been involved in building Zero Energy Homes starting with their first home, The EcoTerra House, located in Quebec. Overall, the United States is the leading nation in which Zero Energy Homes are being built, but the amount of homes being built in other countries is rapidly increasing. This proves that using this relatively new concept is helping to achieve a more sustainable globe.

4.5 The Effect of Location

With the only restriction on location, being that we had to keep our house in Pennsylvania, we decided on the Pottsville area. Like all of Pennsylvania, Pottsville experiences a temperate climate with four seasons. Warm summers with average temperatures in the low eighties, but occasionally reaching the upper nineties and low hundreds, and chilly winters averaging in the low-twenties but consistently getting down to the single digits. With temperature differences as extreme as this, we knew that we would have to implement a high quality, sustainable and energy efficient heating and cooling system. In the end, we decided on a geothermal heat pump which will allow us to use the earth's heat to regulate the temperature of the house. When the point was raised that in Pennsylvania many areas do not have the appropriate topographic features for a geothermal heat pump to be in any way effective, we momentarily scratched the idea. After further research into Pottsville's ability to make the most out of the heating pump, we came to the conclusion that as long as the land chosen to build on is not too close to an old coal mine, a geothermal heating pump will be more than appropriate.

The location of the house has many more effects than just use of a geothermal heat pump. Through our research we also found much information on the possibilities of powering our house. Looking first at wind power we were disappointed in the prospect of using wind energy in Pottsville. Wind speeds in Pottsville reach an average high in March at about ten miles per hour (10 mph). For the rest of the year the average lies at about eight miles per hour (8 mph).

Comparing this information to our expected energy needed to power the house and the limitations of our budget, we decided that using solar energy would not be practical for powering this house. Our next option for a renewable source of energy was the sun. We instantly saw this as the best option for powering the house we were designing. Even with the hours of sunlight varying from six hours in the summer to almost three hours in the winter, solar was still the most viable option. However, one issue that we would be quick to encounter with solar panels in the winter is the accumulation of snow. In this case, the owner of the house would have to make an effort to remove the snow to facilitate continued solar harvesting. With a final decision on using solar energy to power much of the house and a geothermal heating pump to regulate the temperature, we made the most of the natural energy available to us at our location.

5.0 Concept Generation

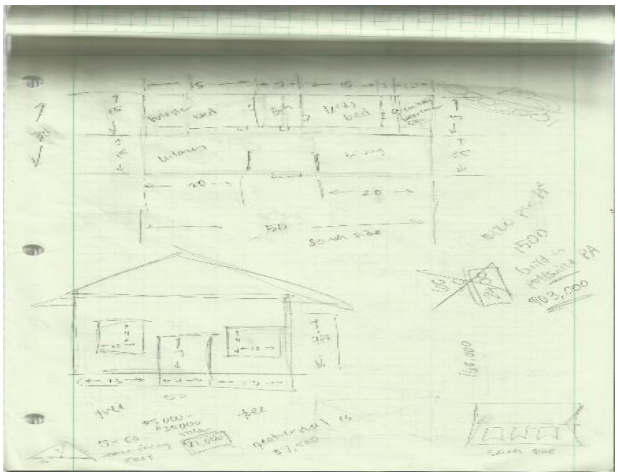
In this section we will present the concepts that were generated during the creation of our design. We came up with a few floor plans we thought would be beneficial to the zero energy aspect of our house. Most of our designs were similar to each other only varying with just a few errors and adjustments. While contemplating, extracting and inspecting we will decide which design is the best and more suitable for our Zero Energy Home.

5.1 Concepts

Concept A-

Concept A (shown in Picture 1) is a simple design of a Zero Energy Home we thought would benefit the home. This house would be 1,500 square feet and rectangular in shape. Concept A would have very little walls to eliminate cost and maximize the air circulation. This concept will use wind and solar energy. This house would have a normal roof with an incline on an angle suited to the solar panels that would be installed. There would be one bathroom between the master bedroom and the children's room. Next to the children's room there would be a laundry room as well as a utility room. This design also included a living room and a kitchen on each side of the house. This is shown in Picture 1.

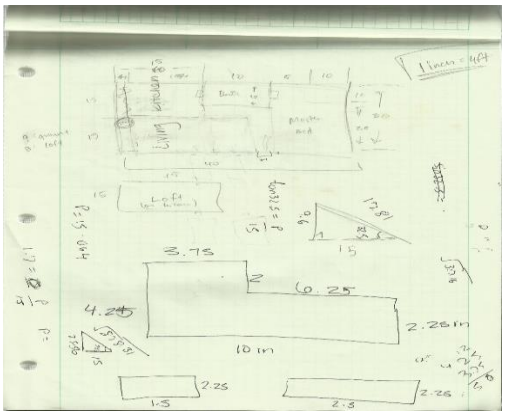
Picture 1



Concept B-

Concept B (shown in Picture 2) is very similar to Concept A. The difference is that in the layouts the rooms are different along with the downsizing of the rooms. Concept B would be about 1,200 square feet and will use hydrogen energy. This design, like Concept A, would also have very little walls. This concept would have the living room and the kitchen side by side on the same side of the house. The bathroom would still be by the children's room and the master bedroom. Another difference that is noticeably different is that the master bedroom would have a closet that would include the utility room and the laundry room. This is shown in Picture 2.

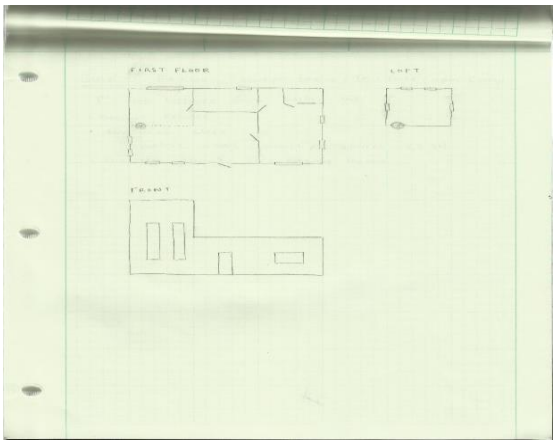
Picture 2



Concept C-

Concept C (shown in Picture 3) is a combination of Concept A and B, along with introducing the concept of a loft and different energy methods. The loft creates better circulation for the home which would ultimately decrease heating and cooling costs. The loft would make the house open with less corners and walls. The living room would be placed in the front of the house so the sun would be able to shine through and with an open entrance to the kitchen in the back. The bathroom would be in the center back of the house for the ease of entrance for every family member. The master bedroom would be on the opposite side of the living room. The master bedroom would contain a closet, as well as a dual laundry and utility room. The children's room will be lofted for better air circulation as mentioned before. This concept uses solar and geothermal energy. This is shown in Picture 3.

Picture 3



6.0 Concept Selection

After illustrating all of our concepts, we had to evaluate which concept would benefit the concept of zero energy the most efficiently. Using the process of screening we were able to evaluate each concept relative to each other. We organized our data by creating a chart in an Excel spreadsheet. Each concept will be labeled at the top while the needs will be listed on the left. By doing so, we will rate each need relative to each concept. After we have rated each need we will tally the concepts. We then will place them through the process of scoring which will weigh the concepts for importance.

6.1 Concept Screening

In order to decide which concept was best suitable for our needs, we used concept screening (Table 7) to establish which of the concepts was incomparable. During the screening we chose Concept A as our reference concept in comparison to the others and analyzed how each concept satisfied the needs. The process of screening helps us decide which design we wanted to use as our final design that would be the best for our customer.

Table 7- Screening

		Concepts	
	A	B	C
Needs	One floor Wind Energy	One Floor Hydrogen + Solar	One Floor + Loft + Solar + Geothermal
Sustainable in Pennsylvania	0	+	+
Self-Sustainable Energy	0	+	+
Uses Renewable Resources	0	+	+
Affordable	0	-	+
Attractive Design	0	+	+
Comfortable	0	-	+
At least 2 Bedrooms	0	+	+
Laundry Room	0	+	+
Utility Room	0	+	+
Appliances	0	+	+
Kitchen	0	+	+
Living Room	0	+	+
Insulated Windows	0	0	+
Big Television	0	+	+
Furniture	0	+	+
Landscape uses passive energy	0	0	+
Trees	0	-	+
Fireplace	0	0	0
Sum of +'s	0	12	17
Sum of 0's	18	3	1
Sum of -'s	0	3	0
Net Score	0	11	17
Rank	3	2	1

6.2 Concept Scoring

After Screening, the top design was Concept. To gain a better distinction between the concepts we used the process of Concept Scoring (Table 8) to make our final decision. We did not use a reference concept in the scoring process because we wanted to see how Concept A would compare to the other two concepts. We used a weighting system in order to grasp the relative importance of needs to the concepts. From the scoring process, we calculated a ranking that led us to the decision of our final design. The concept that was the highest in rank was Concept C. Concept C will become our final design in which we will continue to improve.

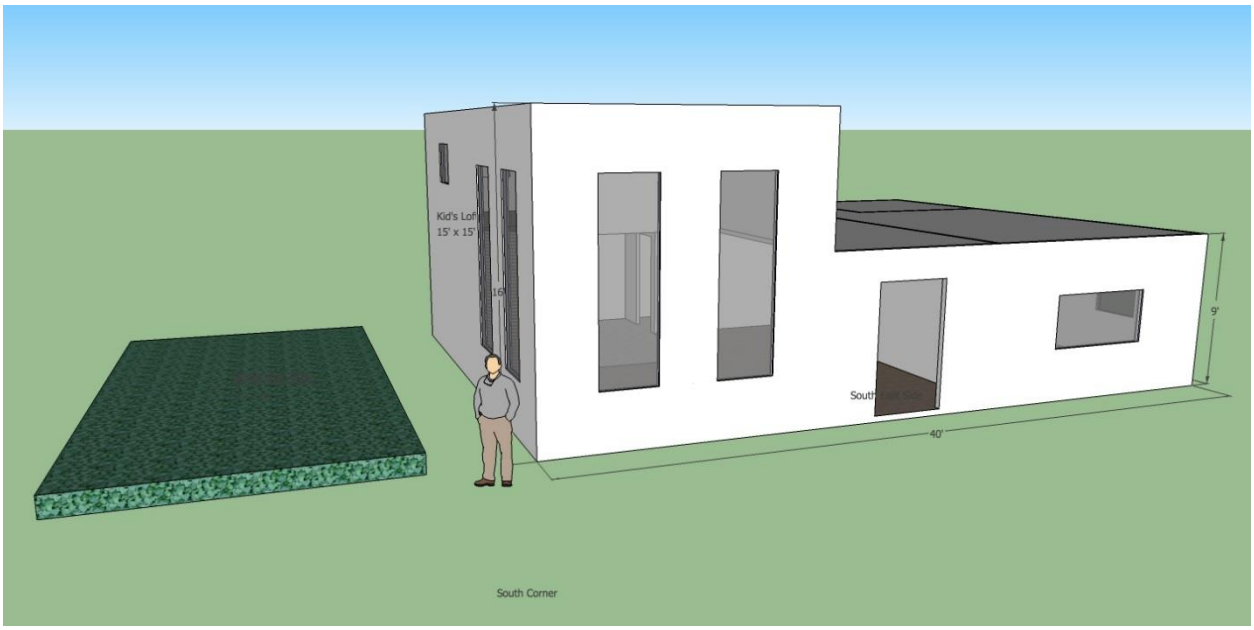
Table 8-Scoring

					Concepts		
			A		B		C
			One floor + Wind Energy		One Floor Hydrogen + Solar		One Floor + Loft + Solar + Geothermal
Needs	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Sustainable in Pennsylvania	25%	3	0.75	4	1	5	1.25
Self-Sustainable Energy	25%	3	0.75	4	1	5	1.25
Uses Renewable Resources	25%	3	0.75	4	1	5	1.25
Affordable	25%	2	0.5	2	0.5	4	1
Attractive Design	10%	3	0.3	4	0.4	5	0.5
Comfortable	25%	3	0.75	2	0.5	5	1.25
At least 2 Bedrooms	25%	3	0.75	3	0.75	3	0.75
Laundry Room	20%	3	0.6	3	0.6	3	0.6
Utility Room	25%	3	0.75	3	0.75	3	0.75
Appliances	25%	3	0.75	4	1	5	1.25
Kitchen	25%	3	0.75	3	0.75	3	0.75
Living Room	20%	3	0.6	3	0.6	3	0.6
Insulated Windows	25%	2	0.5	4	1	5	1.25
Big Television	10%	2	0.2	4	0.4	4	0.4
Furniture	25%	3	0.75	3	0.75	3	0.75
Landscape uses passive energy	15%	2	0.3	3	0.45	5	0.75
Trees	15%	2	0.3	2	0.3	5	
Fireplace	10%	3	0.3	3	0.3	2	0.2
Total Score			10.35		12.05		14.55
Rank			3		2		1
Develop: Yes/No			No		No		Yes

7.0 Embodiment Design and Final Design Description

Our final design was Concept C. The final design of our Zero Energy Home has numerous materials and methods that will help achieve a net zero energy. Our team has broken up the materials for our home into parts that we will explain in great detail. Each part will include why we included them and what goal they achieve in the Zero Energy Home. Each part has contributed tremendously in order to obtain the net zero energy outcome. We will also include a design of our home, a final price list and a final appliance list.

Zero Energy Home Final Design



The Basis of Design

When coming up with a design for this home, originally we had created a one-story home with kitchen, living room, master bedroom, bathroom, laundry room, and children's bedroom. This setup had many corners inside of the house and did not facilitate for a good circulation of air within the house. To create better air circulation we decided to loft the children's bedroom above the kitchen. Moving the bedroom up there allowed us to cut down on the size of the home. Even though we cut down on the actual size of the home, when we moved the bedroom we were able to expand the feel of the home. The high ceilings in the living room and the open floor plan between the kitchen, living room, and entranceway makes the house have a much larger sense of being. With an open floor plan, there is also an improved air circulation.

The orientation of the home played a large role in the design of the home. We decided to have the front of the home, with all of the windows and with the front door, oriented to the south-southeast. With this side facing this direction, we were best able to use the passive heating capabilities of the sun. This also applied to the left side of the house. The left side faces the

south-southwest, allowing it to absorb heat from the sun in the later hours of the day. On this side of the home, we allotted money for the family to start a home garden, using the same energy from the sun.

Geothermal Energy

For heating and cooling the home we decided to use a geothermal heating and cooling unit. The machine of choice is the 5 Series 502W12 High Temperature Hydronic Unit, which functions similarly to a hot water furnace in the typical home. This unit uses the difference is temperature between the earth and the outside air to heat or cool the home, depending on the outside temperature. The unit can heat the water to temperatures of one hundred thirty degrees Fahrenheit (130° F), which is highly efficient for using only the heat of the earth.

Solar Energy

To power the home, we decided to use solar panels. Based on our expected use of energy to power all of our appliances, we calculated that we would need to use at least five (5) Solartech SPM130P-WP 130 Watt Multicrystalline Solar Panels. These solar panels can each produce one hundred thirty watts (130 W) in one day. To be on the safe side for rainy days, etc. we thought it would be more than appropriate to cover the entire roof with solar panels, totaling thirty six (36) panels. We also purchased a battery that the extra panels would be able to charge.

Lighting

We found references for energy efficient lighting through Energy Star. We chose a simple Lithonia Lighting 6 in. Recessed White LED Baffle Downlight that costs $34.97 each. Based on the layout of our house and assuming that we would need four fixtures per 15x15 square foot room, we estimated that we would need 22 light fixtures. This would come to a total cost of $769.34 for light fixtures. These fixtures are LED compatible which improves optics, limits electricity needed and allows for dimming installation. The dimming switches help to lower energy costs by allowing the owners to play with the brightness and therefore, how much energy is being consumed. These fixtures we have chosen are Energy Star approved. We wanted to use LED lighting because they are more efficient than incandescent and fluorescent bulbs. LEDs have a long life, from 30,000 to 50,000 hours, and they do not give off a large percentage of their heat. Energy Star LEDs have excellent color and deliver brightness that matches ordinary bulbs. LED light bulbs that are approved by Energy Star can range anywhere from $20-$60. However, they pay for themselves by what they save in electricity and bulb lifetime.

Insulation

Our team has decided to go with Spray Polyurethane Foam Insulation. We were looking for an insulation to greatly reduce heating costs and Spray Polyurethane Foam Insulation or SPF exceeds our expectations. SPF can reduce household energy consumption from 30%-50%; this can make a significant impact in a Zero Energy House and put less pressure on our Geo-Thermal Heating System. Using closed-cell SPF yields an R value of 6-6.5 per inch. This is an excellent number since the higher the R value the better the insulation resists heat flow.

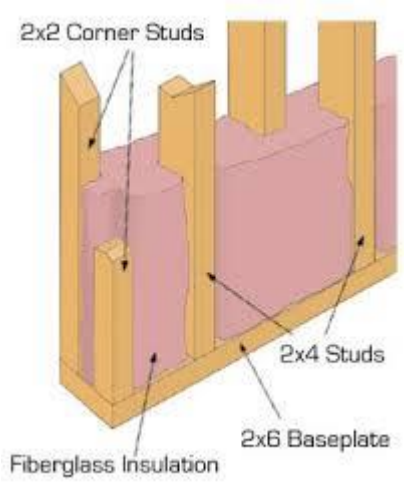
Not only, does spray foam keep hot air inside and cold air outside in the winter, but it performs the opposite in the summer. It is designed to keep cool air inside as well, which can greatly help our customers since we will not be installing an air conditioner. Among other benefits are that closed cell spray is rigid, strong and expands. It fills all the cracks and crevices in the walls, flooring and roof in order to drastically reduce or eliminate any air leakage. This makes the home quieter, stronger and more structurally sound.

Another feature of the spray foam we desired was its ability to improve indoor air quality. One of the two children who will be living in this house has asthma. Therefore, we tried to take that into account when building their house. SPF, because of its air-tight walls, reduces potential mold, mildew, dust, and allergen growth. Specifically, SPF prevents moisture accumulation and moisture breach of the walls which significantly prevents mold. Mold has been proven to instigate asthma attacks, sneezing and coughing, itchy eyes, and lung damage. SPF has the highest rate of prevention against these unwanted effects.

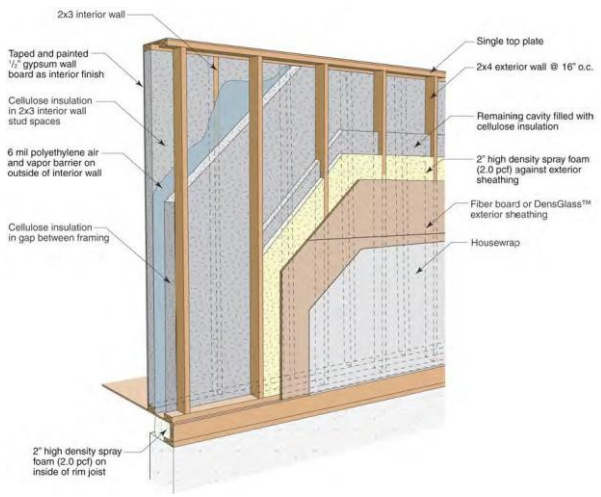
A downside to SPF is the expense. It is more expensive than most insulation and ours will cost around $10,700. However, it has been determined that SPF pays for itself in about three years' time which we believe to be a worthwhile trade-off. SPF is also permanent; therefore, it will not need to be replaced and should last for the lifetime of the house.

To aid the SPF insulation in our ZEH we decided on 12 inch thick double walls with off-set studs. This type of wall design helps eliminate thermal bridging and when added to our spray foam the thermal bridging is at a minimum. The wall will be a 2x4 frame with studs 16 inches on center. When it is all said and done there will be about 3-4 inches of spray foam insulation to protect the house.

Picture 4



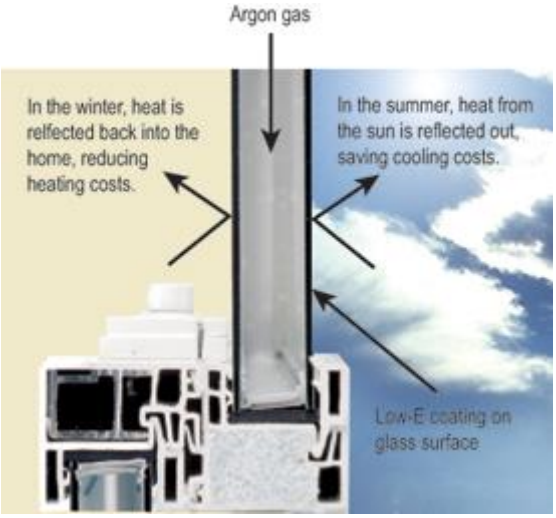
Picture 5



Windows

A weakness of most houses is the windows. They can let a good amount of heat escape, therefore, we decided to research windows carefully in order to prevent this as much as possible. We decided upon Jeld-Wen's energy efficient tilt and turn window. Their windows contain insulating Argon gas in between the window panes. Argon gas is heavy relative to air; therefore, it makes it more difficult for cold or hot air to pass through the window. They were designed to serve the dual purpose of cooling the home during the summer and keeping the heat in during the winter. This is an Energy Star approved product and has been proven to decrease energy costs. The windows we have chosen will cost about $200 each give or take. All research showed it depends on the size when ordering.

Picture 6



Doors

Another small weakness of a house is the front door or any door leading outside. Our house only has one door and our goal was to make sure it was insulated well. For the front door, we first began our research on the Energy Star website. Our door is a 6-panel primed smooth fiberglass door. It is energy efficient; Energy Star qualified and rated one of the best for insulation. When comparing fiberglass with steel and wood doors, fiberglass came out on top. It was less expensive, requires little maintenance, does not dent easily, will not rot, and has five times the insulation of a wood door. The door we chose costs $199.

Roofing

In our house we chose to install an insulated shingle roof. The types of shingles that we chose are wind resistant, durable and energy efficient. These shingles reflect the sun's rays which can lower the temperature of the roof. This is beneficial in the summer because less heat will be transferred into the home which can reduce cooling costs. Ultimately, this will extend the lifetime of the roof.

Siding

We decided to install Fiber Cement Siding. Fiber Cement Siding is a better energy efficient alternative than vinyl siding. Fiber Cement is energy efficient because of how well it is insulated. We decided to use a dark shade of purple so that the sun will attract, creating a warmer house inside during the winter months. Creating a warmer inside will lower the heating costs during those months. Fiber cement is not only low-maintenance but is also better for the environment, creating half the bout of carbon dioxide that vinyl does. Fiber Cement is durable and will not deteriorate which creates a lifetime warranty.

Table 9- Final Cost Estimate

Location	Pottsville, PA
Avg Price/sf	$69.00
Total Floor area (sf)	1425

Price to Build Base Home	$98,325.00

Floors	1.5
L/W	0.75
W (ft)	40
L (ft)	30
H (ft)	16
Wall Area (sf)	1890
Ceiling area (sf)	1200
Exposed Floor Area (sf)	1200
Total Surface Area (sf)	4290
South Wall Area (sf)	465
Total heat loss (Btu/hr-sf-F)	111
Total heat loss after insulated (Btu/hr-sf-F)	39

Geothermal Heat Pump	5 Series 502W12 High Temperature Hydronic Unit	*able to cover all of heating
Efficiency (EER/COP)	19/3.5	
Price	$7,500.00	

Solar Panel System	
Price of Panels	$12,636.00
Price of installation	$4,000.00
Price of Battery	$4,979.00
Misc. Costs	$7,000.00
Total Price	$28,615.00

Energy required for appliances (kWh/yr)	848
Cost of appliances	$20,515.79

Total Cost of Building Home	**$154,955.79**

Energy needed daily (kWh)	Avg sunlight per day (hrs)	Energy from solar array daily (kW)	Watts per solar panel	Solar panels needed	Solartech SPM130P-WP 130 Watt Multicrystalline Solar Panel 24 Volts	Solar Panels used	Price of Solar panels	Avg Energy generated (kW)
2.323	4.33	0.537	130	5	$351.00	36	$12,636.00	13.5
					26 in by 58 in			
					Area = 10.47 sf			
					Roof area = 450 sf			

Table 10- Final Appliance List

Appliance	Brand	Price	Water Consumption	Energy Consumption	Size	Weight	Flow Rate	Savings Rate vs. Normal Product	Estimated Yearly Operating Cost	Energy Star Certified
Shower Head	Alsons 657CBX	$38.92	N/A	N/A	5.5x4.5x3.9 in.	12.8 ounces	1.85 GPM or 2.5 GPM	26%	N/A	No
Television	Seiki SE28HY10	$180.59	N/A	40.0 kWh/yr	17.4x25.4x8.07 in.	N/A	N/A	N/A	N/A	Yes
Toilet	KOHLER	$228.00	1.28 gallons/flush	N/A	30.75x17.625x28.75 in.	107 lbs	N/A	about 50% (1.28 gal/flush vs. 3.5 gal/flush)	N/A	No
Refrigerator	General Electric (GE)	$829	N/A	370 kWh/yr	64.75x28x31 in.	166 lbs	N/A	N/A	$39	Yes
Spacemaker-Washer and Dryer	General Electric (GE)	$1,599	N/A	163 kWh/yr	75.5x26.8x30.85 in.	271 lbs	N/A	N/A	$17	Yes
Dishwasher	General Electric (GE)	$599	N/A	275 kWh/yr	34x23.75x24	74 lbs	N/A	N/A	$33	Yes
Range- Cooktop and Oven	General Electric (GE)	$529	N/A	N/A	47x29.875x28.75	130 lbs	N/A	N/A	N/A	No
Kitchen Facet	Delta Foundations	$81.65	1.8 gallons/min	N/A	2 or 3-hole 4 in installation	N/A	1.8 GPM	N/A	N/A	No
Bathroom Facet	Delta Classic	$116.80	1.5 gallons/min	N/A	4 in installation centerset	N/A	1.5 GPM	N/A	N/A	No
Shower	Delta Styla	$750.00	N/A	N/A	60x32 in. one piece tub shower	N/A	N/A	N/A	N/A	No
Light Bulbs	Energy Star LED	$769.34	N/A	N/A	6 in	N/A	N/A	N/A	N/A	Yes
Total Cost: $5,721.3										

8.0 Conclusions

In conclusion, our group effectively accomplished the goal. We had to design and create a Zero Energy Home under certain constraints. Our team effectively met the needs of the customer as well as creating a home that was energy efficient and sustainable. We were also able to keep the cost of the home under budget giving the family money to buy furnishing items of their own. We used the design process as well as concept selection in order to achieve our final design at the highest quality possible. We believe we succeeded beyond the expectations projected. As a team we fulfilled and met our mission statement's goal. Our Engineering Design team not only created a high quality Zero Energy Home, but we were also able to satisfy all of the customer's needs while surpassing all of our goals.

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