Zero Energy Home

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EDSGN 100 Section 9

Team Number 1 (Team PSU)

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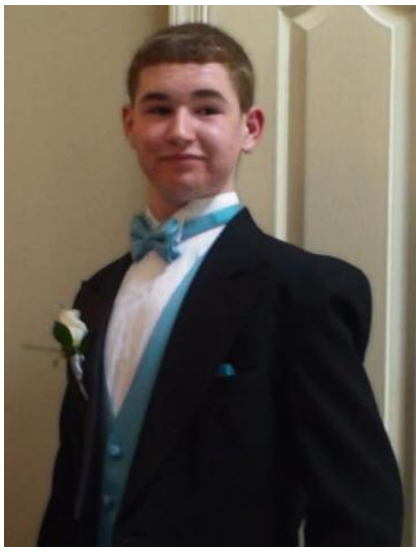

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Abstract

Our group has created a zero energy home that will provide a comfortable living space for a family of four while using less energy than it creates. The final design of the house we created was based on meeting customer requirements while being reasonable. The house has solar panels on the roof since solar energy is the main energy source. There is also a geothermal system incorporated into our house to provide heating and cooling into the house. The house is located in Pittsburgh, PA with square footage of about 1500 sq. ft.

Introduction

Most homes in the world are using fossil fuels in order to generate energy and power for the homes to use. However, not only are fossil fuels costly, but they are also harmful to the environment. Zero energy homes are being created to try to prevent some of the harmful effects that the fossil fuels are causing on the environment. Zero energy homes are designed to use zero net energy from utility grids. In order to do this, the home has to consume less energy than it produces for it to be considered a net zero energy usage. There are several ways that a zero energy home can achieve this.

To achieve the net zero energy, zero energy homes have to use renewable energy sources that may include solar, nuclear, hydroelectric, wind, geothermal, etc. Usually zero energy homes have multiple sources of renewable energy to keep the home from using energy from the utility grid. However, there are some houses that do just use one form of renewable energy sources as long as there is an abundance of that source. The majority of zero energy homes use solar energy and wind or geothermal energy sources in order to power the homes. Another way to achieve net zero energy is by energy efficient appliances like Energy Star into the house to keep the cost of energy lower. Zero energy homes often times have insulation material that is more effective than the typical American home. These are only few of the qualities that make up a zero energy home.

Executive Summary

The CASA Agency is interested in decreasing the carbon dioxide use of the world. A prototype is being developed on effective zero energy homes to help meet the goal. Each year nearly 6 billion metric tons of carbon dioxide by humans and average households in the United States used about 11,300 kWh per year. This is about 940 kWh per month for each household. However, zero energy homes would help produce as much energy as it consumes if not extra energy. The objective of this project is to design a zero energy home that will be able to produce enough energy to compensate for the energy used for a family of four. The zero energy homes will be made of green or eco-friendly materials while making the house still have an attractive appeal.

In developing the design, surveys and patents will be looked at to help guide the design of our house. Customer needs and zero energy homes specifications will be taken into consideration when creating designs for the home. The customer needs that will be taking into consideration are an energy efficient house, an inexpensive house that is low maintenance, and a house that can comfortable fit a family of four. The design will include energy efficient appliances, house set up that uses the least energy, and solar panels to help capture solar energy. One of the initial designs of the house was a two story house with 4 bedrooms and 3 bathrooms. However, the design that was chosen based on customer needs was a single story house with three bedrooms and two bathrooms with an open floor plan for the kitchen, dining room, and living room.

Several risks are present with this prototype design. The highest risk that is present is solar energy not being able to provide enough energy to the house especially on non-sunny days. This risk will be lowered by have two backup energy systems. One backup will be another source of energy that economically friendly and the other will be electrical energy like average homes have. Another big risk is making a zero energy home within the budget of $200,000. To help stay within the budget, the materials and appliances that are chosen need to be within a reasonable budget to help reduce the cost of the project. The final prototype is scheduled to be delivered to CASA Agency on October 16, 2013.

Mission Statement

Our mission for this project is to design an energy efficient home that essentially uses zero net energy while maintaining a house design that is aesthetically appealing. The house will also be designed to be comfortable fit a family of four while staying on the small size in order to keep energy cost and cost of the home down. To do this, we will use renewable energy sources, energy efficient appliances, and insulation that will contain heat in winter.

Customer Needs Analysis

Customer Needs	Need Statement
I want to use less energy.	The house will use renewable energy.
I want a house that fits a family of four.	The house will have 2 bedrooms and 2 bathrooms while maintaining energy efficiency.
I want windows.	The house will have windows on each side of the house to allow light and heat to come into the house.
I want an appealing house.	The house will be built to have a nice appearance while being energy efficient.
I want a house that is low maintenance.	The house will not need constant work and upkeep because it will be smaller.
I want a house that is not too expensive.	The house will be priced reasonably for the amenities that are included in the house.
I want a house that is durable.	The house will use durable but uses efficient material that could possibly be reused.

Our customer needs were based off of two surveys that we created. We asked simple questions about prices of houses, the interior design of the house, energy efficient appliances, and renewable energy sources for the main source. We found that most customers wanted a house that uses renewable energy, but they wanted the house to still have a nice appearance and suitable for their families. They also wanted a house that was not too expensive and over budget because of the energy efficient features.

External Research

Benchmarking

Our group researched zero energy homes that are already built and being used by families. We found a house in Ann Arbor, MI that has some of the same ideas and concepts that we plan to use in our zero energy home. This zero energy home in MI has slightly bigger conditioned square feet of space than our design. However, the house has 3 bedrooms and uses solar panels along with geothermal heating and cooling for the energy supply. This house produces less than 10,000 kWh annual and that is a goal for our house.

Location (city, state)	Ann Arbor, MI
House size (floor area in square feet)	2200 sq. ft. of conditioned space/ 1300 sq. ft. living space
Number of floors	3 floors
URL of web site where info is found	http://www.greenbuildingadvisor.com/homes/mission-zero-house-net-zero-retrofit http://www.treehugger.com/sustainable-product-design/americas-oldest-michigans-first-net-zero-energy-home-photos.html
Number of occupants	N/A
Number of bedrooms	3 bedrooms
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Solar panels, Geothermal Heating/ AC and Hot Water
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Sun Power Solar system, water, and electricity
Size of photovoltaic system (kilowatts)	8.1 kW
Solar water heater (yes or no)	yes
R-value of wall insulation	R-13 Farmers dense-packed cellulose insulation
R-value of ceiling insulation	R-30 Demilec Sealection 500
Ventilation air heat recovery (yes or no)	Water Furnace Envision (3 tons)
Predicted or measured annual energy use	Less than 10,000 kWh
Any other pertinent info	Oldest net –zero energy house; The rooftop solar system is expected to generate 12.5 megawatt hours per year; the total cost of going net zero was $47,130; the improvements will eliminate $77,400 in energy costs over 20 years and the family will receive over $27,000 in renewable energy credits

Location

Location for a zero energy home is very important, especially when using renewable energy sources. If the zero energy home is using solar power as a main energy source, then it should be in a place that generally gets a decent amount of sun. In places that only get decent amount of sun will most likely have another source of energy in order to keep it a zero energy home. The location we chose was Pittsburgh, PA. On average, the amount of days that Pittsburgh gets sunlight is 160 days per year. Even though this seems like a low amount, many years Pittsburgh has more than 160 days of sun. When there are days with very little or no sun at all, the house will have a geothermal system to back up the energy source.

Information on Pittsburgh:

Estimated median house or condo value in 2011: $90,500

Mean prices in 2011:

All housing units: $126,766

Detached houses: $129,877

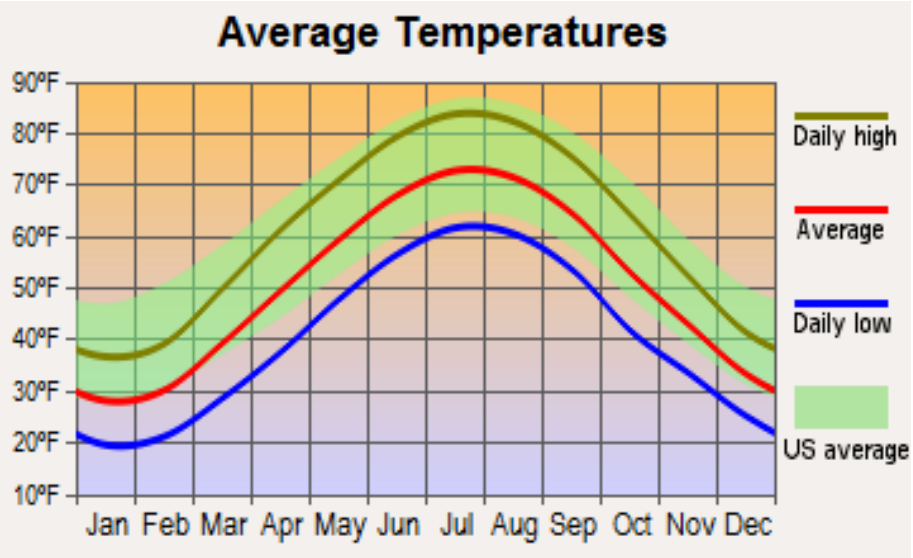
Townhouses or other attached units: $93,951

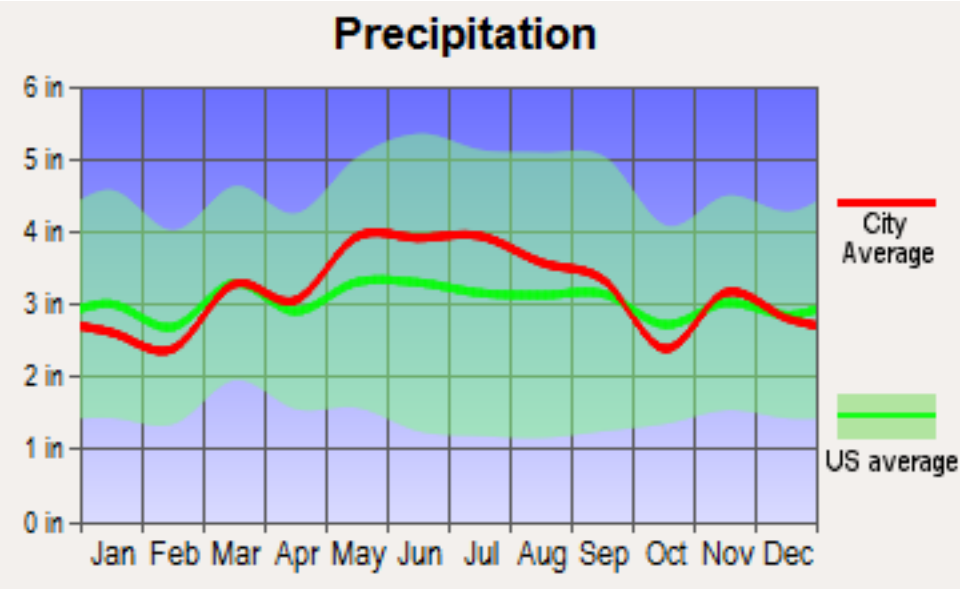
In 2-unit structures: $118,042

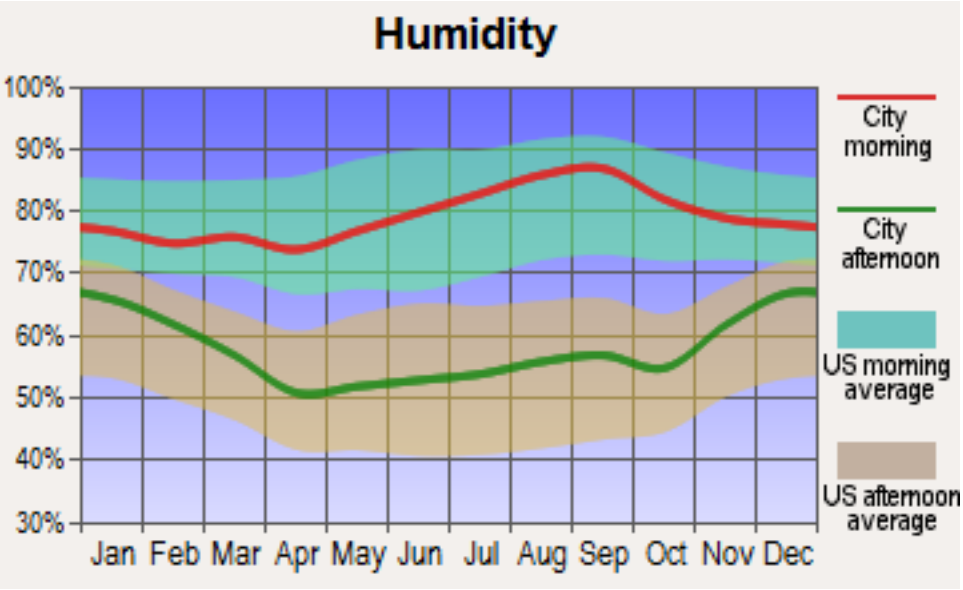
In 3-to-4-unit structures: $159,768

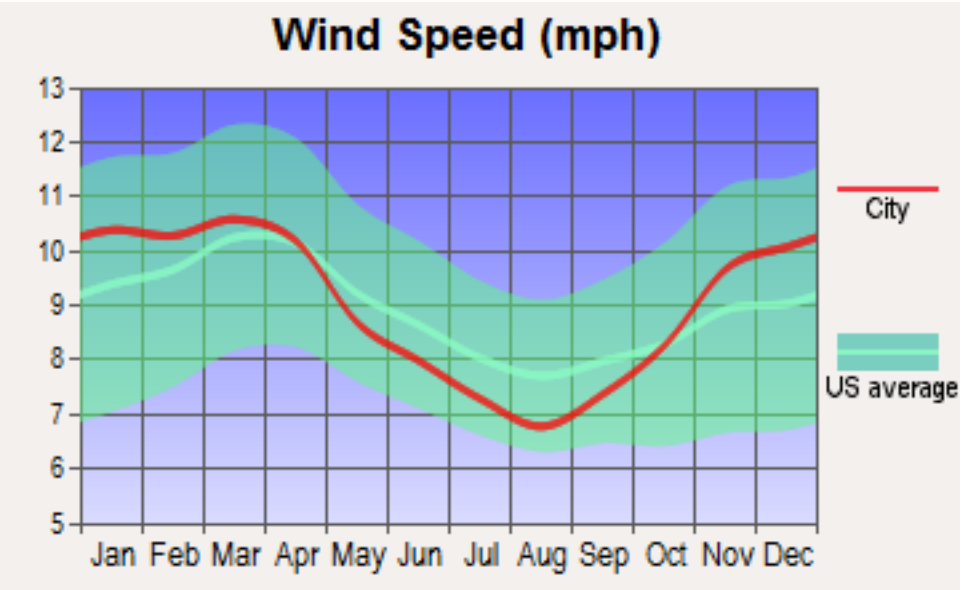
In 5-or-more-unit structures: $211,705

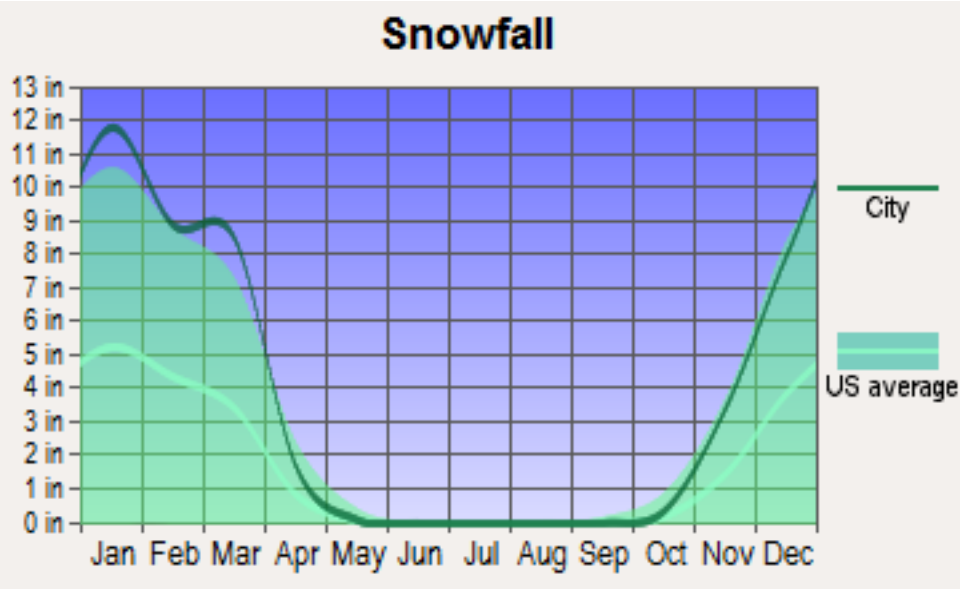
Mobile homes: $46,698

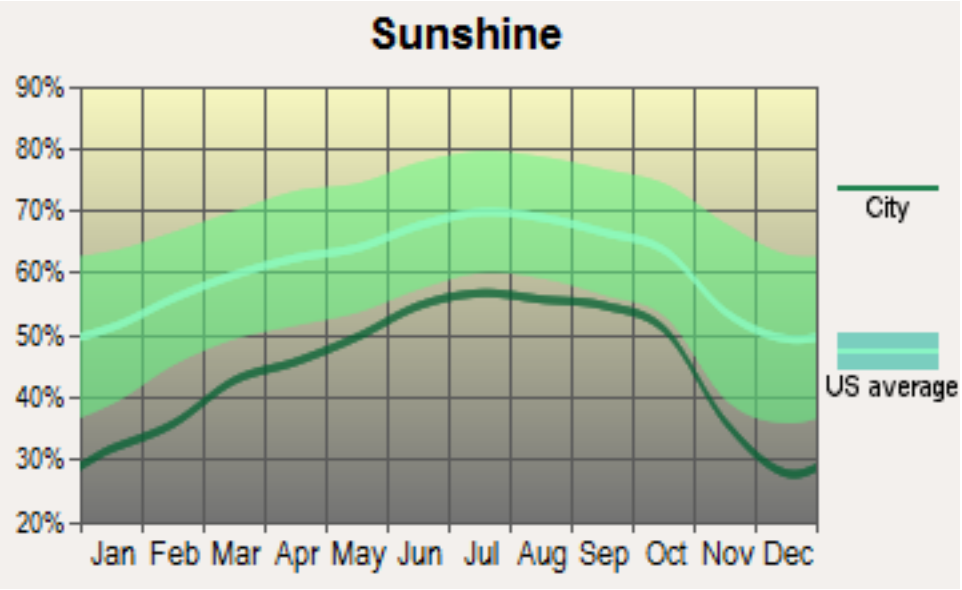



Precipitation
6 in
5 in
4 in
3 in
2 in
1 in
0 in
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
City Average
US average


Humidity
100%
90%
80%
70%
60%
50%
40%
30%
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
City morning
City afternoon
US morning average
US afternoon average


Wind Speed (mph)
13
12
11
10
9
8
7
6
5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
City
US average


Snowfall
13 in
12 in
11 in
10 in
9 in
8 in
7 in
6 in
5 in
4 in
3 in
2 in
1 in
0 in
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
City
US average


Sunshine
90%
80%
70%
60%
50%
40%
30%
20%
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
City
US average

Solar Panels

In our house, we chose to use solar energy as one of our main energy sources from renewable energy. Therefore, we completed research on various solar panels and companies that make them. The solar panels we are using for our house are the ones created by Mitsubishi Electric.

- They include photovoltaic modules which capture energy from the sun and use it as electricity to power the zero energy home.
- About 3.12 kW PV system will save annual energy of about the equivalent of 770 liters of oils.
- On sunny days, the PV models use the suns energy to power the house but also stores some in the utility grid.
- On cloudy days, it still receives solar energy but the power output is reduced, so it will need help from another energy source.
- The Mitsubishi Electric solar panels have a Bypass Diode function that allows the solar panels to minimize the effect of shadows on the solar grids, which allows the solar panels to still capture as much energy as possible.
- No cleaning is necessary of the solar panels.
- Individuals will be allowed to claim a federal tax credit of 30% of the value of the PV system.

Geothermal Energy

Geothermal energy used Earth's internal heat to produce energy that is usable for zero energy households. Geothermal energy can range from shallow ground water to hot water and hot rock that is found a few miles under the Earth's surface. Geothermal energy is the second renewable energy source that our house will use. The geothermal system we are using is produced by GeoComfort. Geothermal systems use geothermal heat pumps that are ground source heat pumps. They rely on the sun to heat the ground at Earth's surface to capture the energy. The process the geothermal system uses is essentially solar energy. Because the Earth absorbs 48% of sun's energy, the underground temperature is fairly warm which allows a water solution to flow through a ground loop system by absorbing heat from the Earth and moving it into the geothermal system inside the house. Once in the geothermal system, the heat is transferred through the pipes into the air to provide warm air. This process is for winter or cold days. When it is summer, the geothermal system takes heat from the house and transfers it through the same systems back into the ground.

- Most homeowners will have a 30% to 70% reduction in costs for heating and cooling.
- Geothermal systems have the lowest life-cycle cost of all heating and cooling systems according to the EPA.
- Geothermal systems are safe because there is no combustion causing no chance of explosion or harmful fumes that can cause poisonous toxins.
- Geothermal systems are able to capture reclaimed heat during heating and cooling modes and are able to use it to heat domestic water. This could reduce heating cost by 50 to 60%.

Renewable Energy Sources

Before we picked what renewable energy source to use for the house, we did research on the different types available.

- Solar: the solar photons can be converted to heat, electricity, or energy; costs about $0.16-$0.25/kW-hr
- Wind: motion of air molecules that can be harvested in wind turbines to spin and great electricity; costs about $0.10-$0.33/kW-hr
- Biomass: organic materials used to produce electricity; costs about $0.12/kW-hr
- Water: flowing water that can produce electricity; costs about $0.09/kW-hr
- Geothermal: uses Earth's internal heat to create heat and electricity; costs about $0.10/kW-hr

Global Marketplace

Many places in the world are starting to realize that using fossil fuels is becoming a real problem that needs to be stopped. Many countries are starting to implement zero energy homes into their culture in order to try to create a healthier environment. There are reports that in the upcoming years the net-zero buildings market will increase by $1.3 trillion by the year 2035. This increase in market value shows that there will be an annual growth rate of 43% energy efficient homes that are zero energy. Much of this growth will occur in European countries.

Concept Generation

Concept Selection

	Geothermal	Solar	Wind	Hydroelectric	Big House	Small House	Many windows
Cost	0	0	-	-	-	+	-
Energy Efficient	+	+	+	+	-	+	+
Low Maintenance	0	0	0	0	-	+	-
Durability	+	+	+	+	+	+	+
Ease of Manufacture	0	0	0	-	-	+	+
Appearance	+	+	-	-	+	+	+
Produces energy	+	+	+	+	0	0	0
Fits family of four	0	0	0	0	+	+	0
Sum +'s	4	4	3	3	3	7	4
Sum -'s	0	0	2	3	4	1	2
Sum 0's	4	4	3	2	1	1	2
Net Score	4	4	1	0	-1	6	0
Continue	yes	yes	no	no	no	yes	yes

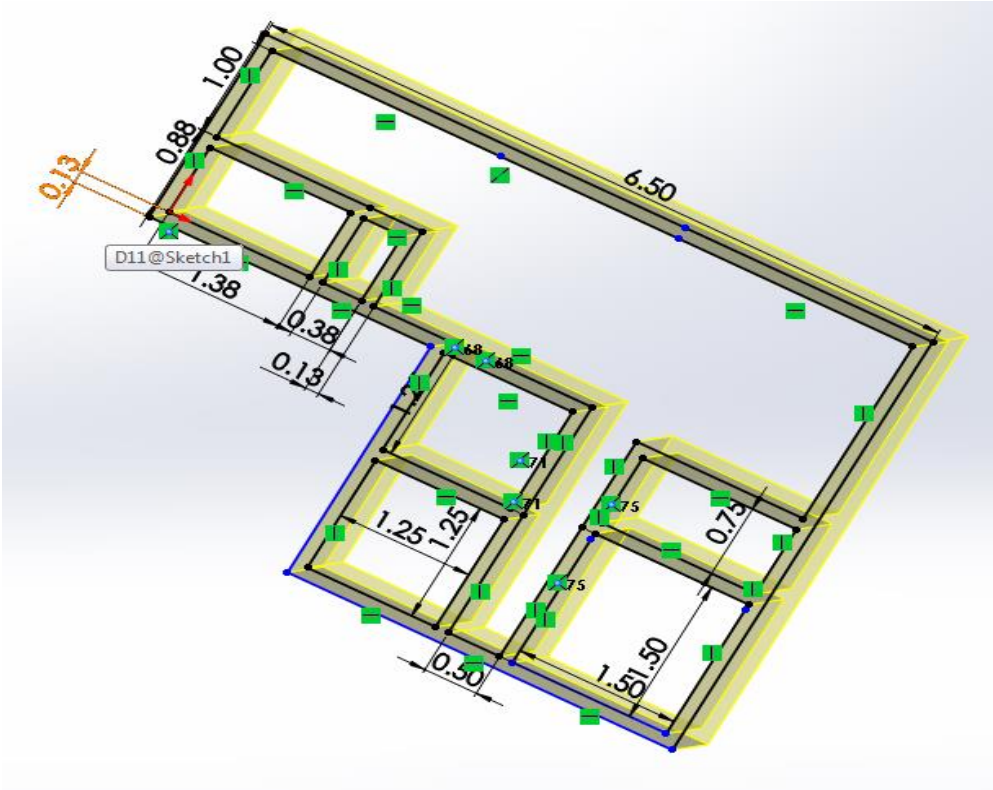
Our concept selection was based on the customer needs. We need to evaluate the types of renewable energy, the size of the house, and the amount of windows that the house would have. We compared these with respect to cost, energy efficiency, suitable for a family of four, and appearance.

Concept Scoring

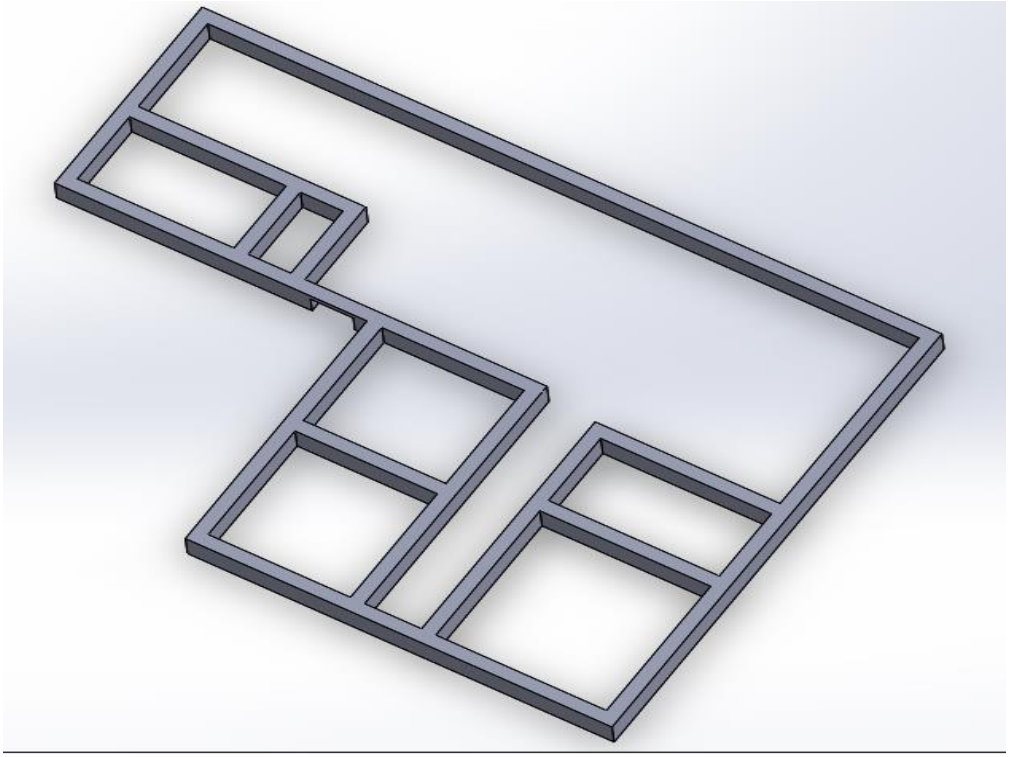
Concepts							
		Solar		Wind		Geothermal	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Cost	15%	4	0.6	3	0.45	4	0.6
Energy Efficient	25%	5	1.25	4	1	4	1
Appearance	10%	4	0.4	3	0.3	4	0.4
Durability	15%	3	0.45	3	0.45	4	0.6
Ease of Manufacture	10%	3	0.3	2	0.2	4	0.4
Low Maintenance	10%	3	0.3	3	0.3	3	0.3
Produces Energy	15%	4	0.6	4	0.6	4	0.6
	Total Score	3.9		3.3		3.9	
	Rank	2		3		1	
	Continue	yes		no		yes	

We took the renewable energy sources that we thought would be suitable for our house and put it on a weighted scale to see which energy source we would actually use. Once we completed this concept scoring matrix, we decided that solar and geothermal energy would be the best option for our house.

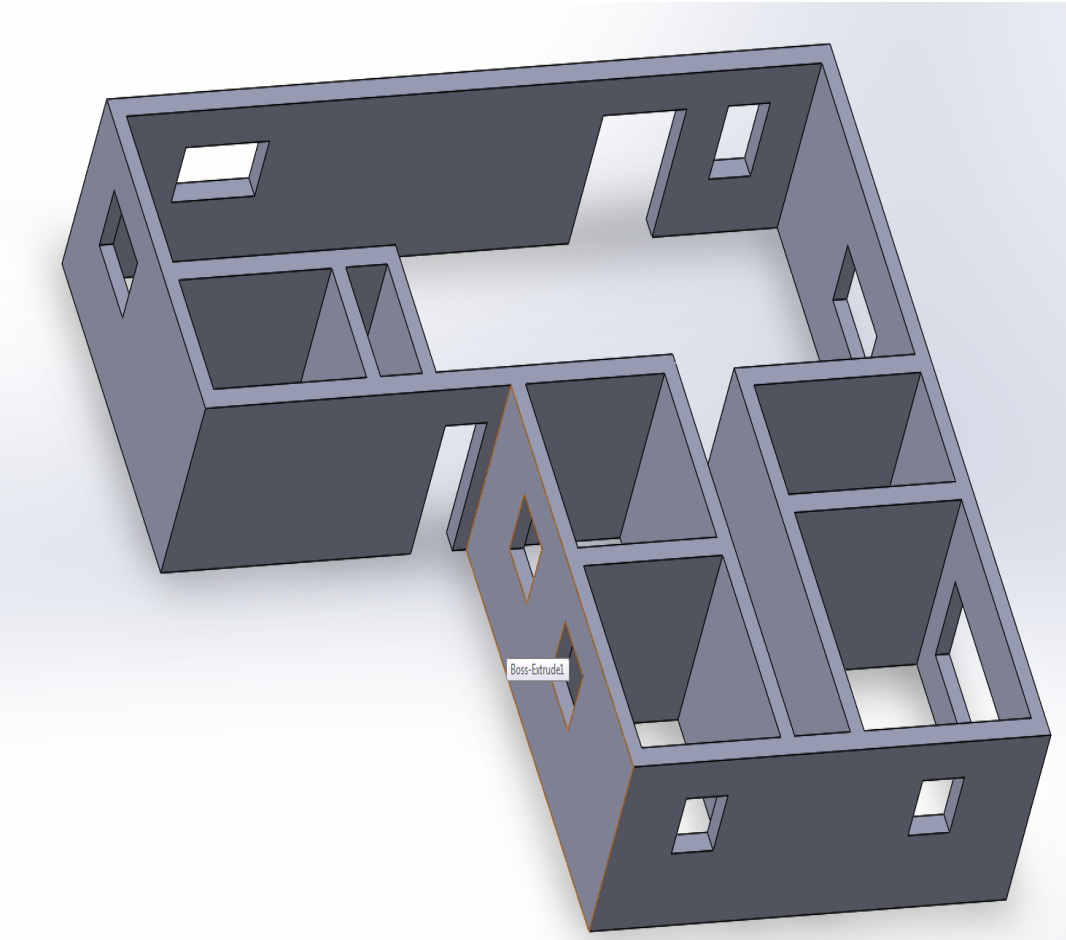
House Designs and Sketches



This is a sketch of our house with all of our dimensions. The dimension scale we used was 1/8”=1’.



This is an interior view of our house. This shows the floor layout of the bathrooms, bedrooms, and kitchen and dining room along with the living room.



This is an interior and exterior view of our house. This shows the rooms again along with the height of the house and windows added on the outside.

Zero Energy Home Calculators

Penn State Center for Sustainability

General Info

Location	Pittsburgh
Electricity cost ($/kwh)	0.1
House type	1 story
Conditioned floor area (sq.ft.)	1514
Number of bedrooms	3

Envelope Details

Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R40
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1610
North wall area (gross) (sq.ft.)	468
East wall area (sq.ft.)	342
South wall area (sq.ft.)	468
West wall area (sq.ft.)	342
North window area (sq.ft.)	18
East window area (sq.ft.)	30
South window area (sq.ft.)	66
West window area (sq.ft.)	21
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

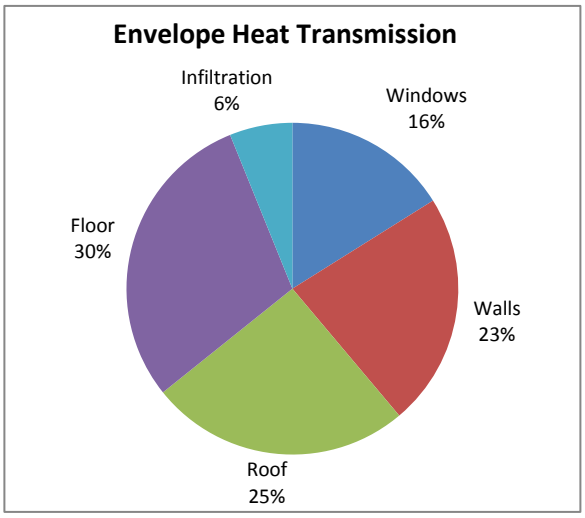
Solar Technologies

Size of PV system (kw)	4.71
Solar water heater	Yes

Behavior

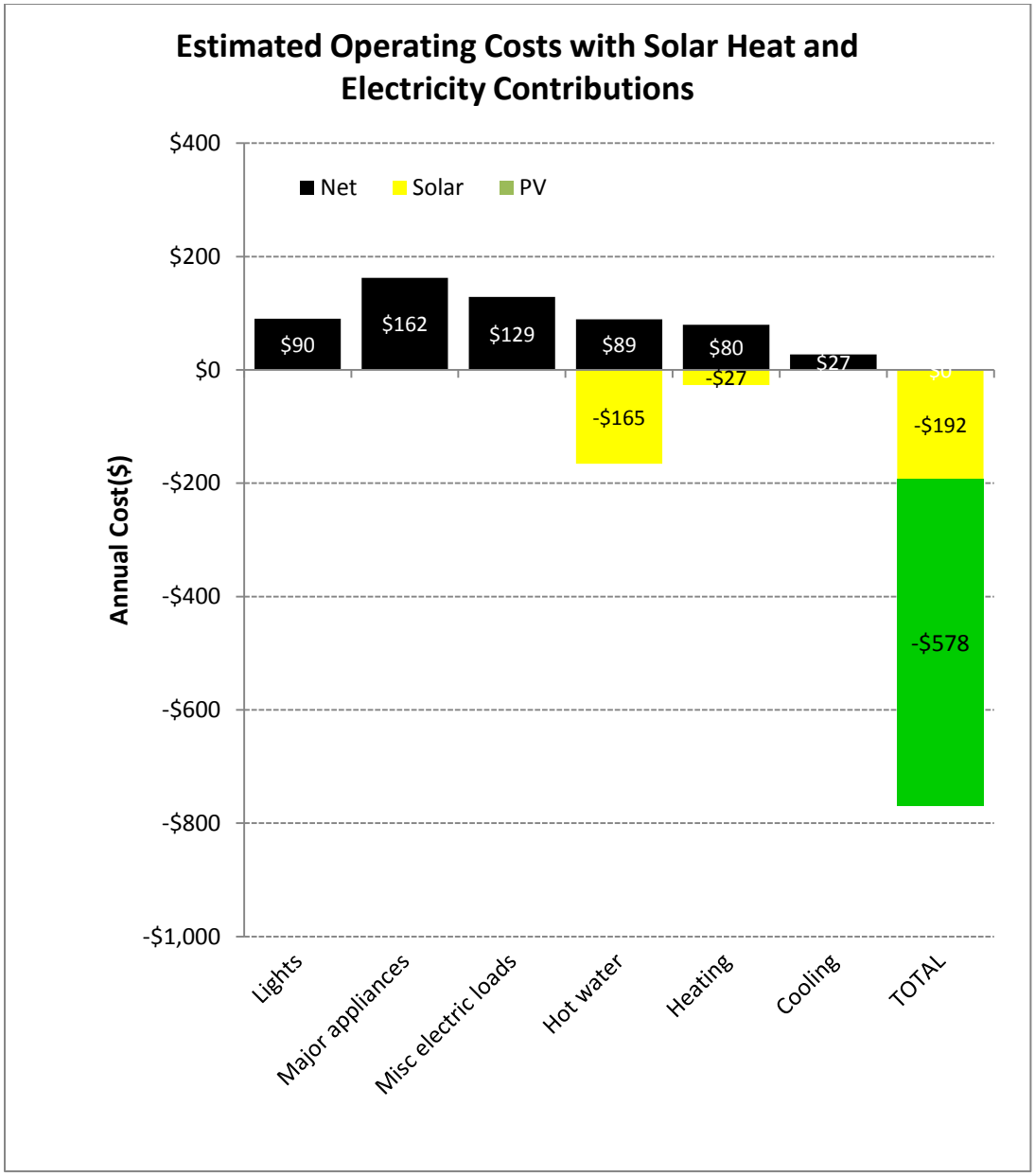
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	70
Cool thermostat setting (F)	76

Results



Base House Cost	**$ 153,556**
PV Cost	**$ 23,553**
Upgrade Costs	**$ 20,191**
Total House Cost	**$ 197,299**

ZEH Calculator Continue



Final Design Description

The budget for this project was $200,000 and our house with all of our amenities came in at a total of $197,299. Our final design of our house ended up being a single story house with 3 bedrooms and 2 bathrooms. It will comfortable fit a family of four. There is an open floor plan for the kitchen, dining room, and living room. The energy efficient appliances we will use are Best brand. This brand may not be the best for energy efficiency; it is efficient enough and keeps the house under budget. We also have solar panels on our roof to provide us with solar energy to maintain our house. We also have geothermal pumps in our house to help control the heating and cooling of the house. Our house also includes many windows to allow the sunlight to not only light the house but heat the house directly.

Conclusion

Our group successfully designed a zero energy home to meet the budget of $200,000 while meeting the needs of our customers. Our home is going to be energy efficient while be aesthetically appealing. The house will not only be a net zero energy home, but it will give back some energy to the environment. Most of the budget went into the layout of the house and the solar panels. The homeowners of our house will be able to take tax credit because of the zero energy consumption that their house will be using.

Our house would definitely be a house that customers would want to live in to not only save them money but to also help the environment. Hopefully with the design of our house, people all over the world will be able to use our zero energy home which will one day help to decrease the harms we are doing on the environment today.

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