The Fortress of Sustainability

EDSGN 100, Section 16

Team six: Ohm My God

Submitted to: Wallace Catanach

3/07/2014

Sean Elicker, sie5050@psu.edu; Christian Diamond, cjd5444@psu.edu; William Pelosi, wyp5058@psu.edu; Bill Powell wjp5089@psu.edu

William Pelosi, wyp5058@psu.edu

Bill Powell wjp5089@psu.edu

Christian Diamond, cjd5444@psu.edu Sean Elicker, sie5050@psu.edu

Index:

a) Executive Summary

b) Introduction

c) Customer Needs Analysis

d) External Research

- **i) Library/online/patent research**
- **ii) Benchmarking**
- **iii) Product Dissection**
- **iv) Global marketplace**

e) Concept Generation

f) Concept Selection

maybe

g) Embodiment Design, Energy Calculator, and Final Design Description

h) Conclusions

k) References

A. Executive Summary:

The purpose of this project was to design a livable Zero Energy Home with a budget of 140 thousand dollars. In order to accommodate the family of four which has commissioned this project we will produce a house with sufficient square footage (800 sq. ft.), a significant amount of luxury appliances ($5260), and a sizeable photovoltaic array (4.27kw) combined with a solar water heater to ensure the house can be qualified as a zero energy home.

B. Introduction:

For our project, we have been tasked with designing a home that is self-sufficient in terms of energy usage, a Zero Net Energy Home. In addition to generating its own power, our home will be required to cost under $140,000. This aspect has made things more difficult, as we have to make a lot of sacrifices along the way to achieve this goal. In addition, the customer's needs will add further constraints to our designs, Of which many will be deemed unsuitable after a rigorous selection process, resulting in one concept that will be deemed to the supported design. Throughout this report, the reasoning behind our decisions will become clear, and we will show that our design is not only innovative, but effective.

C. Customer Needs Analysis:

Customer Statement	Needs Statement
"I want to be able to entertain all of my friends for parties!"	Must be accomodating for guests
"I want the house to be able to generate more energy than it consumes."	Must be energy sustainable
"I don't want to die from carbon monoxide poisoning in my sleep!"	Must be safe
"I want people to walk by my house and gawk at how pretty it is."	Be Visually Appealing
"I want to come home from work, and be able to relax for the rest of the day."	Must be comftorable
"I,like, don't want my tv and stuff to take up a lot of energy."	Must be energy efficient
"I want to be able to have a fun time with my family."	Have the ability to have fun in the house

Customer Statements and needs statement conversion

Needs statement and metrics matrix

		Metric	Open Floor plan	Window space square footage	Energy Star certified appliances	Floorspace (800ft2)	PV size (4.76 Kw)	water heated by solar energy	smoke and carbon monoxide detection	Insulation R value	Luxury appliances
	Need										
1	Be Visually Appealing		x	x							
2	Must be comftorable		x	x		x		x		x	x
3	Must be energy sustainable			x	x		x	x		x	
4	Have the ability to have fun in the house		x			x					x
5	Must be accomodating for guests		x			x					x
6	Must be energy efficient			x	x		x	x		x	
7	Must be safe							x	x	x	

D. External Research:

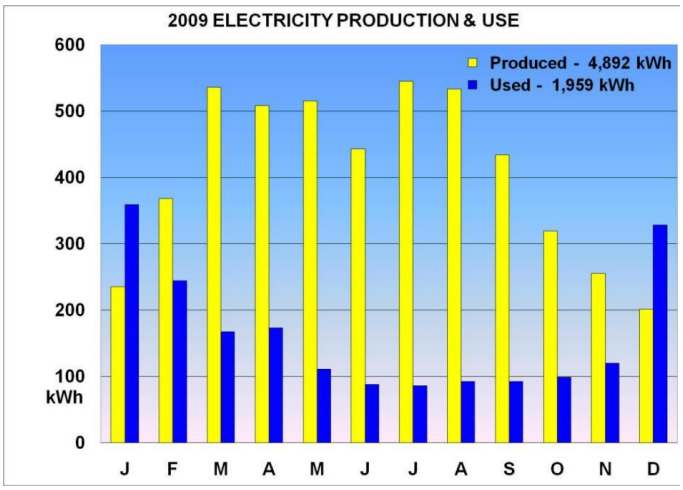
Patent Research

After meticulous research, it was determined that no patents under federal law, as well as under the law of the county of Lebanon, PA were violated by the design of our house. According to the United States Patent and Trademark Office, only processes, machines, articles of manufacture and compositions of matter can be patented. Abstract ideas, such as the custom parameters to which we constructed the house, cannot be patented.[1] Indeed, the specific,

patented mechanical innovations that will be implemented in the house (such as company-produced appliances) have been purchased from the rightful owners of the patent and all credit has been given to the rightful owners.

Product Dissection:

In order to create the ideal zero net energy home for a family of four we started our research with previously built homes that created the energy that they consumed. One house that was taken into account was the Montague Urban Homestead in Massachusetts. Initially, this house looked like a great place to start due to its location in the northeast region and the fact that it won the 2009 Massachusetts zero energy challenge. The house is a one floor single family home of roughly 1150 square feet. The most prominent feature of the house is the grid of photovoltaic cells that provide the house with almost all of its renewable energy, creating 4.94 kW. This information is good to obtain as photovoltaic energy is very inexpensive compared to other options such as a geothermal pump. Furthermore, studying the construction of this home showed us that insulation is key in creating a zero net energy environment with the ceiling having R=100.



- Electricity usage and production for the first year of the house, picture of finished product (3).

Additionally, another home that we looked at was a house located in the town of Charlotte in Vermont. Similar to the house in Massachusetts this home was designed for a single family, but with a few key differences. For example, the house is much larger with a 2800 square foot floor plan and multiple floors. However, to accommodate for this increase in size the designers utilized the surrounding environment with a 10 kW wind turbine that generates almost all of the energy for the home. The rest of which is covered by photovoltaic cells on the roof. Although a wind turbine is very expensive to construct and seems unlikely with our budget, the house still taught us about the importance of open air floor plans that contribute to airflow and overall heating of the home.

-Picture of Charlotte Vermont House (2).

Global marketplace:

In order to make the house comfortable for the family it was decided that certain luxuries and appliances should be provided. In order to

accommodate this several designs were stricken from the portfolio through the use of a selection matrix. The design that was selected for the preliminary design was an 800 sq. ft. home with two bedrooms, two bathrooms, a dining room, a kitchen, a small pantry, a laundry room, and an entryway with a closet. Due to the design's size as well as the quantity of appliances there was no room in the budget for a geothermal pump, nor were we able to feasibly fit a pool, a garage, or a hot tub into the design.Despite this the prototype design fits all of the customer needs and falls within the budget, allowing us to present this design as the final result from the project.

E. Concept Generation:

Mission Statement

Product Description	A house fit for a family of four that is energy sustainable
Benefit Proposition	Will have a far less significant impact on the environment and serve as a secondary source of income for the inhabitants
Key Buisness Goals	House will cost under $140,000 to produce, will generate more energy than it consumes annually
Primary Market	A middle-class family of four that cares about the environment
Secondary Market	Zero energy home enthusiasts
Assumptions	Will be self-sufficient in terms of energy while being comftorable to live in and affordable
Stakeholders	Owners, property agents, real-estate agents

Concept Generation Challenges

Assumptions	The house will remain under the budget and produce more energy than it consumes
Customer Needs	The house must be visually appealing, comftorable, energy sustainable, accommodate guests, able to let family have fun, energy efficient and safe
Target Specifications	The house will cost under $140,000 to produce, the appliances will all be Energy Star certified, the insulation will have a top of the line R value and the pv system will be of sufficient kilowatage.

Concept Generation Brainstorming Highlights

Concept 1: A two-story geothermal house

Initial brainstorming led to a possible design involving a two-story house that would have relied primarily on a geothermal pump system to obtain its energy. A two-story house would have been very accommodating especially for a middle class family of four, and a geothermal heating unit would have surely provided the energy necessary for the house to become completely energy self-reliant.

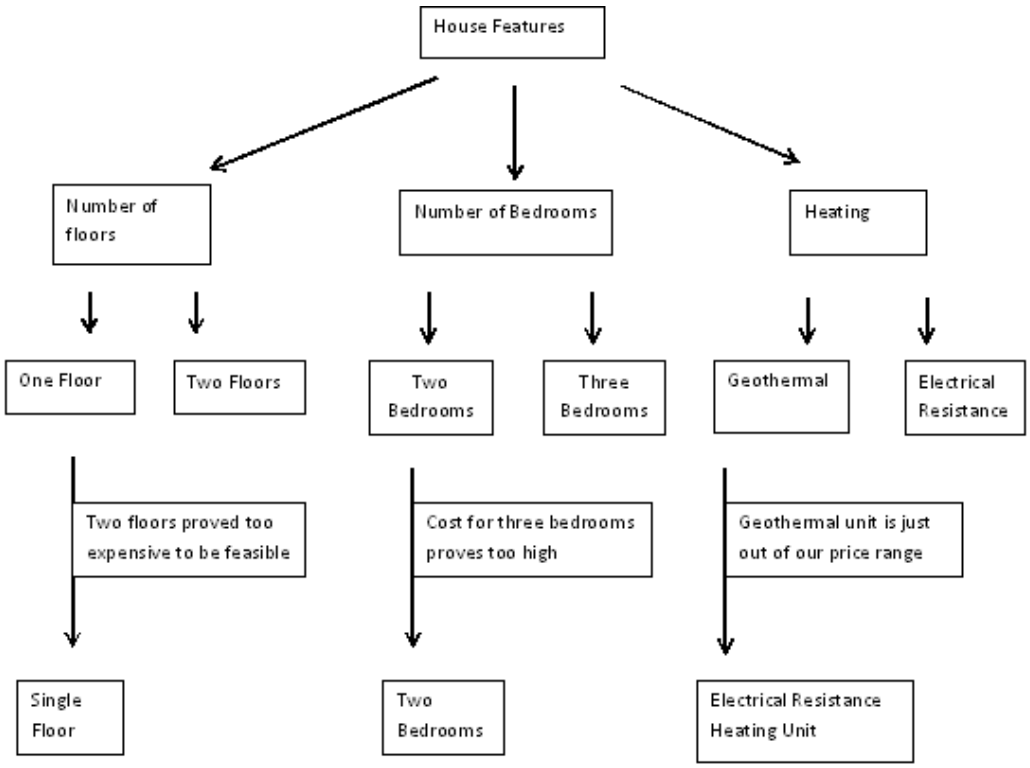
Concept 2: A one-story house with a thermal mass

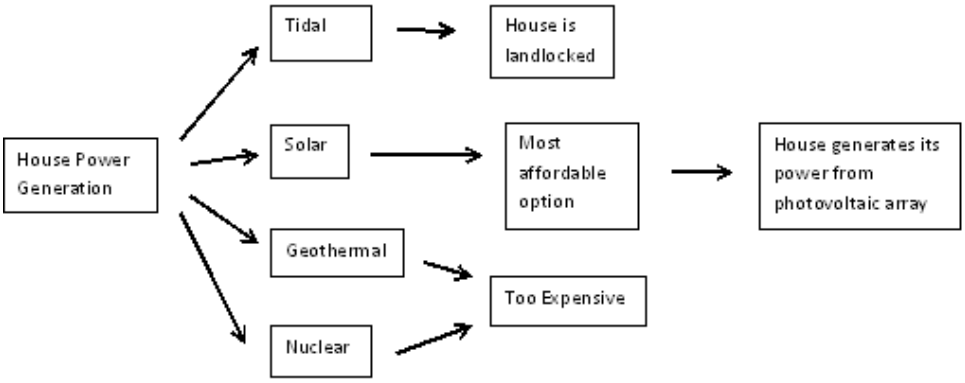
After determining the house should be single story, multiple methods of attaining energy were considered, one being the installation of a thermal mass. The thermal mass would take up a large amount of the floor space by the south-facing window and be able to absorb plenty of heat over the course of the day. This method was appealing due to the safe location of the thermal mass underneath the floor and its ability to collect energy in the form of heat, not just light.

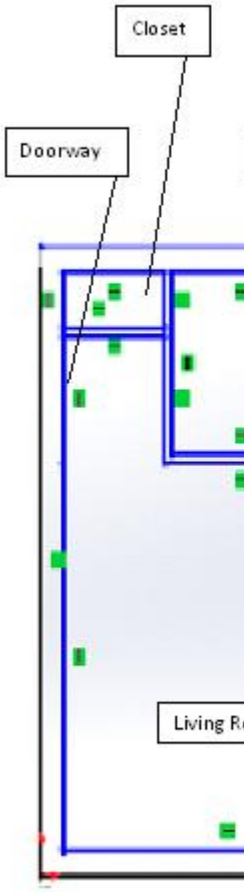
Concept 3: A one-story house with a solar panel pv system

After both a geothermal pump and thermal mass were considered as the primary means of obtaining energy, the utilization of solar panels was considered. A pv system of 4.76 Kw was cheap enough to fit within the budget, yet effective enough so that it generated enough electricity that a net surplus of energy would be collected annually. Also, an 800 square foot house provided enough roof space to install a sufficient area of solar panels.

F. Concept Selection:

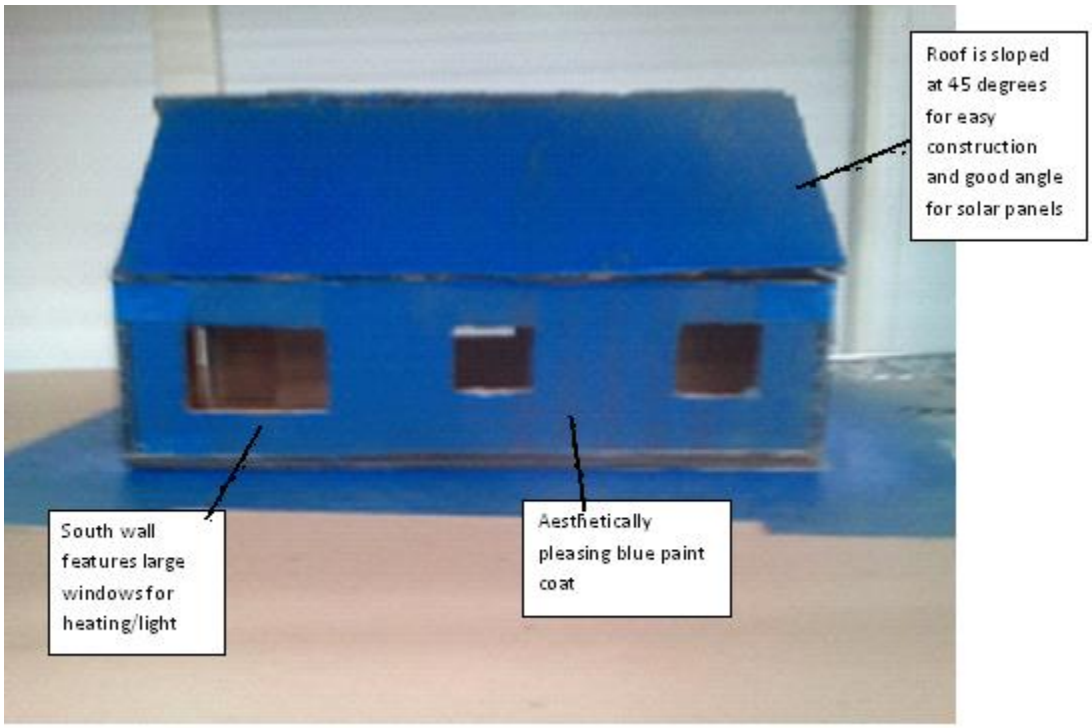






Our final design features a large open floor plan, with a connected kitchen and dining room, separated from the living room by a half wall. Despite the modest square footage of the house, this creates the impression of a lot of space. The two bedrooms are put on the far side of the house from the living room to be as out of the way as possible. Two bathrooms are strategically placed in the design, one by the bedrooms for quick access, and one by the living room so guests won't have to venture into the depths of the house to relieve themselves. In addition to the openness, the living room and dining room areas feature large windows to allow light to enter. A closet and laundry room are located out of the way but remain easily accessible.

G Embodiment Design, Energy Calculator, and Final Design Description



Embodiment Design:

Ideally, the zero net energy house is designed for a family of four including a mother, father, son and daughter. The house is modeled to accommodate for specific customer needs

while also accomplishing the goals of a zero net energy home, creating the power that it consumes. The group was tasked with preliminary research that consisted of previous homes built in the last several years, zero net energy homes built on the north eastern seaboard or places of similar climate, and other such details as the floor plan and list of appliances. Using these findings and guidelines we were able to create a model zero net energy home that embodies various others on the east coast.

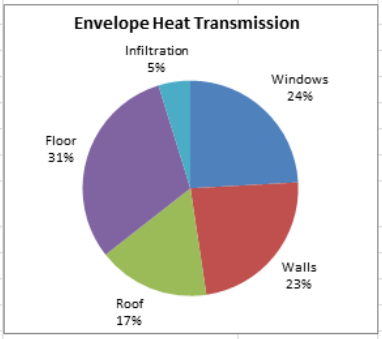
Penn State Center for Sustainability

General Info	
Location	Philadelphia
Electricity cost ($/kwh)	0.1
House type	1 story
Conditioned floor area (sq.ft.)	800
Number of bedrooms	2
Envelope Details	
Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1130
North wall area (gross) (sq.ft.)	400
East wall area (sq.ft.)	200
South wall area (sq.ft.)	400
West wall area (sq.ft.)	200
North window area (sq.ft.)	64
East window area (sq.ft.)	20
South window area (sq.ft.)	80
West window area (sq.ft.)	0
Air tightness	Tight with heat recovery
Appliances	
Refrigerator	Best
Clothes Washer	Best
Dishwasher	Best
Small Appliance Input	
Extras	
Garage	a. None
Hot Tub	a. None
Pool	a. None

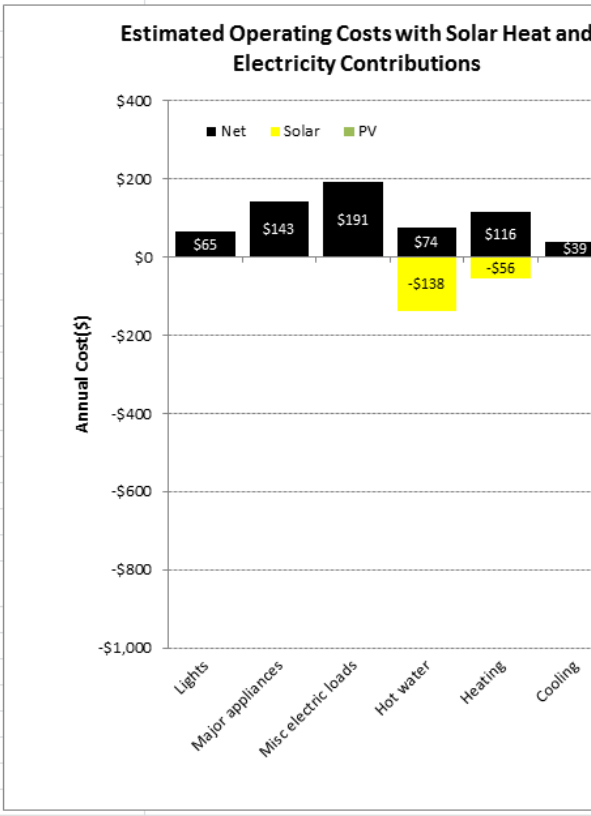
Zero Energy Home Calculator

Heating & Cooling	
Type of heating & cooling system	Electric resistance
Solar Technologies	
Size of PV system (kw)	4.87
Solar water heater	Yes
Behavior	
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	70
Cool thermostat setting (F)	76

Results



Base House Cost	$	106,351
PV Cost	$	24,350
Upgrade Costs	$	9,010
Total House Cost	$	139,711



Benchmarking:

When constructing our house and designing plans for the energy sources we took into consideration the homes we research in the Product Dissection. From these homes we gathered that the best renewable energy source and also one of the cheapest was a grid of photovoltaic cells on the roof of the home. Although the wind turbine from the home in Vermont generated more than double that of the cells it was far too expensive for our budget and the single floor plan with a small amount of floor space did not require such high energy levels. However, we did incorporate an open air floor plan with a half wall connecting the living room and kitchen as well as no ceiling separating the floor from the roof. Also, the Massachusetts house gave us the idea for the highest insulation for our walls and ceiling as the designers of that home expressed the importance of insulation in relation to energy conservation.

House of Quality:

Title: Zero Energy Home
Author: Oh my God
Date: 3/4/2014
Notes:

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Total Window area	2 Floor Area	3 Price	4 Number of bedrooms	5 Carport/Garage	6 Luxury appliances	7 Safety appliances	8 Insulation R-value	9	10	11	12	13	14	15
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	X	X	X	▲	▲									
1	3	25.0	7.0	Must be safe							O	O							
2	3	21.4	6.0	Must be energy sustainable	O		O		O			O							
3	3	17.9	5.0	Must be energy efficient	O		O		O			O							
4	3	14.3	4.0	Must be comfortable		O		O		O		O							
5	3	10.7	3.0	must have the ability to have fun in		O				O									
6	3	7.1	2.0	must be visually appealing	O														
7	3	3.6	1.0	must be able to accommodate guests		O		O		O									
8																			
9																			
10																			
				Target or Limit Value	1000 ft^2	800 ft^2	5.75 Ku	$2	$1	Tested 10	2	40							
				Difficulty (0-Easy to Accomplish, 10-Extremely Difficult)	7	5	4	3	0	6	0	7							
				Max Relationship Value in Column	3	3	3	3	3	3	3	3							
				Weight / Importance	139.3	85.7	117.9	53.6	117.9	85.7	75.0	235.7							
				Relative Weight	15.3	9.4	12.9	5.9	12.9	9.4	8.2	25.9							

H. Conclusion:

After the selection process, The concept that was selected was the 800 sq. ft., single story house with a 4.27 kwh PV system. Our design for this project has fulfilled the scope of the project, as in addition to generating its own power, our home falls under the $140,000 target. It also provides luxury appliances such as two TVs, a coffee maker, and a fan; thus providing a

comfortable and sustainable living environment for this family of four.

K. References:

1. "Patents." *The United States Patent and Trademark Office*. N.p., n.d. Web. 06 Mar. 2014.

2. **"**Charlotte Vermont House." *The Whole Building Design Guide.* Web. 06 Mar. 2014.

http://www.wbdg.org/references/cs_ch.php

3. "Massachusetts zero energy challenge winning home." *Build it Solar*. Web. 06 Mar2014

http://www.builditsolar.com/Projects/SolarHomes/MAZeroEnergy/MAZeroEnergy.htm