Zero Energy Home

The Tim Allens

Engineering Design 100

Section 020

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Abstract

The purpose of the Zero Energy Home project is to design a self-sustainable home. The home should be capable of powering itself without connectivity to an electrical power grid. Over the past few weeks, our team has used the engineering design process to create a desirable Zero Energy Home within a $200,000 budget.

Introduction

Sustainability is a point of emphasis in today's society. It is well known that the human race has been harming the planet through emissions and pollution. The overuse and inefficient use of energy that humans are known for needs to be stopped in some way. The Zero Energy Home provides a technologically advanced home that emits zero emissions or pollutants, and sustains itself through its own energy intake. A widespread construction of Zero Energy Homes would decrease energy dependence on nonrenewable resources immensely. The house also allows a family to never have to worry about paying for energy bills.

Mission Statement

In building our Zero Energy Home, our goal was to build a home that would not only meet, but exceed the customer's requirements. Our Zero Energy Home provides an efficient, technologically advanced, and desirable home for our customers, which is also good for the well-being of the environment.

Customer Needs Analysis

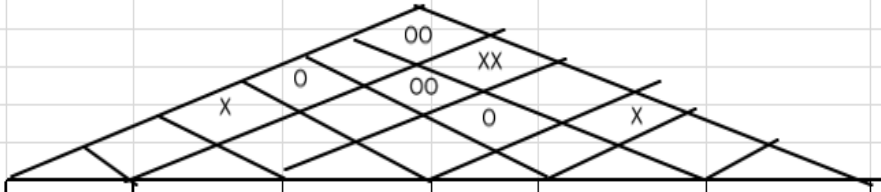
There were multiple customer needs that we had to think about when it came to the design of our Zero Energy Home. Some of these customer needs included: a Pennsylvania location, capable of housing a family of four, Zero Energy, sustainable, total cost under $200,000, and desirable to live in. Overall, the customer wanted us to create a house that was technologically advanced in the area of energy efficiency, consumption, and intake (by implementation of renewable resources), that also did not sacrifice a modern look and feel.

In the engineering design process, it was crucial to constantly review our concepts and plans to assure that they were fitting to the customer's requests. As a result, we created a house with a comfortable square footage that effectively utilized all of the space given to make the house feel as large as possible. We had to focus on and prioritize the customer's needs in order to design the perfect Zero Energy Home for this family.

External Research

One of the first steps in the process of our home designing process was selecting a sensible location in Pennsylvania for the home. In order to determine what location would make the most sense, it was critical to analyze the effectiveness of each main renewable energy source in different areas of Pennsylvania. In general, the use of windmills to power a single home in Pennsylvania is not ideal. There are not consistent or strong enough winds to sufficiently power a home in a cost-effective manner. The use of hydroelectric energy was a possibility, but it would be notably more expensive to implement than other options. As a result of the other two options' shortcomings, it was decided that the use of solar panels would be the most sensible for our house. Due to this, it made sense to find an area in Pennsylvania with a comparably higher solar map compared to the rest of the state. According to the National Renewable Energy Laboratory, the southeastern area of Pennsylvania is exposed to more sunlight and more intense sunlight than most other locations in the state (Solar Maps). Using this knowledge, this location was determined to be more than reasonable to build our Zero Energy Home.

Benchmarking/House of Quality



Direction of Improvement								Competitive Evaluation				
	Technical Characteristics (How) / Customer Requirements (What)	1550 sq. ft	Solar Panels	Insulation	Natural Light	Energy Efficient	Aesthetics	X - Us A - Competitor A B - Competitor B (5 is the best) 1	2	3	4	5
Relative Importance												
10	Zero Energy		OO	O	O	O	X					XAB
10	Maximum $200,000	O	X		O	X	X		B	A		X
10	Family of Four	O									XA	B
10	Located in PA		O			X	O	AB				X
7	Sustainable	O	OO	O	O	O	O					XAB
8	Suitable			OO	X		OO			X	A	B
Importance weighting		3	5	4	3	5	3	1	2	3	4	5
Target Values		Make House	Eliminate Energy Dependence	Make House Suitable/Efficient	Lower Heat Costs	Cut Energy Needs	Desirable To Live In					
Technical Evaluation		XB	X	B	XAB	XA	A	5				
			AB	X		B	XB	4				
		A		A				3				
								2				
								1				

1(low) - 5(high)

Importance Scale

8 - strong

3 - medium

1 - small

OO- Strong Positive

O - Positive

X - Negative

XX - Strong Negative

When designing our home we looked at several other zero energy homes that we used to benchmark. The two homes were located in Seattle, WA (Home A) and Devens, MA (Home B). In the house of quality, we compared our house to these two homes.

In regards to meeting customer needs, we succeeded in meeting all of their requirements. Compared to house A, we had the exact same evaluation, however, Home B overall received a better rating. Home B had better evaluations in almost every customer need, specifically in keeping the price of the house down.

Through the benchmarking process we were able to compare our home's technical characteristics to the other homes'. Overall, we had an equal evaluation compared to homes A and B. Our home's successful implementation of solar panels brought in more energy than the other houses, providing our residents to still use a suitable amount of energy

Concept Generation

	Solar Energy	Geothermal	Wind Energy	Hydroelectric	Large Windows	Insulation	Energy Star Appliances	Solar Water Heater
Practicality	5	3	2	2	5	5	5	3
Efficiency	5	4	2	1	4	5	4	4
Effective in Pennsylvania	4	4	2	2	5	5	5	4
Sustainable	4	4	4	3	5	4	4	4
Cost-Friendly	4	2	3	2	4	4	4	4
Total	22	17	13	10	23	23	22	19
Used in House	Yes	No	No	No	Yes	Yes	Yes	Yes

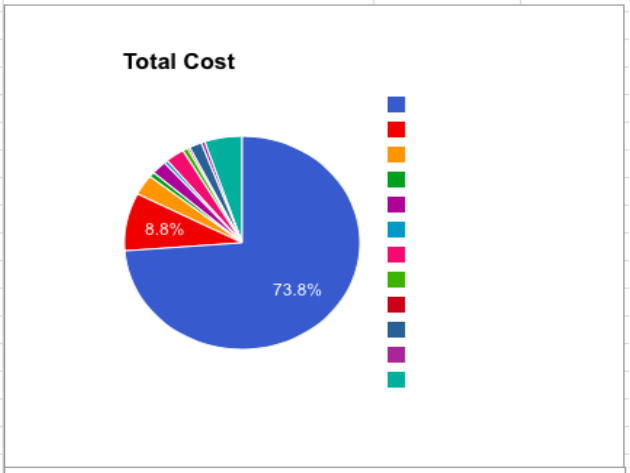
Throughout the process of concept generation and selection, we prioritized the usefulness and practicality of each possible way to optimize the efficiency of our Zero Energy Home. We started out by evaluating the effectiveness of today's main renewable/green resources in our specific home. A geothermal heating system generally made sense to implement in our house, but its high price strayed us away. There is not nearly enough wind in Pennsylvania to make windmills effective in our home, and our house is not near a useful water source to utilize hydroelectric energy. As a result of the ineffectiveness of these renewable resources, the use of

solar energy became the root of our Zero Energy Home, and it sufficiently provides more than the necessary amount of energy needed to power the home throughout the year.

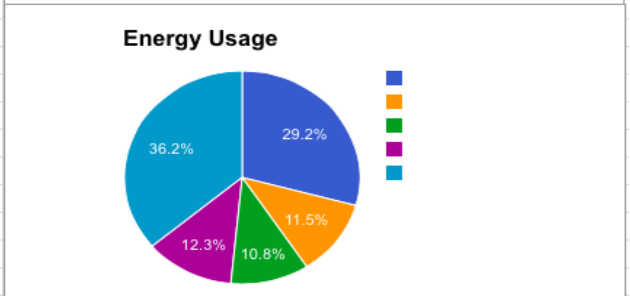
Along with deciding the energy sources for the home, we also had to decide what technologies we could use to further the efficiency of the house. The use of large windows allows natural light and heat to enter the house, which lowers the electricity and heating bills. In order to prevent the home's temperature from rising to an uncomfortable level, a simple installation of blinds and curtains can be implemented, along with our Smart House system. We also noted that in order for a house to be efficient in its heating and cooling, it needs to be well-insulated. Our insulation more than does the required job as far as preventing heated or cooled air from escaping the house. The use of Energy Star appliances and HVAC system was an obvious choice, as they cut down on energy usage, and also were well within our price-range. Also, a solar water heater is easy to implement onto the roof to further the efficiency of our water systems.

Concept Selection

House Products	Cost ($)
Housing Base Cost	$143,000.00
Solar Panel	$17,000.00
Appliances	$6,000.00
TVs	$1,500.00
Trees	$4,000.00
Plants	$1,000.00
Windows	$5,000.00
Lighting	$1,400.00
Solar Storage Battery	$600.00
Solar Water Heater	$3,300.00
Smart House System	$1,000.00
Miscellaneous	$10,000.00
Total	**$193,800.00**



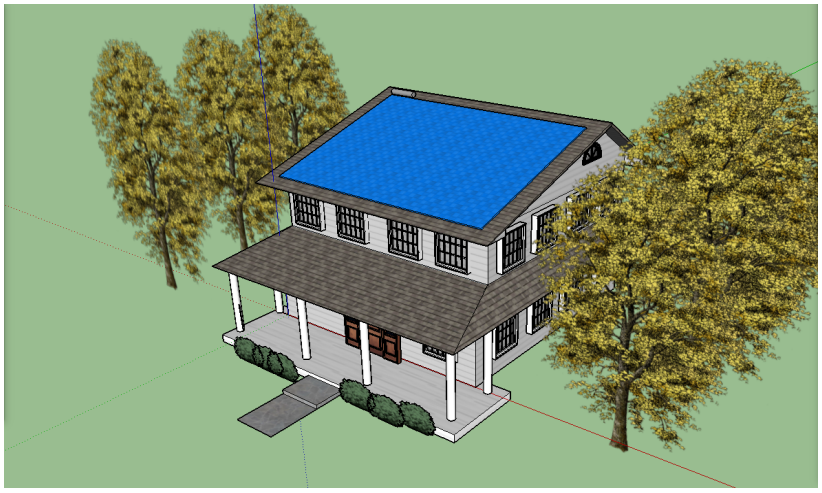
House Products w/ Energy	Energy Consumption (kWh) per month
Appliances	190
Solar Panels	0
TVs	75
Lighting	70
Solar Water Heater	80
Miscellaneous	235
Total	**650**



For the final concept selection of our zero energy home, we decided to use solar energy to make our home fully functional and sustainable. In order to power our house with solar panels, we calculated that we needed 528 square footage of solar panels which would cost $17,000 (Wholesale). The construction of the actual home itself will cost $143,000 based on estimates of other homes and what our group determined would be necessary for the construction of our home.

The appliances in the home cost $6,000 which include the washer, dryer, fridge, oven, microwave and dishwashers that are necessary for the day to day life of the family. Along with the appliances, the TVs in the house cost $1,500. We then added large, dense trees to the side of our house to provide natural shielding from excess sunlight and wind. Our windows are Energy Star and are specially designed to let in natural sunlight, while also keeping the house well-insulated (Energy). The lighting used in our house includes: 20 LED lights, 10 fluorescent light bulbs and 10 incandescent light bulbs. The price of these bulbs plus the cost of the chandelier located above the dining room table total to around $1,400. We decided on these light bulbs to maximize the light and minimize the cost of lighting for our home. We used LED lights because they are the most energy efficient and are effective over long periods of time (Benefits). Fluorescent light bulbs were used for room overhead lights and incandescent lights were implemented in areas where a lot of light is needed for a short period of time. Such areas include: vanity mirrors, closets, and other small areas. We also installed a solar water heater and a solar storage battery to efficiently heat our water using solar energy and a battery to store excess energy that is produced in the house during the months where the house will be getting more sunlight, and therefore producing more energy. Finally, in our home we installed a $1,000 smart house system that improves the efficiency of our house. The Smart House system turns off lights in rooms where they are not being used, sets heating and cooling temperatures to the most sensible setting, and more.

Embodiment Design and Final Design Description



This is the final design of our zero energy home. As one can see, it is a two story house. It is 784 square feet per floor, making it a total of 1,568 square feet for the whole home.

In our external design we decided to make the house facing south in order to acquire the most sunlight in a day to power our home. Our roof is not the normal triangle truss that are most commonly seen in homes. The trusses in this home are angled in a way to get more roofing per square foot on the front side of the home.

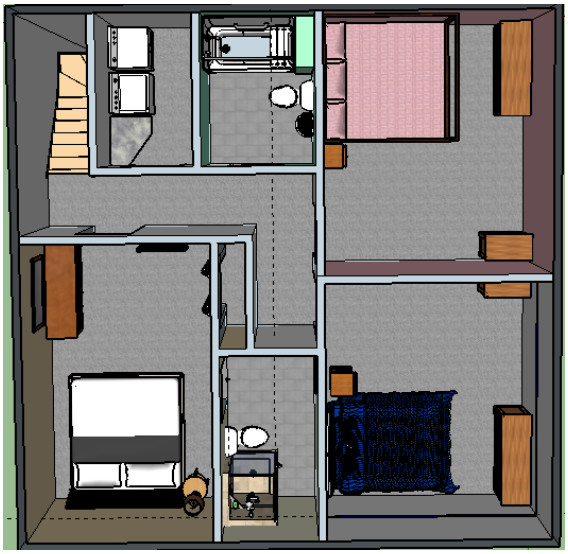
The installation of Energy Star windows was a prime component in the designing of our home. We recognized the importance of letting natural light into our house to cut our energy bill from lighting costs (Energy.gov). We also made sure that our windows' insulation was optimized to prevent air leakage, which helps minimize the use of the heating and cooling system in the house. Finally, we had to make the house aesthetically pleasing in order to meet customer needs. To do this we included a front porch for the family and a patio out back where the family can relax.

This is our interior design for the first floor of our zero energy home. This floor is 28’ x 28’, for a total of 784 square feet. We wanted to make the interior suitable for the family without sacrificing anything to save energy.

On the first floor we included a kitchen, a family/living room, dining room, and a half bath for the family. For optimum efficiency of heating and cooling, we utilized an open floor plan.

The first floor has a kitchen the is equipped with all Energy Star appliances in order to lower the total energy consumed in the home. It has all the appliances that are needed, like a microwave, range, refrigerator, and dishwasher. The family/living room has a couch, two sofas. and a television. The dining room has a six person table. The last room that is on the first floor is a closed off half bathroom, which includes a toilet and sink.

The first floor is comfortable and suitable for a family of four, while still remaining energy efficient.



This our interior design for the second floor of our zero energy home. This floor is 28’ x 28’, for a total of 784 square feet. This floor provides a comfortable living space for all the entire family.

The second floor has 3 bedrooms, 2 baths, and a laundry room. In order to not let the smaller size of the house hinder the quality of living for the family, the two kids will still each have their own bedroom. They will, however, share a full bathroom. The parents will, of course, live in the master bedroom. The master bedroom is equipped with a full bath and closet.

The bathrooms are engineered to minimize water use by means of low pressure fixtures. The water used in the bathrooms comes from the solar water heater located on the roof.

The laundry room has been conveniently placed on the second floor, for easy bedroom-to-laundry room delivery. The laundry room is equipped with an Energy Star washer and dryer.

Home Usage Guidelines

In order for the home to truly be a Zero Energy Home, the family of residence must understand that living in a Zero Energy Home does not mean that they can waste an abundance of energy. Responsible habits such as turning off appliances and other technology that is not in use, turning off lights when leaving rooms for extended amounts of time, and turning down air conditioning and heating systems when the house is unoccupied, are critically necessary. While

the Smart House system will assist in living this way, the family's active participation in energy efficient behavior is also necessary. If the family neglects to be mindful about their energy usage, they will run out of energy to use.

Conclusion

Our goal to design a zero energy home that is suitable for a family of four, under $200,000, in Pennsylvania and fully sustainable was realized through the design process of our home. As a group, we brainstormed some qualities our home would have based on our customer's needs and from there we determined which ideas would be essential to the design of our zero energy home. We achieved our goal by created a home that produces 850 kWh / per month while only using 650 kWh / per month in Downingtown, Pennsylvania, all under the cost of $200,000 (Microgrid). Throughout this design process we learned how to develop ideas to create a product that suits our customer's needs while remaining in the budget and making our product fully sustainable.

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