Zero Energy Home (ZEH) Project

Nittany Builders Inc.

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Introduction

For our company's maiden voyage, Nittany Builders Inc.'s first project was to research and design a zero energy home. A lovely family of four commissioned NBI to design and test the ideal ZEH that was both comfortable and energy efficient. After assessing their needs, each member of NBI researched the basic components of a ZEH and then designed a home based off of this research. We then selected the best options and combined these ideas into a new design. A detailed analysis was conducted on the design and energy usage of the home. We built and tested a model of our home in a day/night simulation in order to assess our passive solar components. From this test we were able to pinpoint the flaws in our original design, and we will create a new design without these problems.

Our Goal - Abstract

Our goal is to design a home that is self-sustainable, meaning it creates as much energy as the homeowner uses. It has become clear to us that our resources here on earth are limited. We must start to ration them now if we want to continue to live here. Zero energy homes are one notable way to preserve our planet's resources. The purpose of these houses is to consume a net zero amount of energy over the course of one year. We hope to minimize energy intake in our homr by using energy efficient appliances. We hope to maximize energy production by using passive and active solar designs. The model will be assessed based on heat gain and conservation.

Mission Statement

Our mission is to design and create a model of a zero energy home for a family of four that will effectively maximize heat absorption and minimize heat loss.

Concept and Design

Research

Before designing our own home, we each did some research on other existing homes to gather ideas and to see what works best in a climate similar to Pennsylvania's. Here are some ZEHs we found.

Lincoln, MA

House Size	3400 sq ft
Number of floors	3
URL of website	www.zeroenergy.com/p_farrar
Number of occupants	Small family
Number of bedrooms	5
Type of heating system	Air source, heat pump, energy recovery ventilator
Size of photovoltaic system	13.8 kW
Solar water heater	No, heat pump hot water heater
Insulation	Thick walls and roof consisting of dense cellulose and continuous rigid insulation with triple-glazed windows
Annual energy use	Home produces 30% more energy than it uses
Other pertinent information	In the process of achieving LEED Platinum certification from the USGBC

Ithaca, NY

House size	1160 sq ft
Number of floors	2
URL of website	http://energy.gov/sites/prod/files/2014/10/f18/BA_ZeroEnergyReady_IthacaNeighborhoodHousingServices_062414.pdf

Number of bedrooms	3
Type of heating system	Radiant floor, condensing boiler
Main heating fuel	Electricity
Size of photovoltaic system	50 kW
Solar water heater	No
R-value of wall insulation	R-20
R-value of ceiling insulation	R-52
Any other pertinent information	Uses energy efficient appliances

Woodbridge, CT

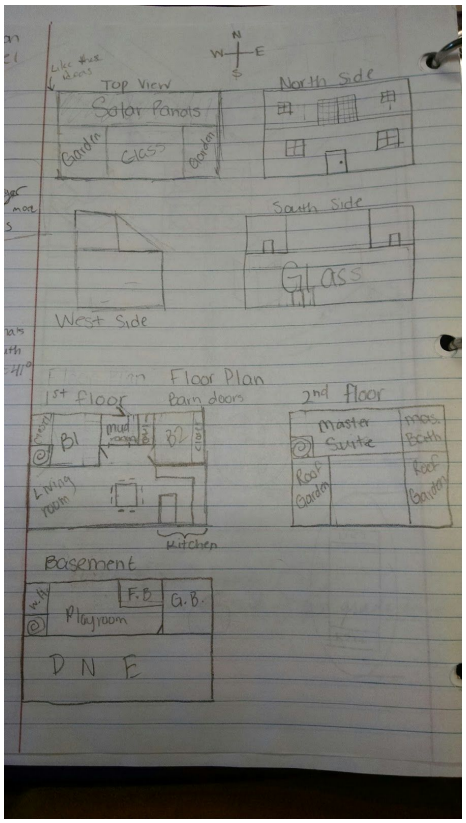
House size	4456 sq ft
Number of floors	2
URL of website	http://energy.gov/sites/prod/files/2015/06/f22/DOE_ZEH_Brookside_09-20-14.pdf
Number of bedrooms	4
Type of heating system	Heat pump
Main heating fuel	Electricity, natural gas
Size of photovoltaic system	7 kW
Solar water heater	No
R-value of wall insulation	R-6.5 exterior with R-18 flash and batt insulation, total R-25
R-value of ceiling insulation	R-68 at attic ceilings, R-50 of closed cell spray in vaulted ceilings
Predicted annual energy use	Without PV $1730, with PV $3014
Any other pertinent information	Rain garden designed to accept all runoff from home, large windows, energy efficient appliances

Solar Panels

Model Number	GE 100
Price	$350.00
Area (sq. m.)	0.975
Rated Power (W)	100
Cost Per Watt	3.50
Efficiency	10.256
# of panels for 5000 W	50
Area for 5000 W	48.75

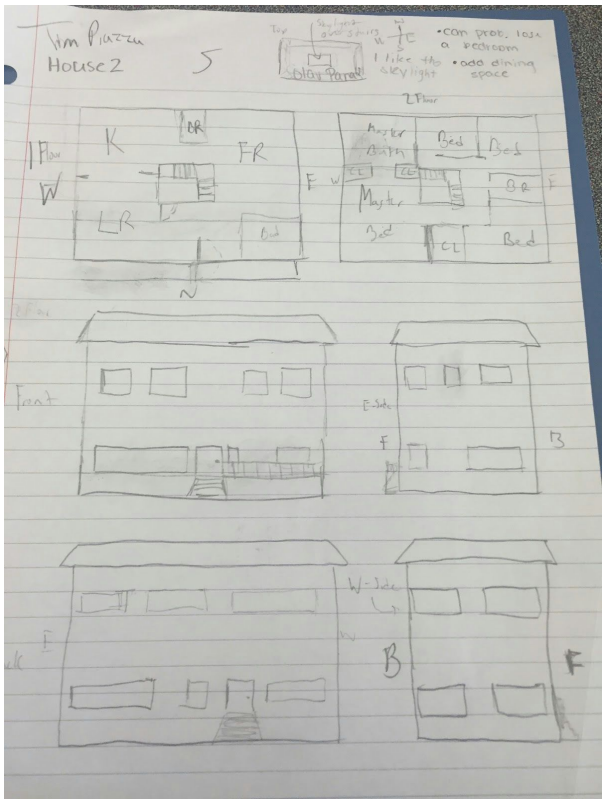
Concept Generation

Concept 1:



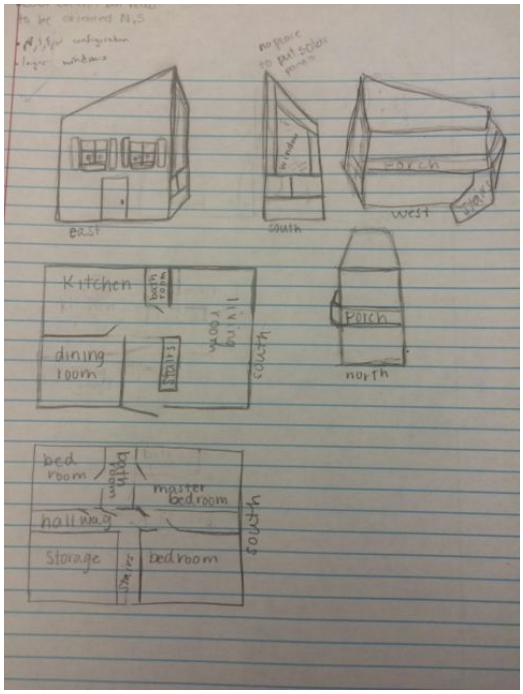
Concept 1 is a two story house with a very unique design. It has two roof top gardens on the second floor, as well as the master suite. The children's bedrooms, kitchen, living room and main bath are all on the first floor. There is plenty of natural light in this home's shared living space due to the large window on the south facing wall, as well as the skylight above. For extra living space, there is a playroom and guest suite downstairs. To make this home zero energy, solar panels can be placed on the roof above the master suite.

Concept 2:



Concept 2 is a two-story, very large home. The main focus of this concept was to provide a living space that allowed for optimal natural light in the form of large windows and a very open floor plan. This concept also allowed for more light by the use of a skylight over the stairs located in the center of the house. When compared to the other homes it did not live up to the other standards due to size of the house and the rooms inside. It is a large home, but maybe just too large.

Concept 3:



Concept 3 is also a two-story home. It has a slanted roof and wall made up almost entirely of a large window. It's roof has optimal amount of space for solar panels, however it was originally planned to be facing the wrong way to collect the most energy from the sun. So it will need to be flipped around.

Concept Selection

		House 1	House 1	House 2	House 2	House 3	House 3
Criteria	Weight	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
Solar panels on south side	20%	3	0.6	2	0.4	1	0.2
Two stories	10%	2	0.2	3	0.3	1	0.1
Affordability based on size	30%	2	0.6	1	0.3	3	0.9
Good use of passive solar technology	30%	2	0.6	1	0.3	3	0.9
Open floor plan	10%	2	0.2	3	0.3	1	0.1

Total Weighted Score			2.2		1.6		2.2

After comparing each of our designs using a concept selection matrix, houses 1 and 3 were tied for first. Instead of trying to find a tie-breaker, we decided to combine the best parts of each home into a new design, which we used to move forward with our project. This new design combined the southern facing solar panels, two stories, and first floor open floor plan of house 1, with the good use of passive solar technology and affordability of house 3.

Design

The most efficient ZEHs tend to be very small for easier heating and cooling, but small spaces are not always very livable. We tried to find a balance between these two very important factors. Our home was 40' by 28', resulting in a 2240 sq. ft. of livable space.

Energy Analysis

Energy Usage Estimate

Electrically Powered Item	Monthly KWH	$/month
Refrigerator	57	$4.62
Freezer	58	$4.70

Dishwasher	13	$1.05
Range/Oven	24	$1.94
Microwave	11	$0.89
TV	17	$1.38
Computer	21	$1.70
Washing Machine	6	$0.49
Clothes Dryer	57	$4.62
Lighting 2 rooms	20	$1.69
Heat Pump	1094	$88.92
TOTAL	1378	$125.01

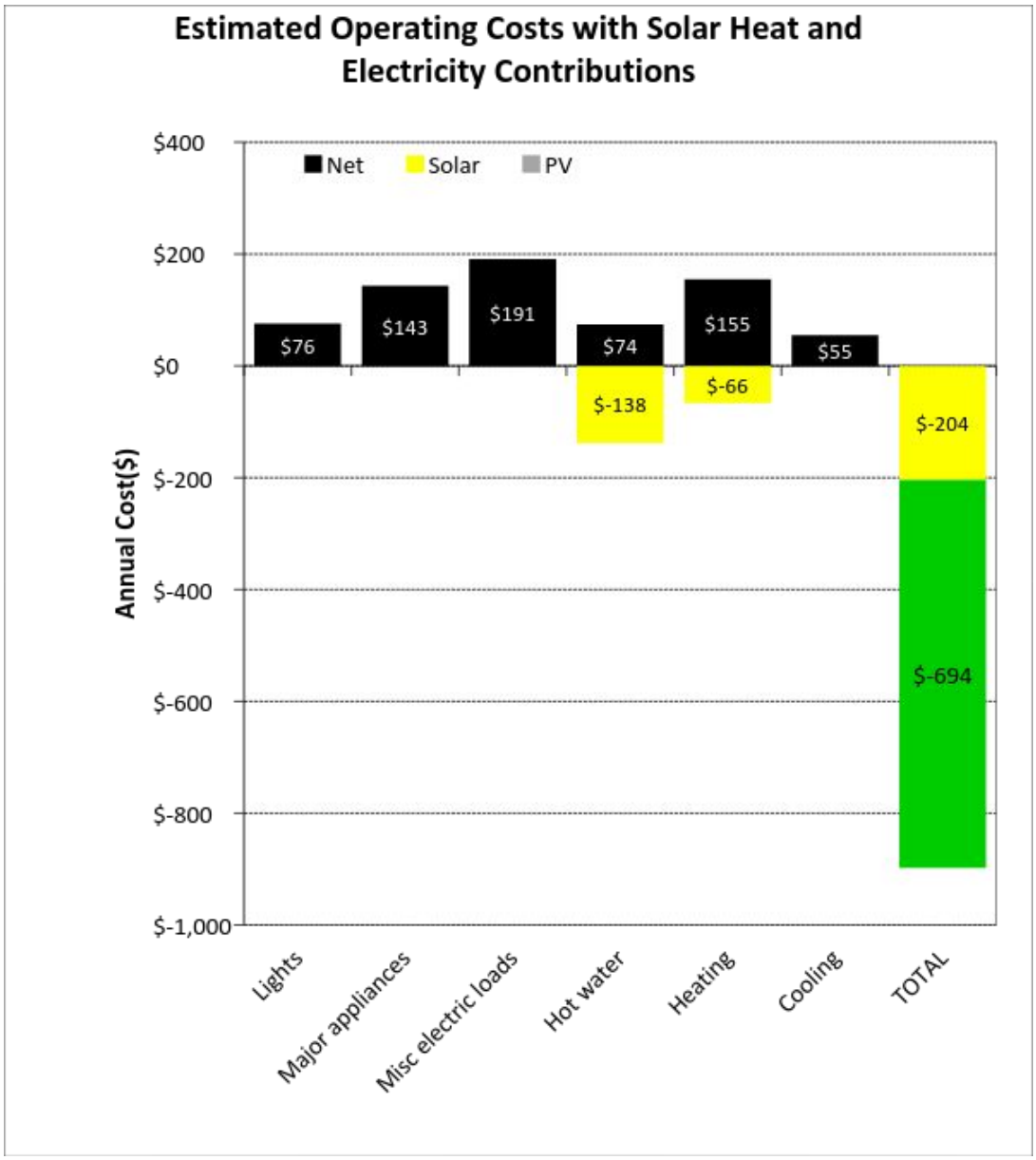
Active Solar Calculations

Array size (kW) = (annual kWh usage) / (365 days/year) / (solar hours/day) / (.75 derate factor)

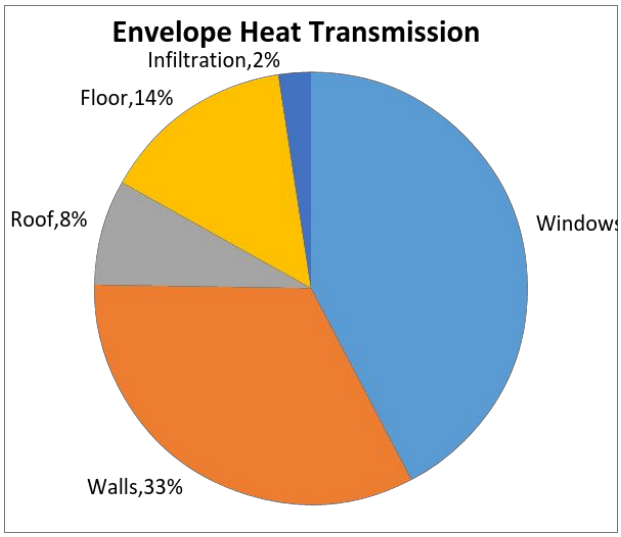
Array size: 15.45 kW

Average sun hours	3.91 kW/sq m
Annual electricity usage	16,563 kWh
Solar PV System size	12.38 kW
Total area required	990.40 sq ft
Number of solar panels	50-62
Cost per Watt	$3.48
Solar cost estimate	$43,082.40
30% tax credit	$12,924.72
Total cost estimate	$30,157.68

Estimated Operating Costs and Heat Transmission



This graph shows the net cost of operating our ZEH. With the systems we have chosen, our home will produce more energy than it consumes, and make money for the homeowners by selling back to the grid.



Model Experimentation

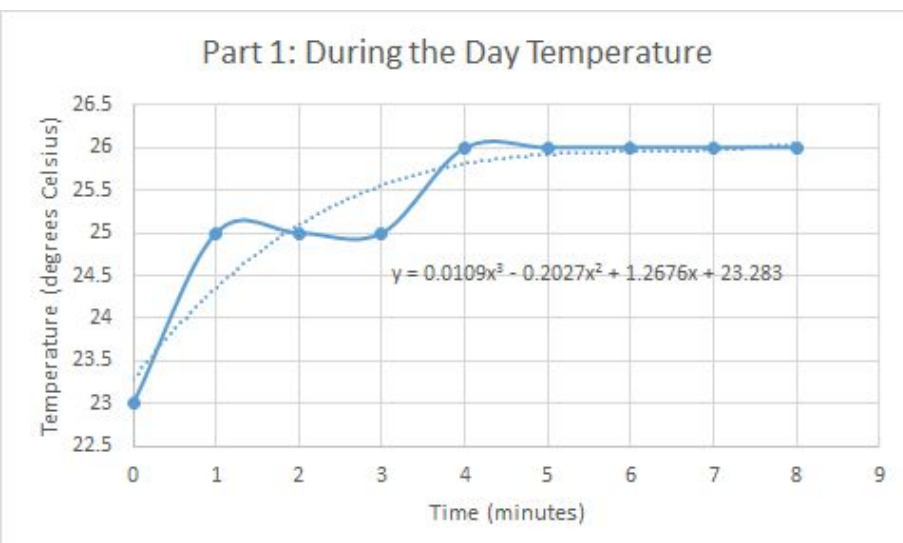
Model Description

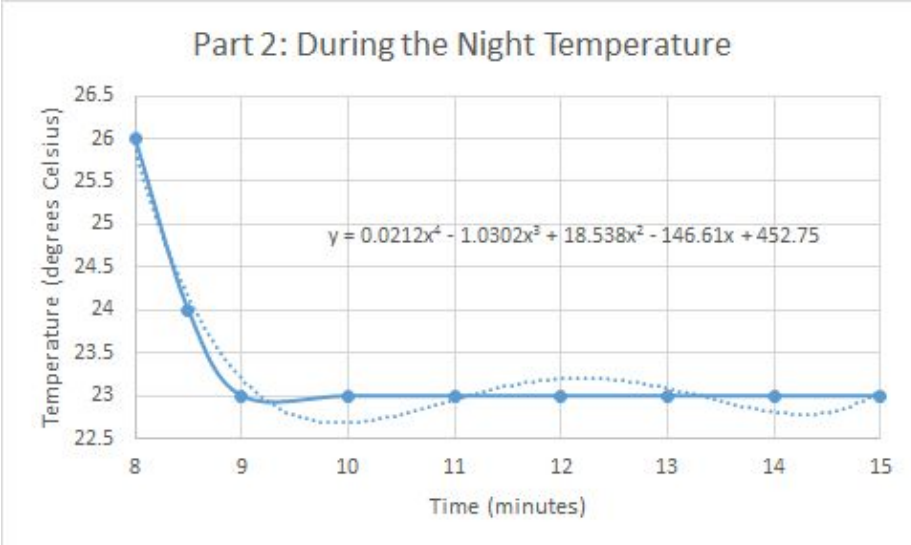
We constructed our model using foam board, saran wrap, rubber, a dark colored t-shirt, aluminum foil, tape and hot glue. Our design used both passive and active solar concepts. All of the walls, the base and the roof were cut from the foam board. Our roof was put at a 45-degree angle to match the angle of the sun at State College. On the roof, we put aluminum foil to symbolize solar panels which will generate energy. On the south facing wall, we added three large windows to let in as much sunlight as possible in order to absorb the most heat. On the north facing wall, we also put large windows in order to let in as much light as possible, especially into the second floor. On the east facing wall we only put one window so that when the wind blew at night, the least amount of heat would be lost. We made the west wall symmetric to the east wall. With the wind blowing into the side of the house with the least surface area, we hoped that the house would be aerodynamic, and simply allow the wind to go by without removing energy. All of the windows were created by cutting rectangles out of the

styrofoam and taping saran wrap folded over to cover the hole, and act as a thick glass window. Inside the house, we laid down a layer of rubber to act as a thermal mass to absorb the energy coming in. We covered the rubber with fabric from the dark colored t-shirt to absorb more sunlight while making the model more aesthetically pleasing. To represent the second floor, we pinned a layer of saran wrap with a floor plan on it to the walls where the second floor would begin. We did this so that when the roof was lifted, both the second and first floor layouts were easy to see. Our model was 7 inches by 10 inches. We chose to create a scale of 1 inch: 4 feet. This made the final area of the house 1,120 square feet per floor.

Testing the Model

To test the model, a day and a night simulation were done on the house while recording the temperature inside. To simulate daytime, the model was placed in front of a large lamp pointing down at the south side roof at a forty-five degree angle for eight minutes. A thermometer was placed inside, and after each minute the temperature was recorded. The night simulation began immediately following these eight minutes. The model was placed with its east side facing a fan with ice for seven minutes. Again, the temperature was recorded each minute.





Conclusion

After completing the test, we know what changes must be made to our house. We would consider that a success. By watching the test take place, the roof appeared to be the only part of the house that was ever directly hit with sunlight. This makes the rest of the windows much less useful. To correct this problem, we decided to add a skylight to our next model. This will decrease the amount of solar panel space, but it will substantially add to the amount of energy being let inside.

Another problem we encountered with our model was air tightness. It is very difficult to align foam board so perfectly that no air can seep through its edges. Since our roof had to be removable for this project, we could not tightly secure it to the walls, and during the testing phase of our project we noticed a few substantial cracks. Of course, in a real home air tightness is not usually a major problem, given all the precision tools used by carpenters these days. But during the night portion of our test where we set our model in front of a box fan, we do think that

our fast heat loss was due to these cracks. If we were to build a second model, we would spend more time ensuring that our walls were well joined to help retain the heat that we build up during the day.

Overall, our team accomplished what we set out to do. Our goal was to build a model of a zero energy home that a family of four could comfortably live in. Our model ended with a net zero transfer of heat. This is clearly not ideal, but we know what needs to be fixed to create and conserve more energy. Through the process of the project, we enhanced our ability to work as a team, our researching techniques, and our designing skills. This project was beneficial for us as engineers, and hopefully it was beneficial to our world, so that unsustainability becomes a problem that we know how to stop.