Zero Energy Home

EDSGN 100 SECTION 005

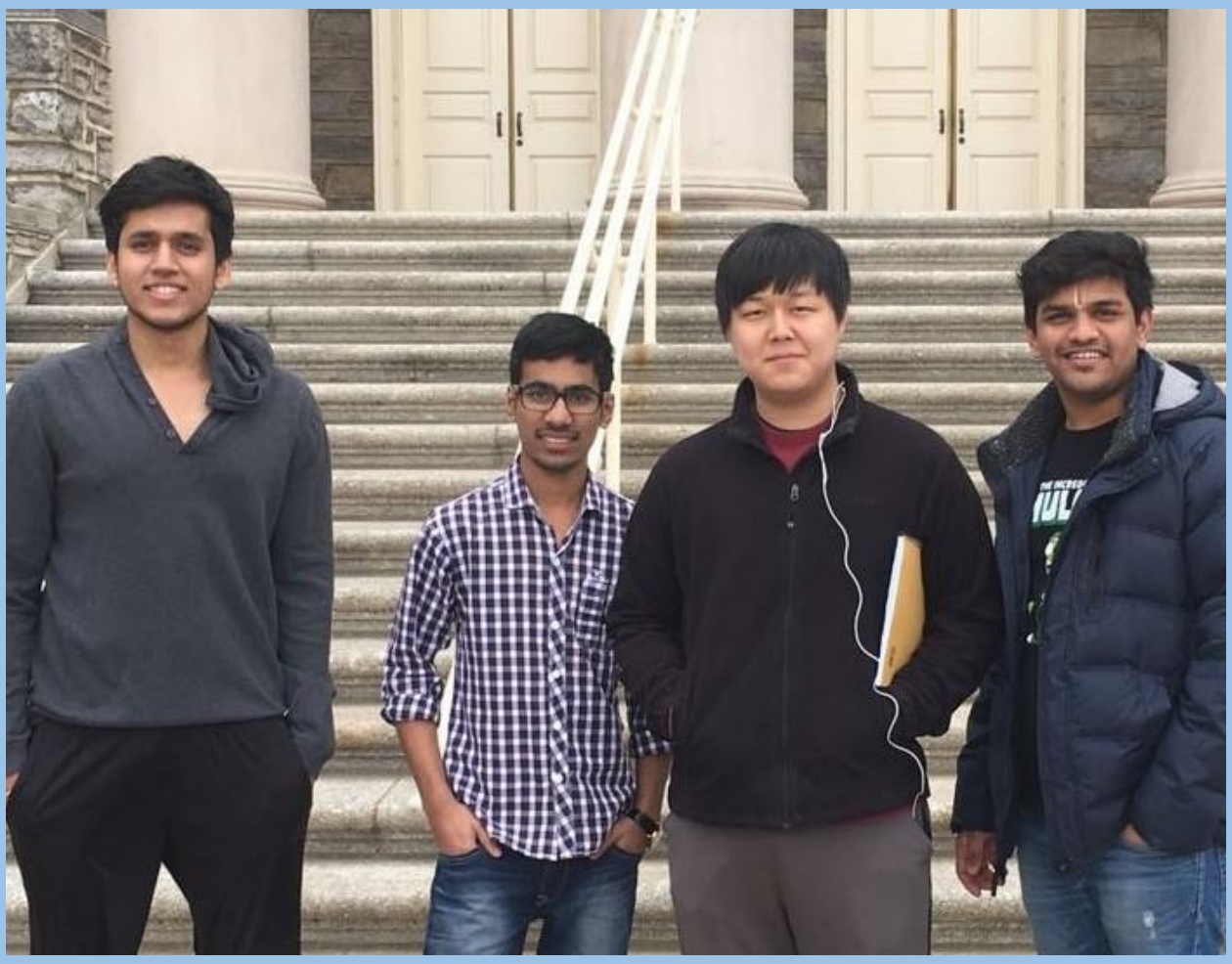
Professor Wallace Catanach

29th February 2016

TEAM TROLLERS

Tanish Meher **Harshal Agarkar** **Minchan Kang** **Saulabhya Mundra** **Robert Kyser**

trm5431@psu.edu | hja5093@psu.edu | mzk5598@psu.edu | ssm5363@psu.edu | rck5166@psu.edu



Mission Statement:

Our goal is to build a Zero Energy Home that is aesthetically pleasing and adequate for a family of four. It will have a net Zero Energy Consumption.

Table of Contents

Introduction	4
Executive Summary	5
Customer Needs Analysis	7
External Research	8
Concept Generation	9
Concept Selection	10
Energy Calculator	12
Embodiment Design	14
Final Design Description	16
Conclusion	21
References	22

Introduction

As you can guess with the name, 'Zero Energy Home' (ZEH) which is also known as 'zero net energy building' is a house (or a building) that consumes zero net energy. And the wording 'net' means that the total amount of energy used by the Home annually would be roughly equal to the amount of renewable energy resources created on the site.

In order to achieve zero net energy, the house needs to reduce its energy demands and generate from renewable sources. Thus, a Zero Energy Home uses photovoltaic system, geothermal heat pump, ventilated air recovery system, etc. Thus, using renewable resources to provide electricity, cooling and heating will make the environment pollution free and help nature survive. And the House also uses effective insulation methods so that there is bare minimal amount of energy that is lost or any threat of a short circuit.

As we all know that there is a very limited amount of non-renewable resources available for people on Earth, the demand for a ZEH will keep increasing and thus the cost of owning ZEH in the future would be much higher than right now. It is able to reduce the cost of monthly living in the House and provides surety to the owner from the future price hike of energy. As a result, ZEH has higher resale value. Although it is valuable enough to be considered among customers, there are still few disadvantages of owning ZEH. The most critical thing is that the initial cost of building could be expensive relative to traditional houses. Also, there are only few designers and builders for ZEH. The thing is, as time passes and technology keeps to be advanced, disadvantage of zero energy building would be smaller and demand on the building constantly increases.

Executive Summary

Human beings have been utilizing energy resources for development and have already used a great deal of non-renewable energy which is extremely limited. “This planet is capable of providing man’s need, but not his greed”, an apt quote by Gandhi**.** An average home consumes about 10,908 kW of energy and this is something that is steadily rising. Hence, we ‘The Trollers’, have designed a Zero Energy Home that is eco-friendly as well as satisfies the needs of any consumer who wishes a great lifestyle. We unanimously chose Harrisburg, PA as the location for our project because it is a cold place and we can test and experiment our Zero Energy Home. Our home will accommodate a family of four. The major energy resources used will be solar and geothermal energy. Along with them, we are also going to use certified ‘Energy Star’ appliances, our house will ensure an efficient and judicious use of energy and resources.

Designing our Zero Energy Home was a crucial thing because our top most priority apart from net zero energy consumption was our customer’s happiness. We visited existing Zero Energy Homes in Pennsylvania such as those in Chester Springs and Breezewoods. We conducted surveys of people living in those houses and researched various patents. This was very helpful while finalizing the design of our project. We came up with ample ways to increase the efficiency of our house while keeping in mind the cost. Our Home takes benefits of an unlimited energy resource i.e. the sun. Since Harrisburg is a cold place, most of the energy used in the city is utilized in heating the houses. Our house is equipped with advanced framing techniques on the walls, floors, and ceilings with an insulation of R-values. All the heating is done by solar or geothermal energy which reduces the overall cost to pay for heating the house. The southern overhanging roof will help maximize winter sun exposure and minimize the heat from the summer sun which was one of our customer’s top needs. Appliances such as refrigerators, washers and dryers, which uses a lot of energy, would have an energy star, making our home a complete ‘Zero Energy Home’.

There were several risks with this prototyped design. One of the highest priority risk was going over-budget of $130,000. After much research and making necessary changes, we finally got the budget of the house to $129,970, which is a good affordable sum for a family of four. The risk could be minimized by the proper use of the allocated funds and following everything by the book and avoiding mistakes at all costs. The final prototype is scheduled to be finished by 25 February 2016.

Customer Needs Analysis

Based on our survey conducted in Pennsylvania, we decided our need statements of our customers for our Zero Energy Home. Our first goal while deciding the customer needs was that the house should be a net zero energy house and considering that we also want our design to be beautiful.

CUSTOMER STATEMENT	NEED STATEMENT
I want my house layout to be beautiful and big enough for a family of 3 to 4.	The house will be 1200 ft^2 one storey house which will have two bedrooms, a living room and a kitchen.
I want an Eco-Friendly house.	Rainwater water harvesting will be installed. Along with that, it will have energy star appliances. Solar panels on the roof.
I want an open ventilation.	There will be big windows in the bedrooms (North Wall). There will be small windows in the living and kitchen as well to have an effective ventilation.
I want a big space for my cars.	The house will have garage installed either built in or installed beside the house.
I want a normal temperature all over the year in my house.	The house will have well-equipped with heating and cooling system.

External Research

The External Research done for our ZEH involved a preliminary and a final research phase. For our preliminary research phase, each member of our group had to pick two existing ZEH homes and find more about such type of houses. We surfed through the internet researching about ZEH homes in Pennsylvania and found, 'Green Homes for Sale' to be the most relevant and appropriate website for our research. Then, through Google we found out about a ZEH neighborhood in Pennsylvania, where the average ZEH cost in the neighborhood ranged $100,000 to $125,000.

The following are the results we found in our research:

1. **Average number of Bedrooms:**
   3

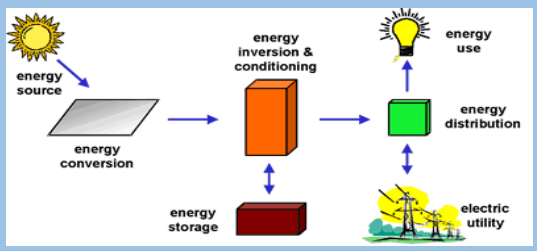
2. **One storey house size:**
   1000-2000 ft^2

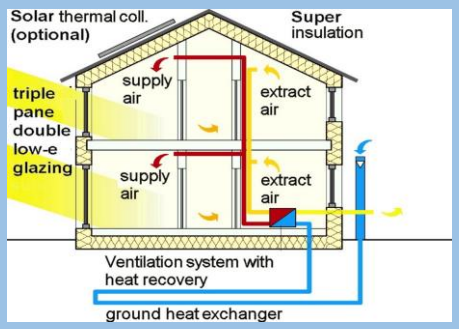
3. **Type of heating:**
   Radiant Floor Heating

4. **Heating Fuel:**
   Electricity or Wood or Oil

5. **Ventilated Air Recovery System:**
   Yes

6. **Average size of Photovoltaic system:**
   6 kW





Concept Generation

Based on the Customer analysis done, we have multiple selection possibilities for the final design of our project:

- **Renewable Energy**
  - Solar using PV system or solar water heater
  - Geothermal Heat pump
  - Hydropower using the river
  - Wind Turbine
- **Appliances**
  - Energy star rated appliances
  - non-energy star rated appliances
- **Windows**
  - Bigger windows in the South side of the house
- **Insulation value**
  - Ceiling insulation R value 40
  - Ceiling insulation R value 50
  - Ceiling insulation R value 60
- **Area and number of storey of the house**
  - 500- 1000 square feet, 2 storey house
  - 1000-1500 square feet, 1 storey house
- **Garage**
  - 1 car, outdoor garage
  - 2 cars, built in garage

Concept Selection

	MATRIX	Wall construction double 2*4 with 10" foam	Ceiling insulation R40	Electric geothermal heat pump	Triple low-e window	Energy star appliances	Roof mounted 4.5 kW P.V. system
NEEDS							
The house will use zero net energy				o		o	o
The house will have heating and cooling systems		o	o	o	o		
No harmful materials will be used		o	o				
The house will have lots of windows for cross-ventilation					o		
Modern architectural design							o
The house will not lose heat		o	o		o		

Selection Criteria	High R-value	Low R-value	P.V system of 2kW	P.V system of 4.5kW	Lots of windows	Few Window	Geothermal	House area 2000 sq. ft.	House area 1200 sq. ft.
Low Cost	-1	1	1	-1	0	0	1	-1	1
Energy Efficient	1	0	1	1	0	1	1	-1	1
Low Maintenance	1	1	1	1	1	1	1	-1	1
Sum +'s	2	2	3	2	1	2	3	0	3
Sum -'s	1	1	0	1	0	0	0	3	0
Sum 0's	0	0	0	0	2	1	0	0	0
Net Score	1	1	3	2	1	2	3	-3	3
Rank	3	3	1	2	3	2	1	4	1
Continue?	Yes	No	No	Yes	Yes	No	Yes	No	Yes

Energy Calculator

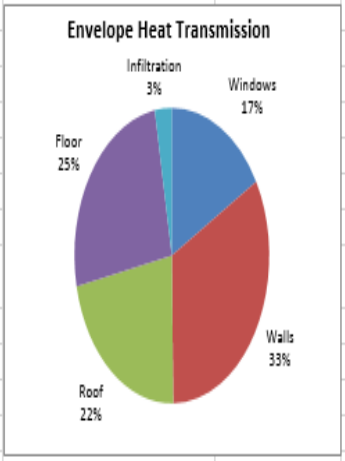
State Center for Sustainability

General Info	
Location	Harrisburg
Electricity cost ($/kwh)	0.1
House type	1 story
Conditioned floor area (sq.ft.)	600
Number of bedrooms	2
Envelope Details	
Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R40
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1200
North wall area (gross) (sq.ft.)	636.02
East wall area (sq.ft.)	370
South wall area (sq.ft.)	636.02
West wall area (sq.ft.)	370
North window area (sq.ft.)	10
East window area (sq.ft.)	10
South window area (sq.ft.)	125
West window area (sq.ft.)	0
Air tightness	Tight with heat recovery
Appliances	
Refrigerator	Energy Star
Clothes Washer	Energy Star
Dishwasher	Energy Star
Small Appliance Input	
Extras	
Garage	g. Built In 2 car
Hot Tub	a. None
Pool	a. None

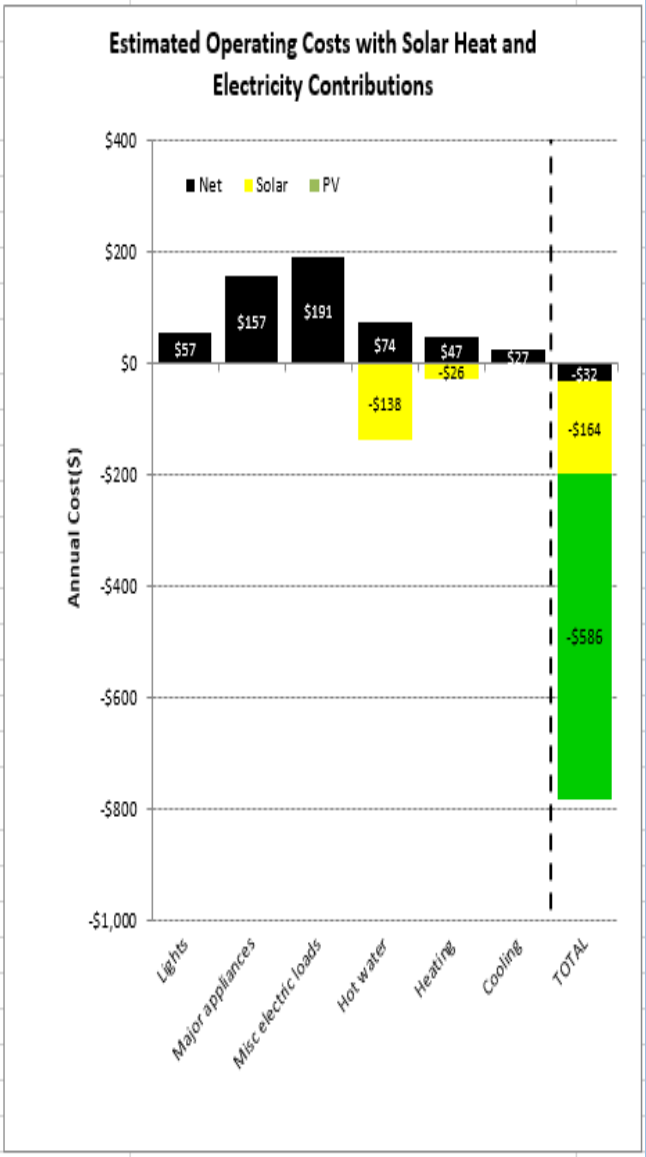
Zero Energy Home Calculator

Heating & Cooling	
Type of heating & cooling system	Electric geothermal heat pump
Solar Technologies	
Size of PV system (kw)	4.46
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	$	93,129
PV Cost	$	22,300
Upgrade Costs	$	14,542
Total House Cost	$	129,970



Based on our customer needs and the idea of Zero Energy Home, we were able to calculate the total cost of the house as well as get an estimated operating cost of solar heat and electricity contributions. We can see in the above figure that:

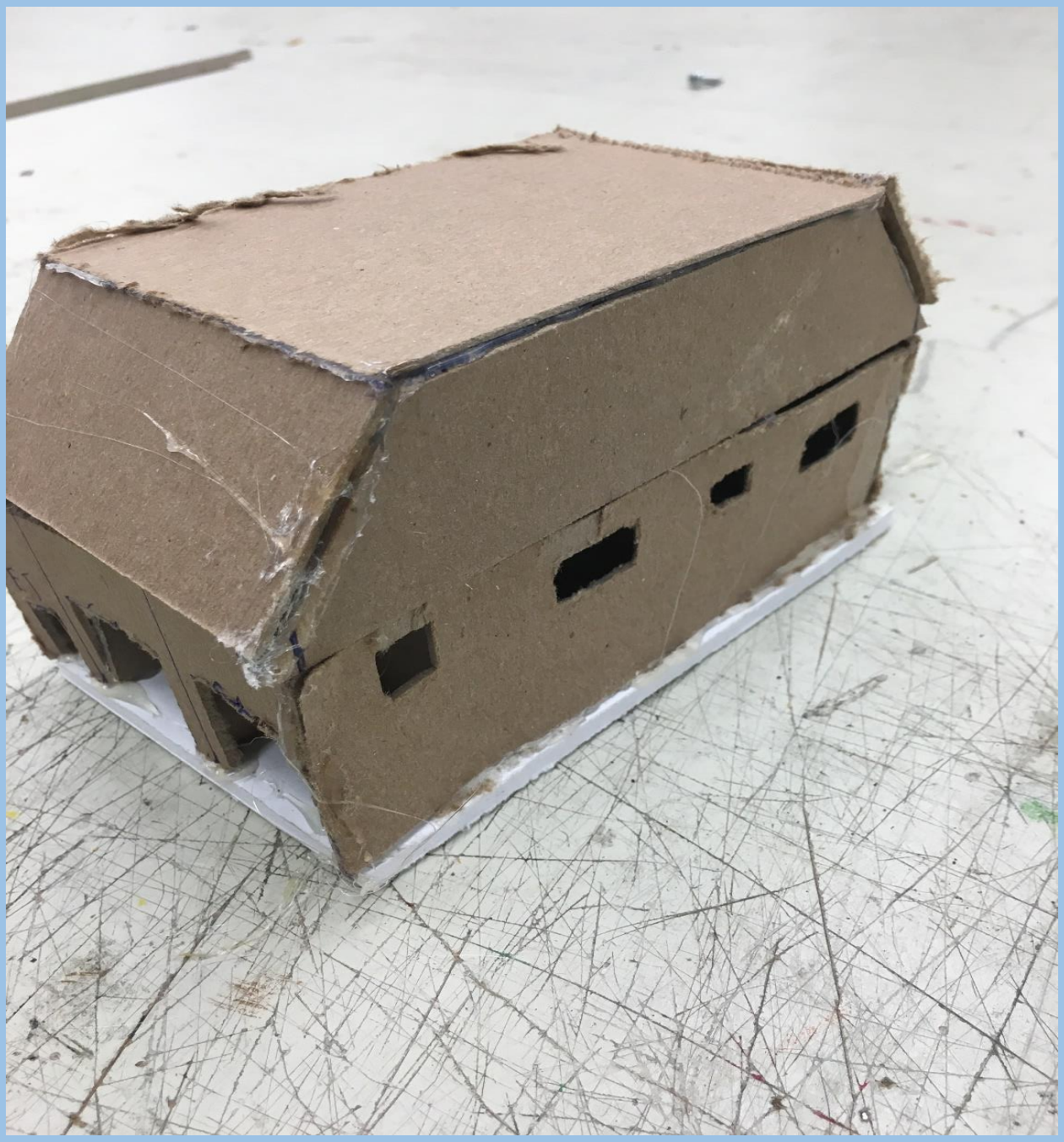
The Total House Cost: $129,970

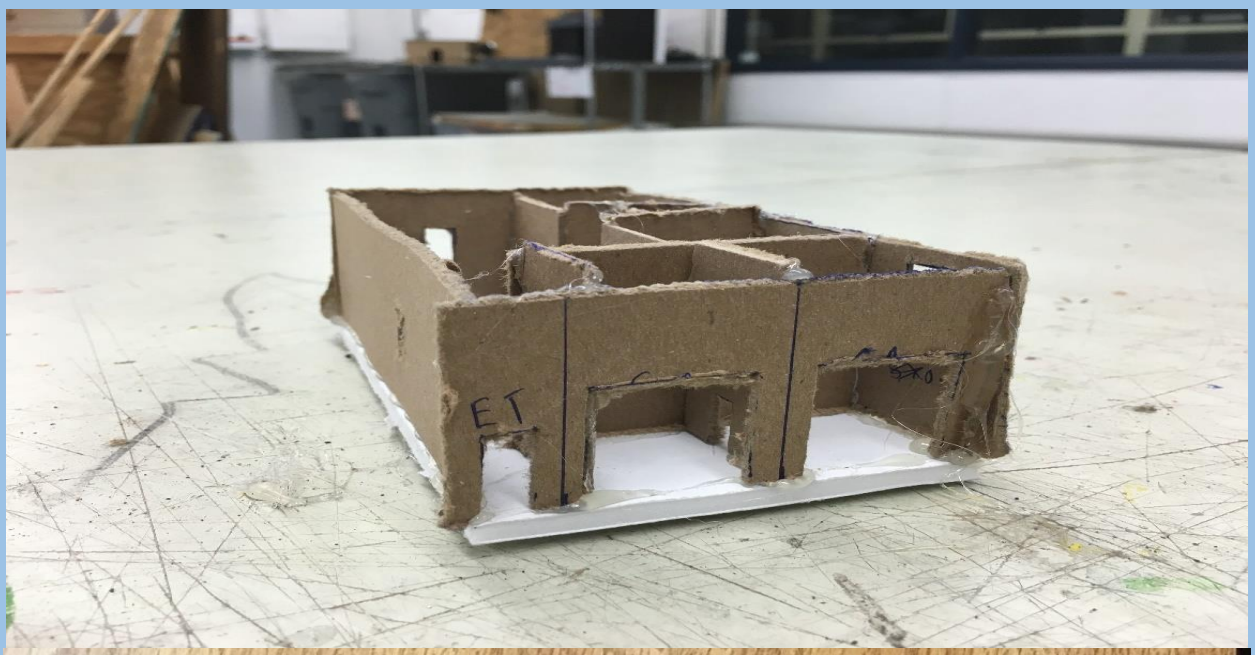
Photovoltaic System Cost: $22,300

Upgrade Cost: $14,542

Thus, our house is a pretty affordable house which will definitely be aesthetically pleasing as well as a net Zero Energy House.

Embodiment Design




ET

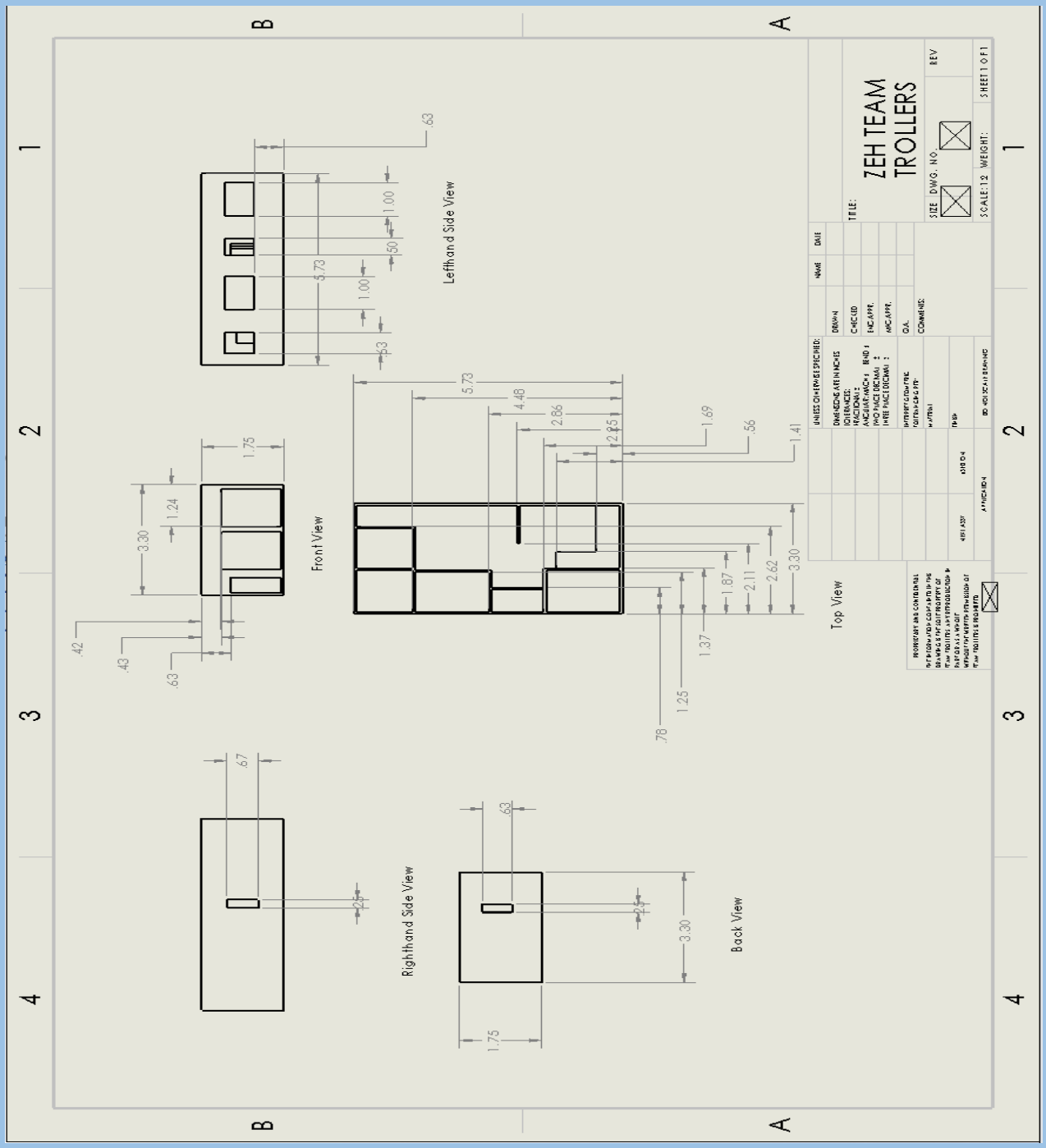
Final Design Description

The design we chose is a one storey house, which includes two bedrooms, one toilet, an open kitchen and a living room. This house is affordable with a total cost of $129,970 and adequate for a family of four.

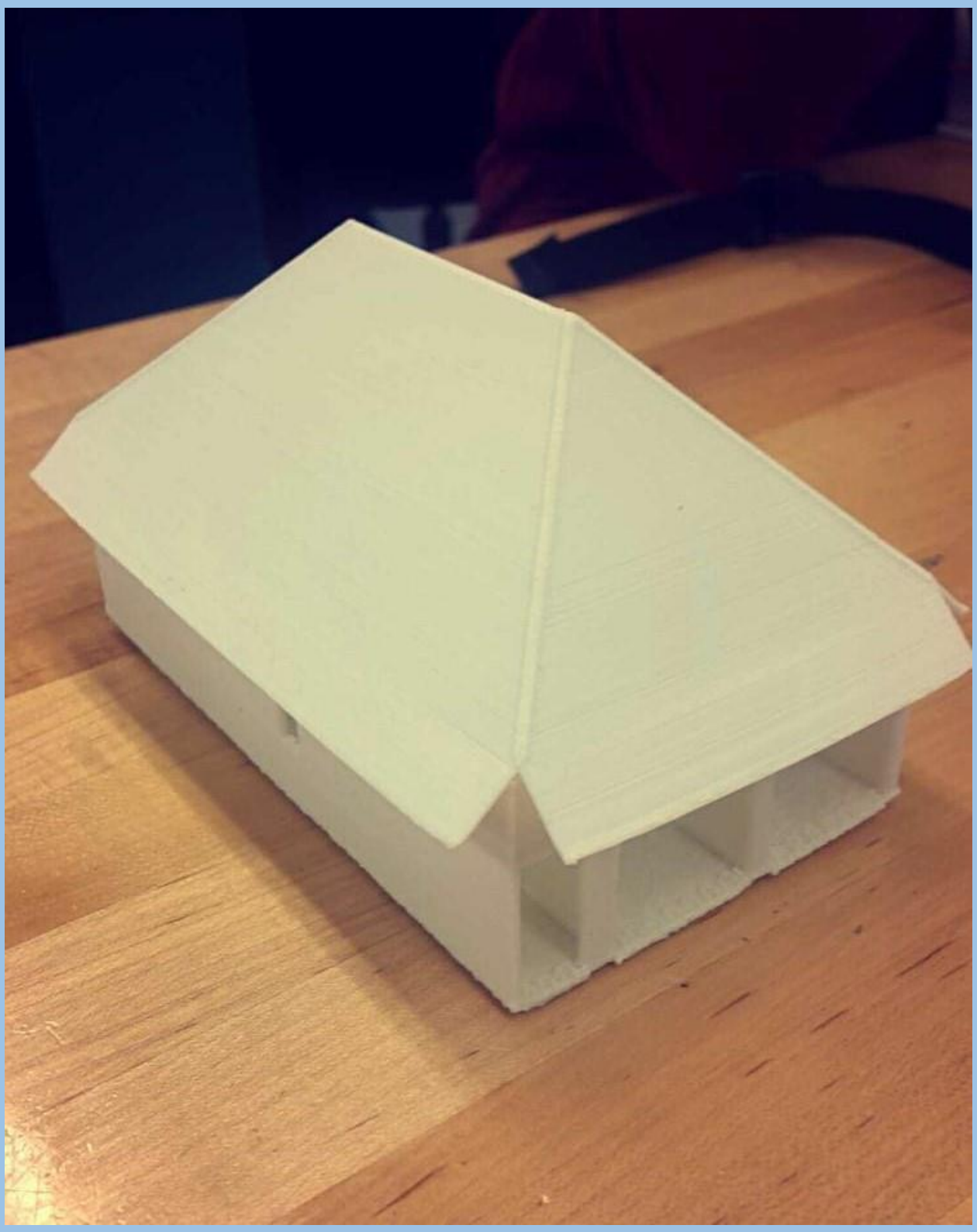
We have made this Home a Zero Energy house using renewable energy, and energy star appliances. It is very beautiful and modern style home and has a wonderful location. The house is very close to Walmart, other general stores and many restaurants of various cuisines nearby.

We decided to 3D print our prototype for presenting our concept to everyone. We used ABS plastic to print it. We used SolidWorks to first design the house according to our dimensions. It took about 10 hours to print the house. The experience was totally worth it.

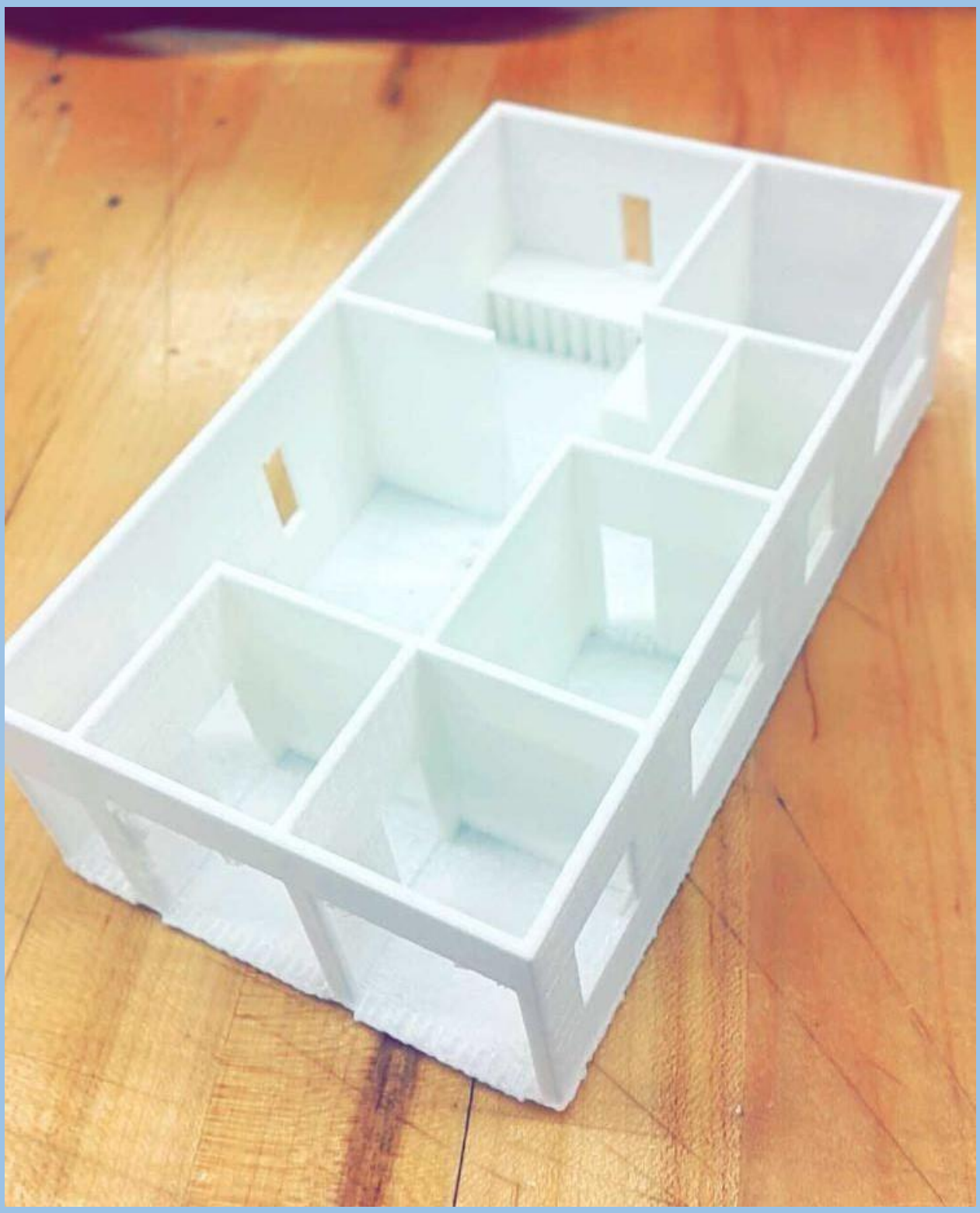
The SolidWorks layout of our Zero Energy Home:



The pictures of our 3D printed house:



Kitchen
Bedroom I
Bathroom
Drawing Room
Bedroom II
Entrance
Garage I
Garage II



Conclusion

Overall, the final prototype of a Zero Energy Home made by Team Trollers proved to be a success. Located in Harrisburg, Pennsylvania. It will attract a wide variety of customers who would not only enjoy the Northeastern climate, but also its opportunities for recreation as well as its beautiful wildlife. Perfectly designed by students from Pennsylvania State University for a family of 4, the house will provide all the facilities that a person requires. As a team we all believe that this project was an eye-opener for each one of us on the engineering process of making a house. We believe this prototype is a testament that showcases our team's skills, imagination and hard work.

Our group worked together diligently and completed the task on time and with successful result. We 3D printed our final design which was something new and exciting for all the members working on this project.

References

- https://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table
- https://en.wikipedia.org/wiki/Zero-energy_building
- https://www.google.com/search?q=green+home&espv=2&source=lnms&tbm=isch&sa=X&ved=0ahUKEwinht2-753LAhXMcD4KHZB4CdIQ_AUIBygB&biw=1366&bih=643
- https://www.google.com/search?q=green+home&espv=2&source=lnms&tbm=isch&sa=X&ved=0ahUKEwinht2-753LAhXMcD4KHZB4CdIQ_AUIBygB&biw=1366&bih=643
- Professor Wallace Catanach