Zero Energy Home

Team : The Four

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Introduction

The alarming situation of the environmental problems such as global warming raises the need for zero energy homes in the community nowadays. The first major step is to create a house that can be self-sustain in term of energy. Hence, we plan to model a zero energy home and build it in Fayette, Pennsylvania. With sufficient reliable research and guidance, the goal of building a zero energy home is realistic and achievable.

Abstract

An improved zero energy home design is needed in the commonwealth of Fayette. After the end of World War II, the population has grown exponentially due to the baby boomers in the late 1940's. With the increase in population and the wealth brought by the war to our country, more and more houses were being built. The increment of houses had consumed more fuel for power generation. Now, we are running out of our natural resources. The huge impact on our ecosystem cannot be ignored as well. The average home uses 8900 kWh per year, so the home needs to produce at least this much energy. A visually appealing zero energy home that can support a family of four with a comfortable living is what we are trying to accomplish for this project.

While developing our design, several zero energy homes were researched such as solar energy, geothermal energy and wind energy. After gathering our data and surveys, we then ranked our ideas and reviewed our engineering specifications. We then put this data into a matrix for better organization. This house is able to support a family of four and be appealing to the public of Fayette. We initially wanted a two story house and looked at some of the options, but discovered that it would not be feasible. This led us to a one story home. We then looked at sources of energy such as wind turbines, solar, and geothermal. We eliminated wind turbines based on our customer needs of visually appealing to the public and its energy efficiency. Among solar, geothermal, and natural light and heat from the sun, our home will meet our customer needs and our engineering specifications.

There are some risks involved in the building of this home. The geothermal heating system needs wells drilled in the yard, this has a possibility of hurting the foundation of the home. Geothermal heating uses puts water under high pressure which could cause a pressure leak and do damage to the house. To lessen these risks, we put more focus on solar energy as it is a safer and more efficient in power generation.

Mission Statement

In this contemporary era, the world has been growing fast due to the advent of technology. However, the consumption of fossil fuel increases drastically in line with the growth of technology.

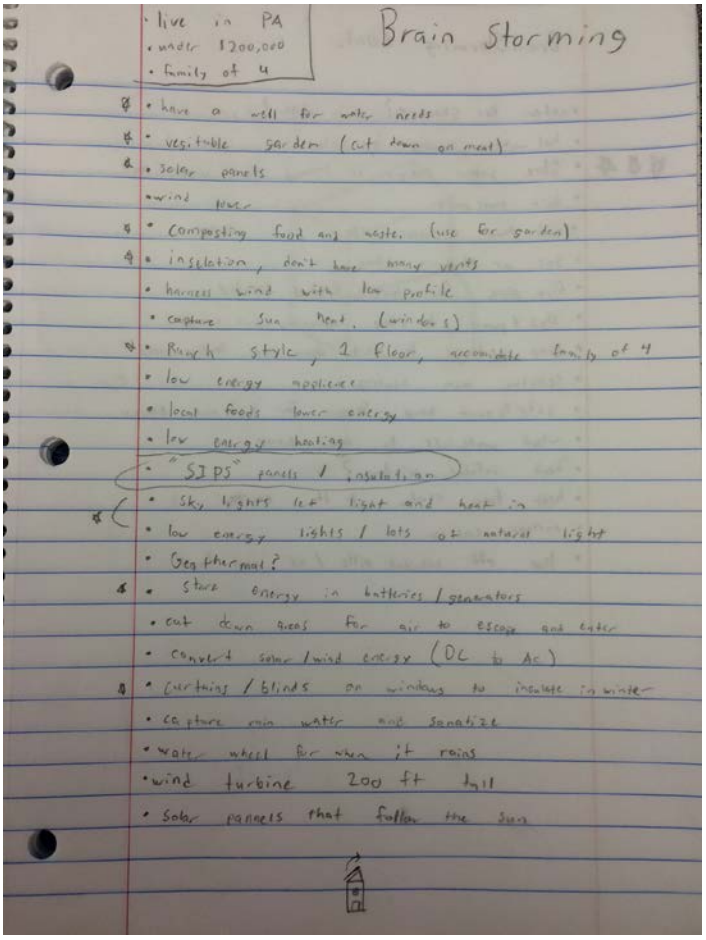
At the same time, the huge impacts, especially greenhouse effect caused by the burning of fossil fuel raise the concern of the society nowadays. Hence, our zero energy home aims to get rid of the fossil fuel consumption and also reduce the environmental footprint.

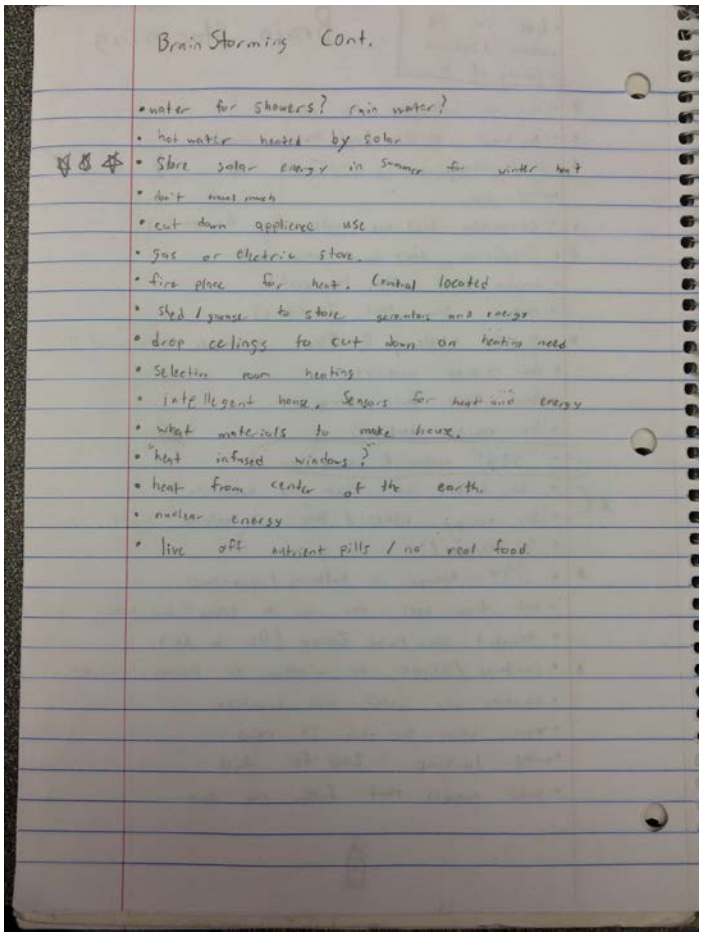
Customer Statements	Customer Needs
The home produces all the energy it needs over a year.	**The ratio of energy consumption vs production needs to equal out to zero.**
The home shows that a Zero Energy Home can work well in the general public.	**The house can work well in a rural neighborhood.**
The home meets the needs of a family of four.	**The house is sizeable and can comfortably accommodate a family of four.**
Made using green technology and materials.	**The house can reduce its carbon footprint.**
Attractive appearance to the public.	**The house appeals to the owners and the public.**
Appropriate cost for the average rural family.	**The house is affordable for a middle class family.**

Brainstorming

We had a pretty creative group when it came to brainstorming. We had ideas ranging from normal to completely abstract. The normal zero energy ideas came up, such as solar panels and large windows.

We also had some abstract ideas such as nuclear power and make the house less than 1000 square feet. We also wanted to attach a motor to our solar panel array and have it move and track the sun as the day went on. Even with some abstract ideas we focused in the end and came up with some creative yet effective ideas.





Customer Needs

Customer Needs		
Number	Need	Importance (5-1)
1	Accommodate family of four comfortably	5
2	Budget of $200,000	5
3	Sustain living conditions for at least a year	5
4	Minimize ratio of energy consumption vs production	5
5	Use of solar energy	5
6	Located in PA	5
7	Proper insulation	4
8	Smart house qualities	4
9	The aesthetics are pleasing	3
10	Use of geothermal energy	3
11	Open floor plan	3
12	Large windows for natural lighting	3
13	Yard with garden and space for kids	3

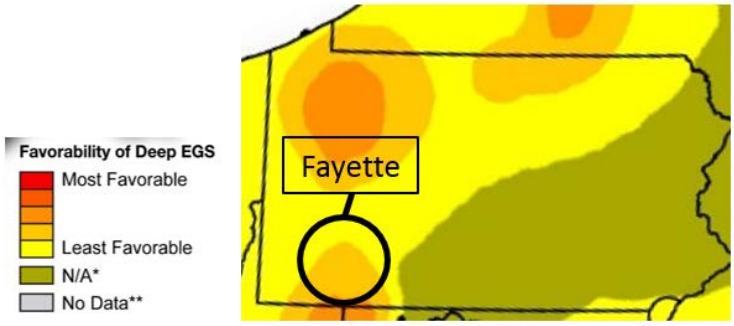
Target Specification

Target Specification	
Energy production (including solar panels and geothermal)	4161 kWh
The house must cost a total of less than	$200,000
The house is located in PA	Layette, PA

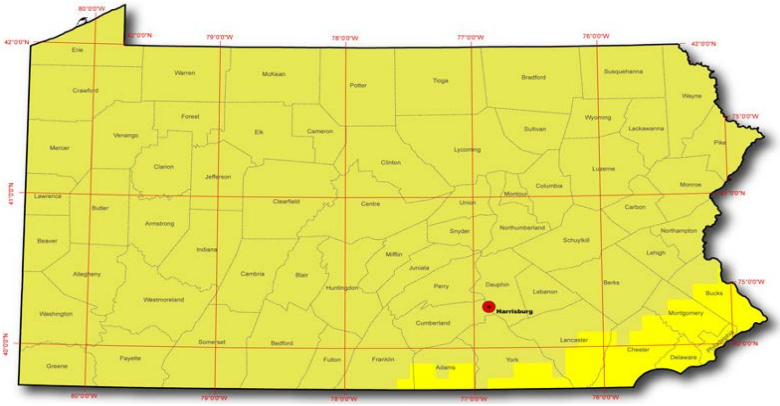
External Research

Location: Fayette County, PA

The southernmost county in western Pennsylvania is Fayette County. Based on the solar map and geothermal map below, we have figured out Fayette County has considerable amount of sunlight and geothermal energy for the energy sources of our zero energy home.



Geothermal Map of PA



Solar Heat Map of PA

SIP's (Structural Insulated Panel)

- High performance building materials for residential use.
- Made up of two structural facings with an insulated foam core in between.

PANEL THICKNESS (inches)	R-VALUE	PRICE PER SQFT	PANEL SIZE (feet)				
			4' × 8'	4' × 10'	4' × 12'	4' × 14'	4' × 16'
4.5	16	$4.27	$136.64	$170.80	$204.96	$239.12	$273.28
6.5	24	$4.64	$148.48	$185.60	$222.72	$259.84	$296.96
8.25	32	$5.02	$160.64	$200.80	$240.96	$281.12	$321.28
10.25	40	$5.40	$172.80	$216.00	$259.20	$302.40	$345.60
12.25	48	$5.62	$179.84	$224.80	$269.76	$314.72	$359.68

SunPower X-Series Solar Panels

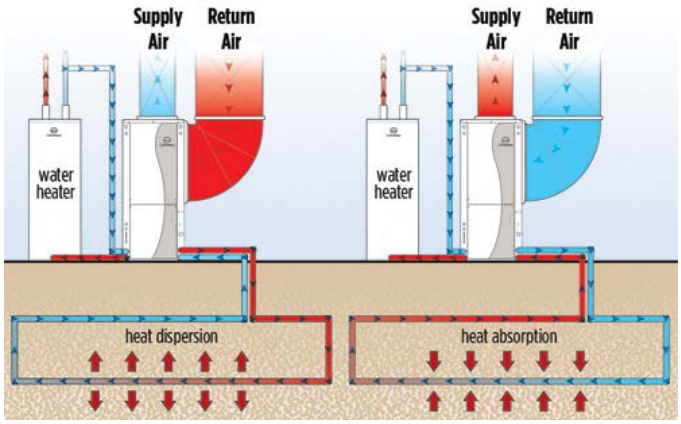
- Currently deliver the highest efficiency available in residential areas, 21.5%.
- Reduce glare with anti-reflective glass to look better.
- Size of about 3.5ft by 5ft. Thickness of 1.8in.
- Self-installation option.

Signature Black
X21 – 335 Panel

X21 – 345 Panel

Geothermal Systems

- Heat from the earth. Clean and sustainable.
- Upper 10ft of the ground maintains a temperature of about 55°F.
- Can apply for a 30% tax credit after installing a heat pump.
- Most systems used to heat water efficiently.



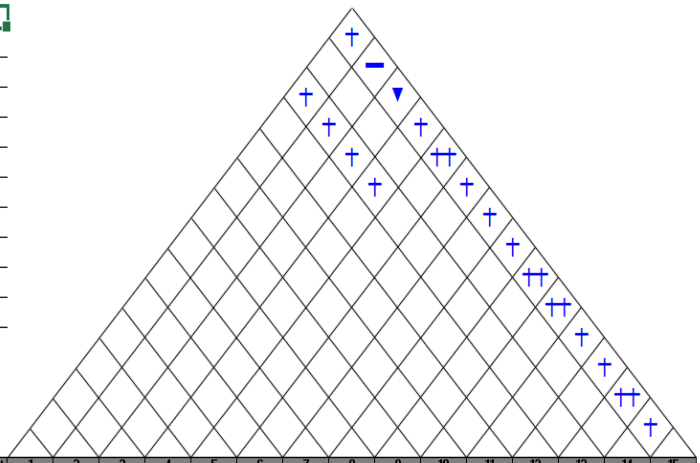
Benchmarking

Location	Gettysburg, PA
URL	http://www.hphpa.com/floorplans/nice
House Size	1,942 sq. ft.
Number of Floors	1
Number of Bedrooms	3
Number of Baths	2
Type of Heating System	Geothermal
Solar Panels	Yes
Insulation	SIP's
Other Key Information	Air Filtration is also used

Location	Fraser, CO
URL	http://www.jetsongreen.com/2011/01/net-zero-energy-house-fraser.html
House Size	5,232 sq. ft.
Number of Floors	2
Number of Bedrooms	N/A
Number of Baths	N/A
Type of Heating System	Solar Thermal
Solar Panels	Yes (17 kW array)
Insulation	SIP's
Other Key Information	Fiberglass Windows and Smart Lighting/Shading

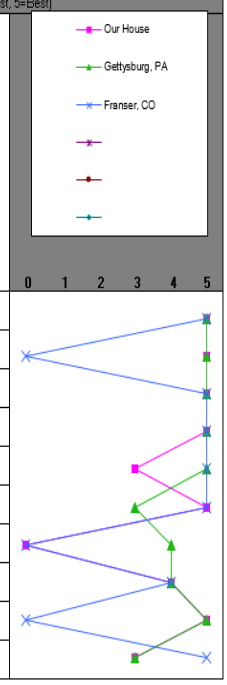
House of quality

Title: Team The Four House of Quality
Author: The Four
Date: 3/5/2015
Notes:



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	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 SIP panels	2 Wood exterior	3 Siding	4 Brick exterior	5 Solar panels	6 Geothermal System	7 Wind energy system	8 Water turbine system	9 Energy star appliances	10 LED lights	11 Incandescent bulbs	12 Open floor plan	13 Reduce vents	14 Water well	15 Store energy	Our House	Gettysburg, PA	Franser, CO			
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)																Competitive Analysis (0=Worst, 5=Best)					
1	9	11.5	9.0	Accomidates family of four comfortably												Θ				5	5	5			
2	9	11.5	9.0	$200,000 budget	Θ	Θ	Θ	▲	Θ	O	▲	O	Θ	O	O		Θ	O	▲	5	5	0			
3	9	11.5	9.0	Sustainable living conditions for over a year	Θ	O	O	Θ	Θ	Θ	O	▲	Θ	Θ	▲	Θ	Θ	▲		5	5	5			
4	9	11.5	9.0	Minimize ratio of energy consumption to production	Θ	O	▲	Θ	Θ	Θ	O	O	Θ	Θ	▲	O	Θ	▲		5	5	5			
5	9	6.4	5.0	Aesthetically appealing	▲	O	O	Θ	O		▲					Θ			▲	3	5	5			
6	9	11.5	9.0	Use of solar energy					Θ										Θ	5	3	5			
7	9	7.7	6.0	Use of geothermal energy						Θ									Θ	0	4	0			
8	9	10.3	8.0	Proper insulation	Θ	O	▲	Θ									Θ			4	4	4			
9	3	11.5	9.0	Located in PA					O	O	▲	▲						▲		5	5	0			
10	9	6.4	5.0	Large windows for natural lighting													Θ			3	3	5			
				Target or Limit Value	R value of at least 38	R value of at least 38	R value of at least 38	R value of at least 38	Annual production of at least 3000k wh	Annual production of at least 3000k wh	Annual production of at least 3000k wh	Annual production of at least 3000k wh	Minimize energy usage	Minimize energy with at least 30 bulbs	Minimize energy with at least 30 bulbs	1500 sq feet size	Increase insulation efficiency	Collect water for sustainability	Energy output equates to consumption						
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	1	6	8	2	1	2	9	9	1	2	7	1	2	5	1						
				Max Relationship Value in Column	9	9	9	9	9	9	3	3	9	9	3	9	9	3	9						
				Weight / Importance	410.3	223.1	179.5	369.2	469.2	346.2	98.7	92.3	311.5	242.3	57.7	300.0	461.5	69.2	191.0						
				Relative Weight	10.7	5.8	4.7	9.7	12.3	9.1	2.6	2.4	8.2	6.3	1.5	7.8	12.1	1.8	5.0						



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Concept Generation

Concept Generation		
Ranking	Idea	Dots
1	Solar Panels	3
2	Thermal double panel	3
3	"SIPS" panels	3
4	Energy star electrical appliances	3
5	Energy storage	3
6	Solar heating system	3
7	Geothermal	2
8	Fireplace	2
9	Electric car	2
10	Smart house system	2
11	Automatic motion light	2
12	Grey water system	2
13	Water wheel	1
14	Windmills	1
15	Biomass	1
16	Nuclear energy	1
17	Skylight	1
18	Roof catch rainwater	0

Concept Screening

Energy Concept Screening

	Concepts	Solar power	Geothermal	Wind Power	Water Wheel
No.	Selection Criteria	1	2	3	4
1	Quiet Operation	+	+	-	-
2	Easy Operation for Home Energy	+	+	+	-
3	Relative Efficiency	+	+	-	-
4	Relatively Inexpensive	+	+	+	+
5	Easy Installation	+	-	0	0
6	Space-Wise	+	-	0	-
7	Visually Appealing	+	+	0	+
8	Easy Maintenance	+	+	+	+
9	Large Amount of Green Energy Generation	+	+	-	-
10	Suitability for Fayette	+	+	-	-
	Sums of +	10	8	3	3
	Sums of -	0	2	4	6
	Sums of 0	0	0	3	1
	Net score	10	6	-1	-3
	Rank	1	2	3	4
	Suitability	Yes	Yes	No	No

Matrix

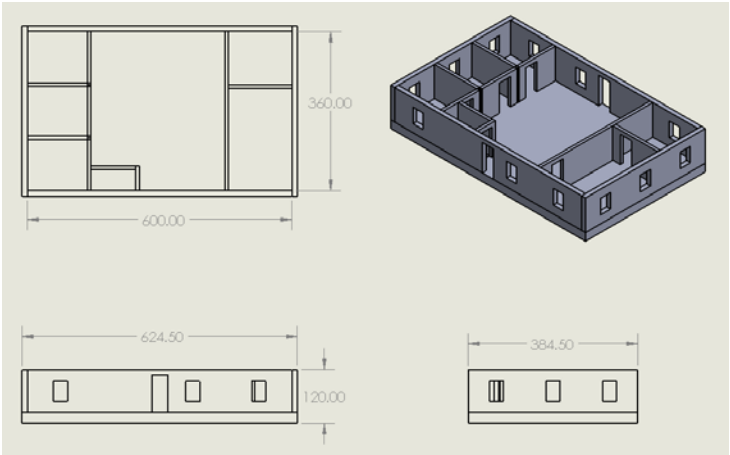
Metric	Produces Solar Energy (kWh)	Total Cost to Build Home ($)	Area of Windows (sq. ft.)	SIP's for Insulation (R38 or higher)	Use of Geothermal Energy (kWh)	Size of House (sq. ft.)	Use of Energy Star Appliances (kWh)
Need	1	2	3	4	5	6	7
Ratio of Energy Consumption vs. production is equal to zero	X				X		X
Large Windows for Natural Lighting			X				
Proper Insulation				X			
Stays Within Budget		X					
Accomidate Family of Four						X	
Smart House Qualities	X			X	X		X

Energy Concept Scoring

Concepts			Solar Power		Geothermal	
Needs	Selection Criteria	Weighting	Rating	Weighted Score	Rating	Weighted Score
1	Quiet	10%	5	0.5	4	0.4
2	Efficiency	30%	5	1.5	5	1.5
3	Inexpensive	10%	4	0.4	4	0.4
4	Easy Installation & Maintenance	30%	5	1.5	4	1.2
5	Suitable for Fayette County	15%	4	0.6	5	0.75
6	Visual Appeal	5%	4	0.2	5	0.25
	Total Score		4.7		4.5	
	Rating		1		2	
	Continue?		Yes		Yes	

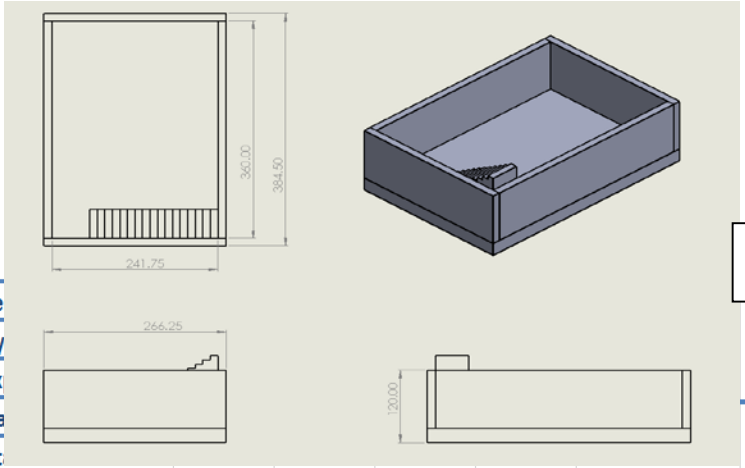
Concept selection

Exterior House Scoring



Final Design

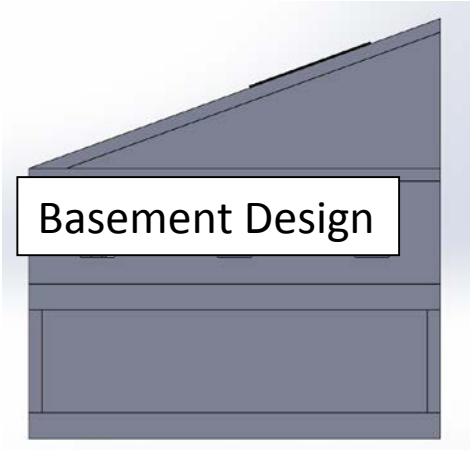
Drawing and Dimensions (IPS)



First Floor Design

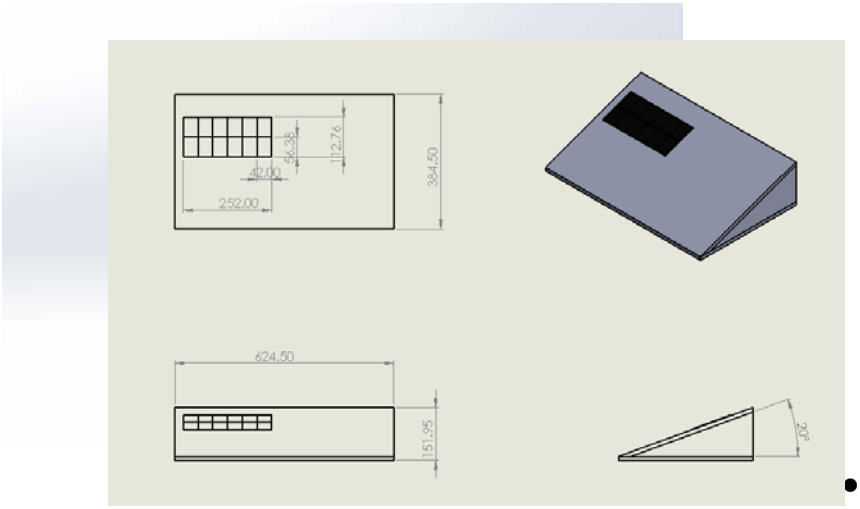
No.	Se				
1	Easy				
2	Inex				
3	R-Va				
4	Sust				
5	Visually Appealing	+	+	-	+
6	Low Maintenance	-	+	+	+
7	Suitable for Fayette C	+	+	+	+
	Sum of +'s	5	5	6	6
	Sum of -'s	2	2	1	1
	Sum of 0's	0	0	0	0
	Net Score	3	3	5	5
	Rank	4	3	1	2
	Continue?	No	No	Yes	Yes

							Scoring
			SIP's		Siding		
	Selection Criteria	Weighting	Rating	Weighted Score	Rating	Weighted Score	
1	Easy Installation & Mintenance	30%	5	1.5	5	1.5	
2	Inexpensive	10%	4	0.4	5	0.5	
3	R-Value of at least 38	30%	5	1.5	4	1.2	
4	Visual Appeal	5%	4	0.2	5	0.25	
5	Suitable for Fayette	10%	5	0.5	4	0.4	
6	Sustainable	15%	5	0.75	4	0.6	
	Total Score		4.85		4.45		
	Rating		1		2		
	Continue?		Yes		Yes		

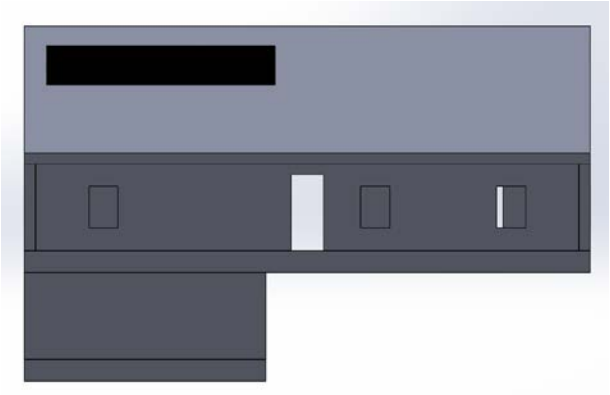


Roof Design

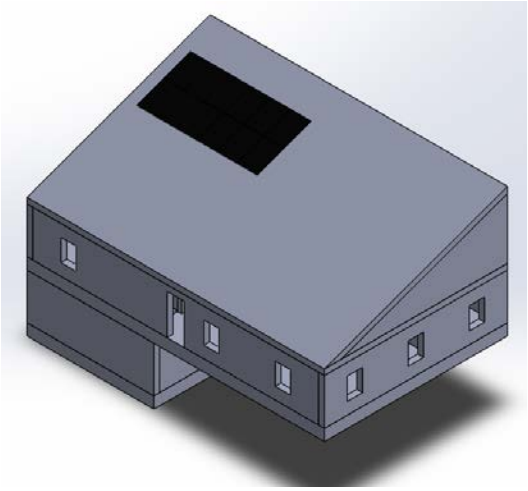
House views



- Back view
- Right view



Conclusion



Researching and designing our zero energy home was a learning experience that was beneficial to every group members. This project helped us develop skills that professional engineers will need on a daily basis in future.

As a group, we utilized each individual's creativity to the fullest in order to design our home. During the brainstorming process, we came up with a variety of great ideas to optimize energy efficiency.

Once we narrowed down those ideas, we selected the most useful ideas to be implemented in our project. Our group had modeled the home on paper initially, and then transferred it into a lively design on SolidWorks.

After much revision, we had created a home that can successfully produce more energy than it will consume. We have met all of the criteria, and fulfilled the customer needs for our zero energy house. Overall, we consider the project a success, and have gained some insight from the design of these unique homes.

Final Costs (Total: $185,956.00)

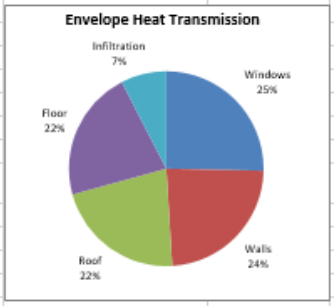
References

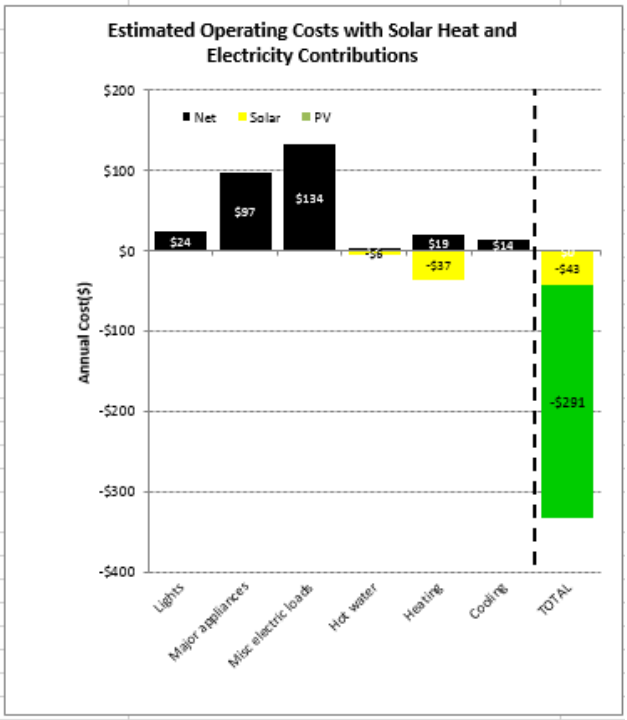
http://www.nrel.gov/gis/geothermal.html

Penn State Center for Sustainability — Zero Energy Home Calculator

General Info	
Location	Fayette
Electricity cost ($/kwh)	0.07
House type	1 story
Conditioned floor area (sq.ft.)	1500
Number of bedrooms	3
Envelope Details	
Wall construction	SIPs 12.25" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1500
North wall area (gross) (sq.ft.)	800
East wall area (sq.ft.)	360
South wall area (sq.ft.)	240
West wall area (sq.ft.)	360
North window area (sq.ft.)	30.67
East window area (sq.ft.)	30.67
South window area (sq.ft.)	30.67
West window area (sq.ft.)	30.67
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

Heating & Cooling	
Type of heating & cooling system	Electric geothermal heat pump
Solar Technologies	
Size of PV system (kw)	3.39
Solar water heater	Yes
Behavior	
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	68
Cool thermostat setting (F)	75
Results	
Base House Cost	**$ 152,630**
PV Cost	**$ 16,962**
Upgrade Costs	**$ 16,363**
Total House Cost	**$ 185,956**





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