# Zero Energy Home

**Edesign 100, Section 14**

Team 3, Submitted to: Smita Bharti, 10/22/13

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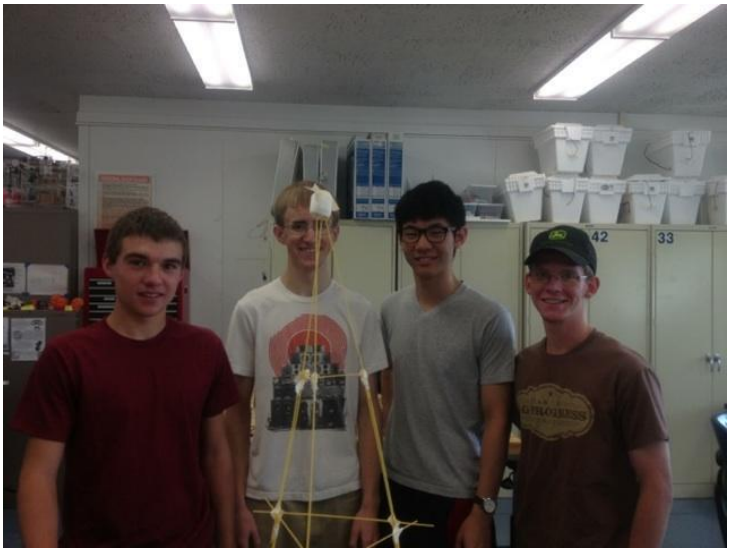
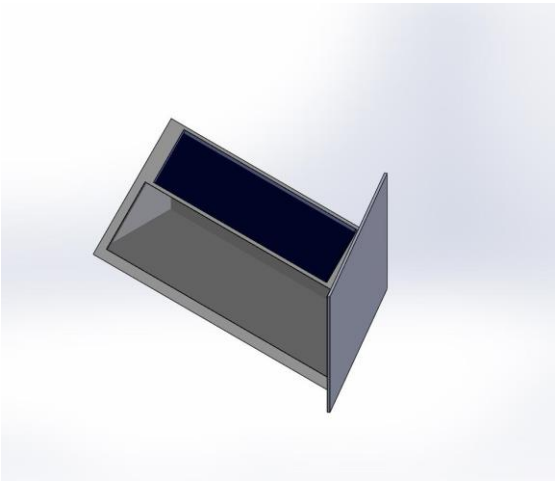




## Executive Summary

This project was the implementation of zero-energy design principles onto a real-world application. The building of a model home, as well as learning about energy-efficient techniques, helped us grasp what it means to be environmentally friendly while still maintaining a high-quality of living. Our group implemented the design process to design a zero energy home and produce a model of it. This helped our group grow as engineers, helping our skills develop by involving them with a real-world application.

## Introduction

The project in question was a culmination of implementing recent ideas of making homes with a zero net energy footprint, as well as the design and concept selection process. This project helped with drawing awareness to the importance, as well as relative ease, of making energy saving changes to a home. The project also focused on thinking critically on how to go about maximizing the energy gain of the home while minimizing energy costs, thus making the house overall neutral when it comes to electricity usage.

The main problem enveloped with this project is how to design a home in a State College, Pennsylvania climate that is ultimately zero energy. The main challenge comes from deducing the energy requirements, as well as thinking about how a home can be zero energy, whether it is through using less energy or producing its own on site. Implementing various passive energy savers, as well as active energy producers, into the homes design also called into question whether the design would be economically viable. Keeping these points in mind, we set about designing the best zero energy home we could.

In order to reach our goal of producing a viable option for a zero-energy home, we implemented aspects of the design process to aid us. This started with preliminary research into the topic, as well as brainstorming as a team to come up with possible concepts to meet our goals. After this, we narrowed down our concepts to a single selection which seemed to best fit our needs using a decision matrix. With a final design in mind, we built a model using principles we had learned about during the research phase, aiding us in producing a model that would perform well in the performance test that was set up for the class as a whole. This test aimed to evaluate the energy retention of different designs, producing data that would show what designs and concept yielded the highest heat gains, as well as the lowest heat lost over the duration of the test. Following the performance evaluation, we reflected on our data to see if there were any conclusions we could draw, as well as any changes that we wish we could have made. Culminating all of these steps, we learned firsthand what it means to think critically about a task at hand and work towards learning more about solving that question.

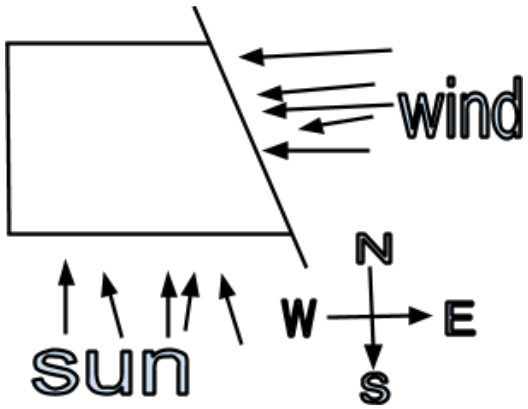
## External Research

First, we researched several other zero energy homes in a State College- like climate to give us examples of how other homes have been built. We researched homes in Charlotte, Vermont, Ottawa, Ontario, and Denver, Colorado. Through this research, we discovered that all of the zero energy homes had a very high R-value for insulation and were extremely airtight to minimize heat loss. The most important characteristic of all of the researched homes was that they were small in terms of square footage, which minimizes the amount of heat needed for the home and therefore minimizing the amount of energy the home uses. We decided to use the idea of a smaller home to design our zero energy home. We also attempted to make our home as airtight and well insulated as possible based on what we learned from our research. These homes that we researched served as valuable benchmarks for our design of our home.

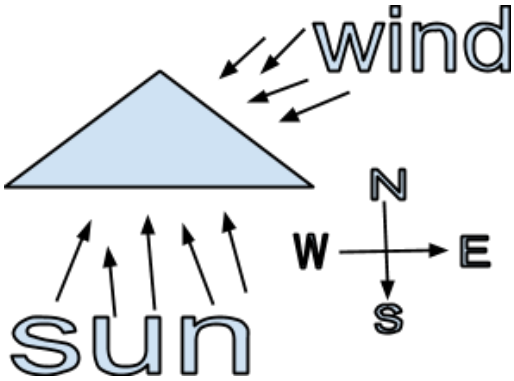
## Design and Energy Analysis

- *Concept Generation*

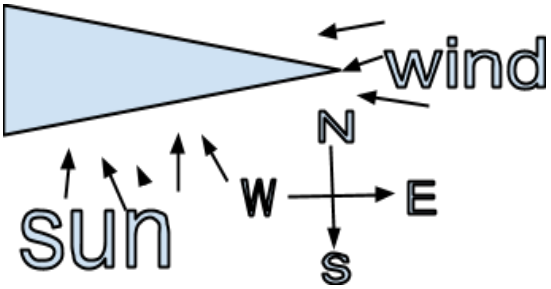
Design 1



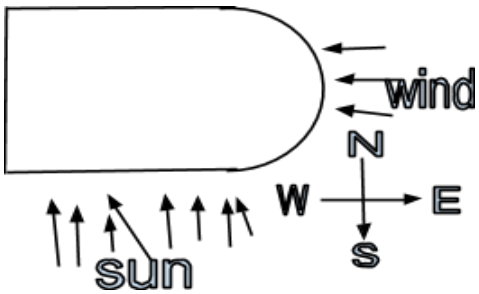

Design 2




Design 3




Design 4



- *ZEH Design Selection*

| Criteria | Standard House | Design 1 | Design 2 | Design3 | Design 4 |
|---|---|---|---|---|---|
| Window Area | 0 | 2 | 1 | 1 | 1 |
| Wind Deflection | 0 | 2 | 1 | 2 | 1 |
| Stability | 0 | 1 | 0 | 1 | 1 |
| Solar Panel Capability | 0 | 1 | 2 | 1 | 1 |
| Total | 0 | 6 | 4 | 5 | 4 |

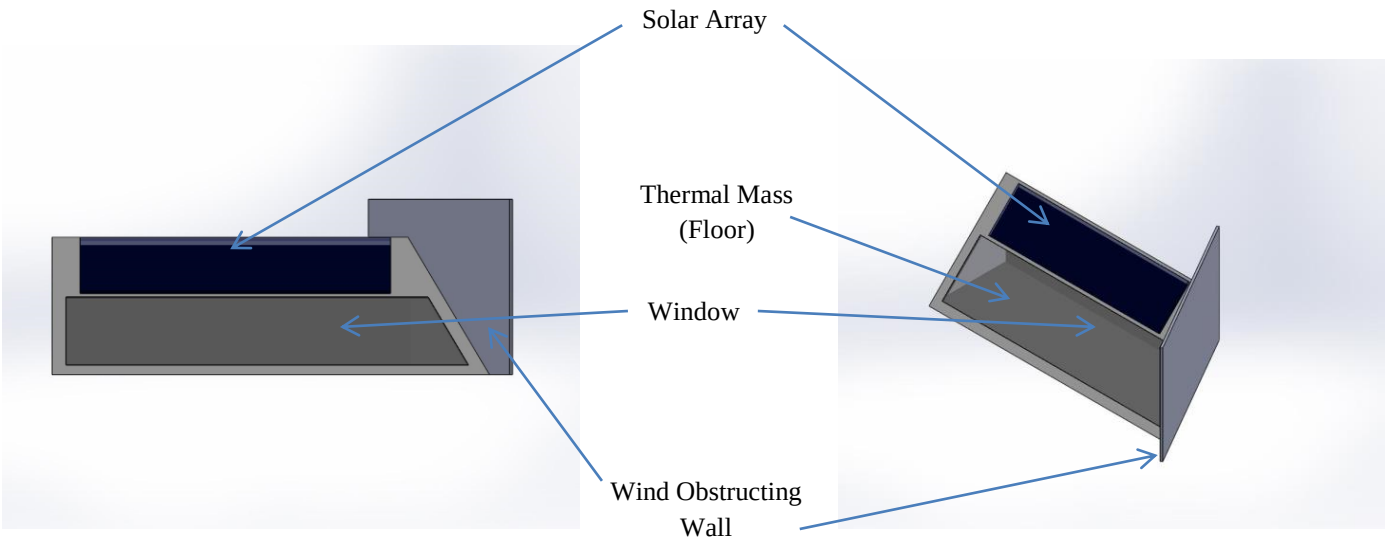
Using concept screening with a standard house as our reference concept, we chose design one for our house because it had the most effective wind defection and window area. There is also multiple solar panel capability. With this design we estimate an annual usage of about 5,400 KWH. To overcome this energy use and reduce it to zero; we installed a large window on the south side of the house to use the sun to heat the house. The energy still was not reduced to zero so we installed 5.1 kW solar panels on the roof to produce the remaining energy. Since the solar array required was so large, we had to reduce the size of the large sun-facing window so that enough solar panels would fit on the roof. We had to sacrifice the greater amount of sunlight for the proper size solar array to achieve a net-zero energy home.

- *Appliance Selection*

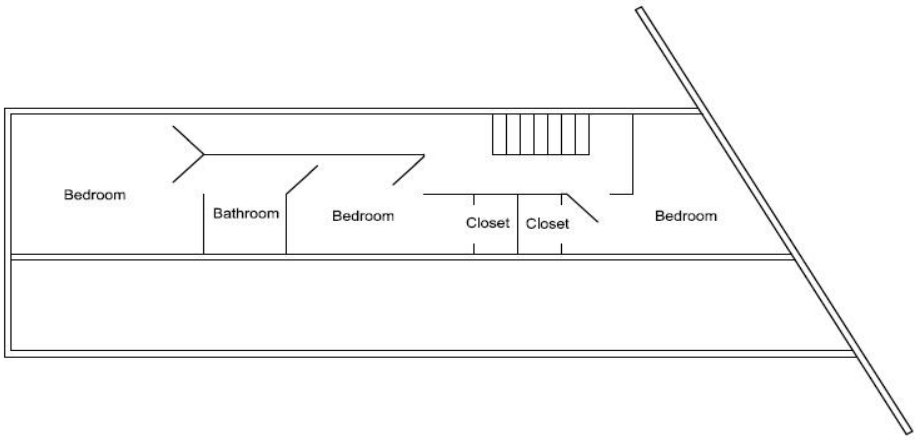
After each team member selected a possible energy efficient washer that could be used in the home, the Maytag MHW6000x washer was chosen because it had a lower purchase cost and a lower operating cost than the other washers, making it the most affordable option.

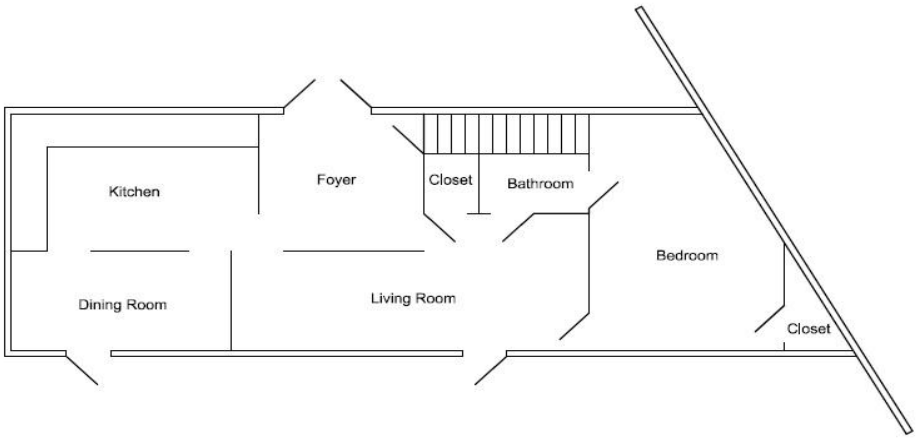
| Greg Ratzell Washer Basic Info | |
|---|---|
| Washer | LGWM3875H |
| Annual Energy Use w/ dryer | 580KWH/yr |
| Annual Water Use | 5.898 kgal ($23.56) |
| Price | $1350 |
| Payback Time(Compared to Jonathan's) | never |
| | |
| Jonathan Cisney Washer Info | |
| Washer | Maytag MHW6000x |
| Annual Energy Use w/ dryer | 542KWH/yr |
| Annual Water Use | 4.829kgal ($19.30) |
| Price | $999.99 |
| | |
| Kurt Lindhult Washer Info | |
| Washer | Samsung WF520ARGSWR/A2 |
| Annual Energy Use w/ dryer | 590 kWh/year |
| Annual Water Use | 5.589 kgal |
| Price | 1075 |
| Payback Time(Compared to Jonathan's) | Never ever |

## Solidworks Model




## Floor Plan



## Model Description

Our scale model was constructed using a 32 x 20-inch sheet 1/8-inch foam core board, 1 square feet. thin clear plastic, 4 square feet aluminum foil, 2 square feet thin rubber, 2 square feet black fabric, hot glue, tacky glue, and masking tape. The first passive feature of our model was the addition of a wind buffer. Since the wind blows from the east, a slightly angled wind buffer was erected out of foam core board to shield the roof of the house from the wind at night. This greatly reduces the amount of surface area of the model that the wind can blow over, which allows the model to conserve more heat at night because less will be absorbed by convection from wind blowing over the model.

Another passive feature of our model is the roof. Our north facing roof was constructed out of the foam core board because the sun does not reach the north facing roof as much as south facing roof because of the sun's path in the sky during the day. Therefore, the south facing roof was constructed out of a foam core board frame around a plastic window, which simulates the windows on the south side of the home that allow sunlight in to passively heat the home.

The thermal mass of our home was demonstrated in our model by using rubber as the thermal mass, which is the floor of our model. It is a passive feature of the model that absorbs heat when sunlight comes through the windows on the south side of the model during the daytime and helps keep the model warm at night by passively releasing heat. Inside the model, our team utilized aluminum foil as the walls to passively reflect light onto the thermal mass to make it warmer. The black fabric and aluminum foil were also used as insulators to assist the model in holding heat in for longer. Glue was used to seal holes and ensure that the model was as airtight as possible, which is important because it allows less heat from inside the model to escape.

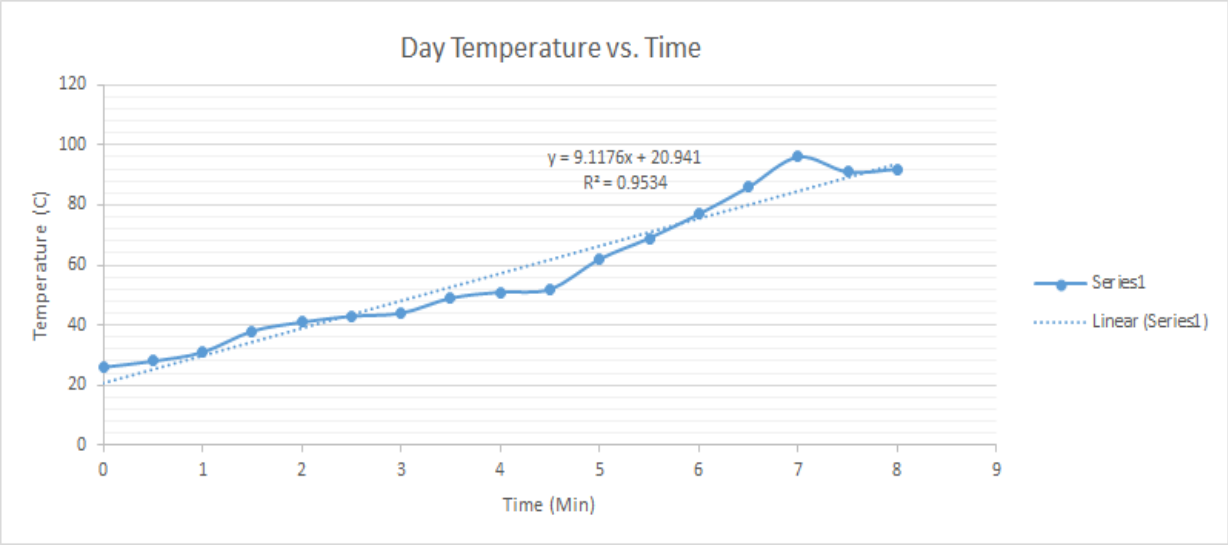
- *Scale*

The scale for our model is 1 square inch to 15 square feet. The scale is quite large to be able to accurately display the size of the solar panels needed to produce the energy required to offset the energy consumed by the home.

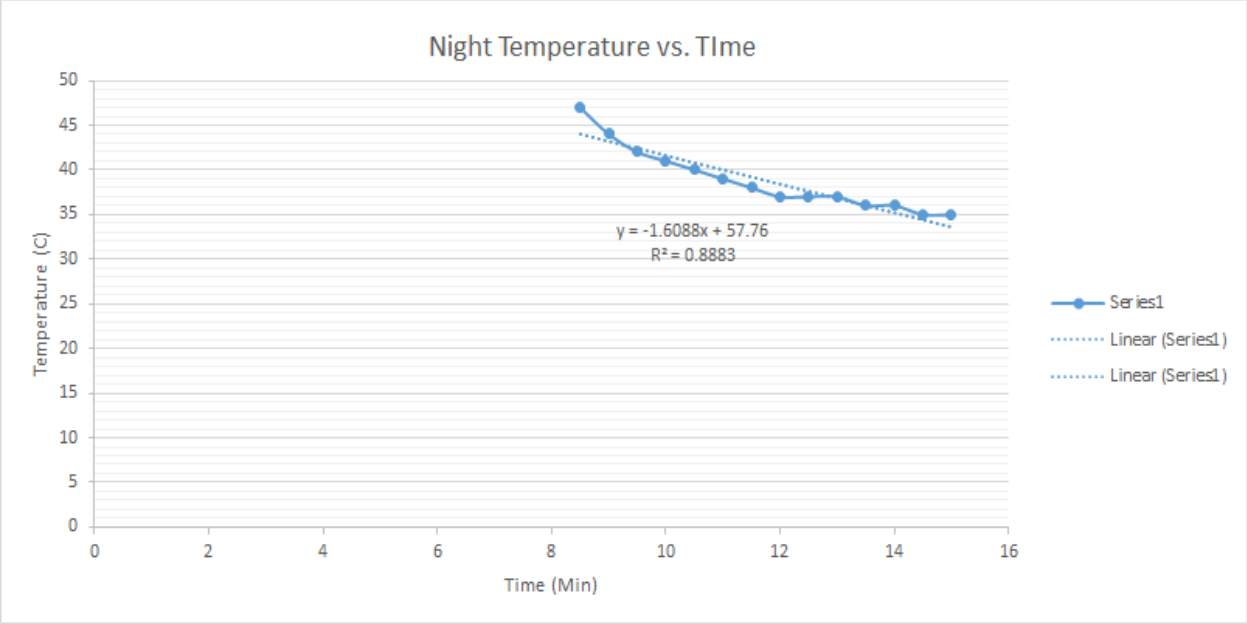
## Analysis & Results

The model of our zero energy home design was tested for heat retention by shining a light on it for eight minutes to simulate the daytime and then a fan blew cold air on the model for seven minutes. Each minute, the temperature inside the model was measured to determine how much heat the model was able to absorb during the day and retain at night.

The largest slope for our plot during the daytime was from 6:30 to 7, when the temperature rose from 86 C to 96 C. The slope of our graph during that time was 10/30 = 0.33 C per sec. (Increasing)




The largest negative slope for our plot during the nighttime was from 8:30 to 9 when the temperature decreased from 47 C to 44 C. The slope of our graph during this time was 3/30 = -0.10 C per sec. (Decreasing)

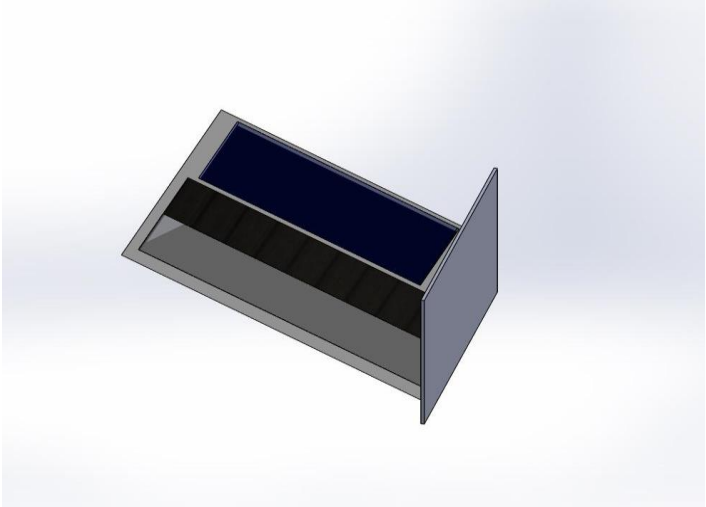


Our ZEH has the significantly greatest temperature gain during the daytime. However, when the sun is gone, the temperature decreased from 92 C to 47 C in 5 seconds. If we calculate from 92 C (the highest temperature in Daytime), we got the worst heat sustainability but if we calculate from 47 C, we got average heat sustainability compare to others'. Still, we got the highest final temperature. Compared to other groups' model homes, we obtained the highest numbers on daytime final temperature and nighttime final temperature. We got the most efficient house.

Our wind wall that blocked wind worked well on the eastward wall to deflect the wind. Other teams usually had a shutter to close at night time. In addition, other teams had more insulation on the roof because research suggested that zero energy homes have more roof insulation than wall insulation.

If we had the time and ability to make changes, we could add a` shutter on the window so that we can keep more heat in during the night time and control the amount of heat during the day so that the home does not overheat.

Isometric view with the blind added to the window:



# References

Brief definition about ZEH and some examples:
http://www.fsec.ucf.edu/en/research/buildings/zero_energy/

Evaluation about two houses in Northeastern United States:
http://www.collegepublishing.us/jgb/samples/JGB_V5N2_b01_hoque.pdf

Zero Energy Design website with some examples:
http://www.zeroenergy.com

Researched Zero Energy Homes:
http://www.nrel.gov/docs/fy08osti/42591.pdf
http://www.riverdalenetzero.ca/Riverdale_NetZero_house_--_project_profile.pdf
http://bit.ly/18xXvWQ
http://usat.ly/cQbdrS