

**Zero Energy Home Design**  
**8 am Design Team**

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## **The Problem**

The 2010 US census showed the US average home size throughout the years. In 1973 the average home has 1,660 sq feet. In 2010 the average home was 2,392 sq feet. It seems today everyone wants to have bigger homes that require more energy and leave a larger ecological footprint. This alongside with our use of nonrenewable resources endangers our future.

## **Our Goal**

Our goal is to build a home for a family of four that is not only comfortable to live in but also sustainable and aesthetically appealing. The home must be a zero energy home incorporating passive and active solar techniques.

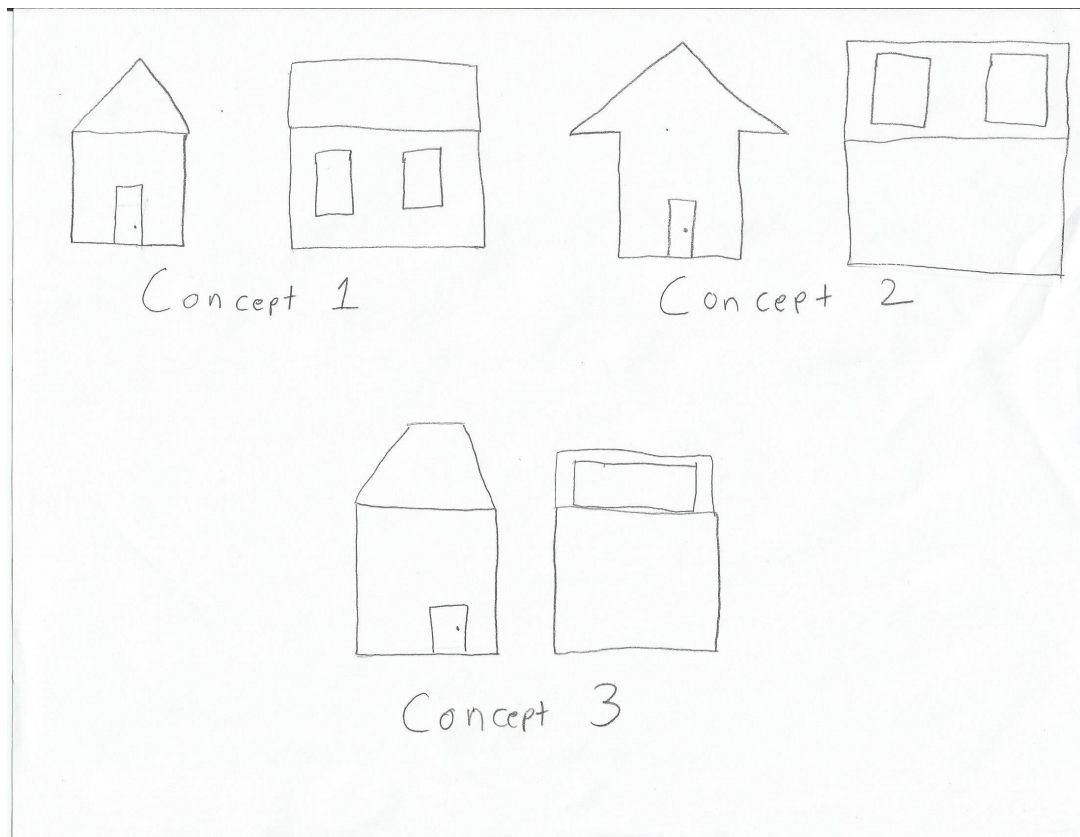
## **Research**

Research was the first task we embarked on in order to see what has been done already, and get an idea of what zero energy homes are like. We started to look for houses in the Northeast of the United States since the home was going to be in State College PA. The first house we found was in Turners Falls, MA. The house was a three bedroom and one bath house with a total of 1,152sq feet. The house used three key features to keep energy usage low. Super-insulation, air sealing, and a 4-inch concrete slab used as a thermal mass in the flooring and south facing windows. They house had 26 solar panels that produced 4892 kwh a year. The house only used 1949 kwh per year.

The second house we found was the Virginia Tech Lumenhaus and it was in Blacksburg, Va. It was a zero energy open floor plan home with a total of 800 sq feet. The home was made by Virginia tech and the home was heated by geothermal and had radiant flooring. The flooring also had a concrete thermal mass slab. The insulation was closed-cell spray foam, and they used 45 grid-tied solar panels. The Virginia Tech Lumenhaus wasn't exactly what we were looking for, but it showed how many options there were when it came to zero energy home design.

Researching was a vital step in our design process. We gained many ideas from seeing what has been done, and we also went back to our research throughout designing to get specific information. We often checked if numbers we calculated were reasonable by comparing them to the information on these houses.

## Concept Generation



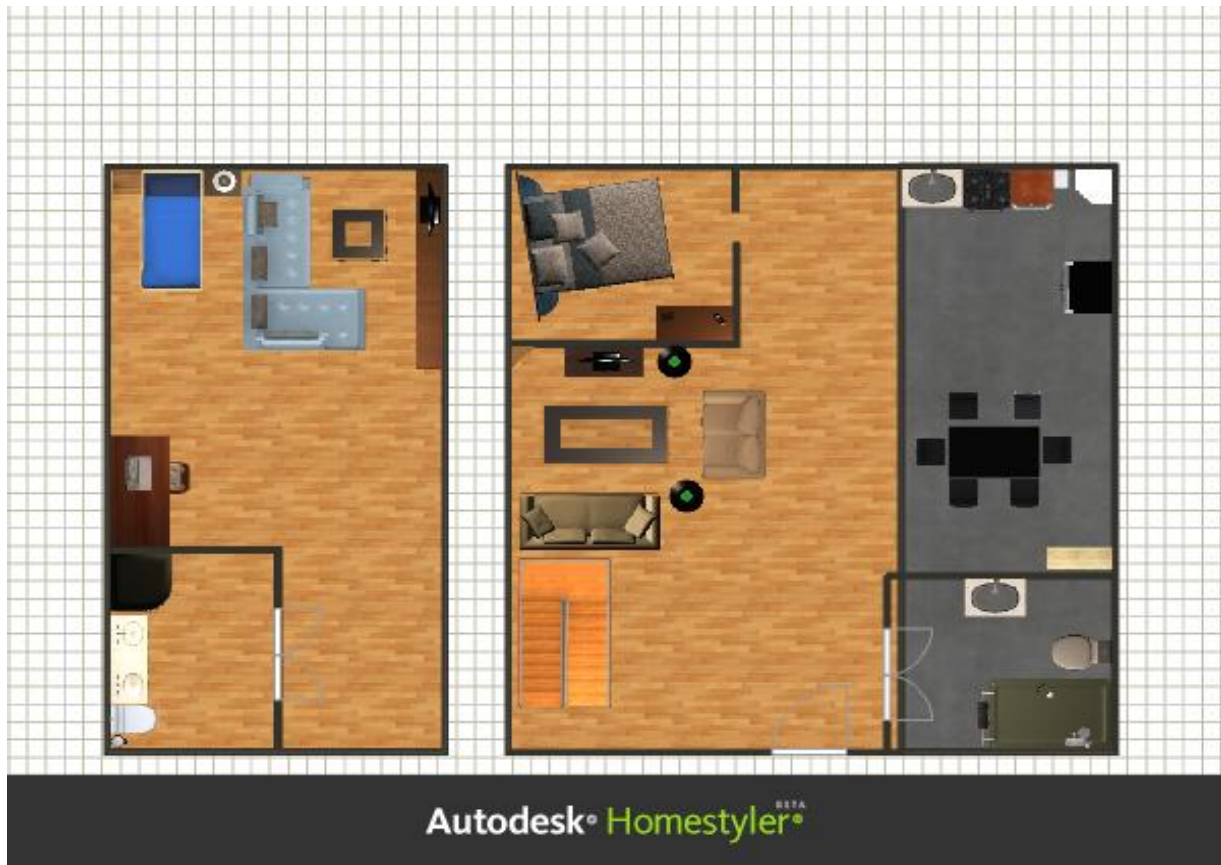
As a team we generated concepts individually. Concept one was a standard home with a pitched roof and some passive and active solar features. Concept 2 was similar to concept 1, but had a large roof area so the home could have a loft. It also incorporated windows that were on the roof which allowed for more sunlight and natural light into the home. Lastly, concept 3 had a large window on the roof and the roof was flat at the top.

## Concept Selection

| Criteria              | Concept 1 | Concept 2 | Concept 3 |
|-----------------------|-----------|-----------|-----------|
| Sunlight Amount       | 2         | 4         | 3         |
| Ease of Building      | 4         | 3         | 2         |
| Passive Solar Methods | 3         | 4         | 3         |
| Aesthetics            | 2         | 4         | 4         |
| Total                 | 11        | 15        | 12        |

We decided to use a concept selection matrix in order rank our concepts. We chose the criteria based on the problem we were trying to solve, and the information we researched about zero energy homes. Concept 2 ended up having the highest score. This was do to it being aesthetically pleasing, letting in a lot of sun, and incorporating the most passive solar methods. Concept 2 has a mass slab below the windows, insulated walls, roof top windows with sliding covers, and solar panels on the south facing side.

## Design Analysis and Solar Methods



Our house was designed with a loft (on the left) to give the home a more open floor plan, and give the family more space. This open floor plan ensures that less energy will be needed to heat the home during the frigid and long months of winter, as well as keep the house cool during the warm months of summer. Along with the loft we designed the house with a window slider. The window slider was designed in order to control how much of the windows would be hit by the sun. This enables the homeowners to allow the lower winter sun in, but still block out the higher and hotter summer sun. We decided to place the windows on the roof as well as under overhangs on the south side, to allow more sunlight in which in turn would heat the home. These windows also allow the house to mostly be lit by natural light during the day. These windows could also be covered up by window

shutters that could keep heat in at night during the winter, and prevent the sun from shining in during the summer, thus keeping it cooler. Another addition was the concrete slab we placed on the southern side of the home. This concrete slab would absorb heat produced by the sunlight that would shine through the windows. The slab acts as a mass slab and helps heat the home at night.



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## Appliance Decisions

A vital part to making a zero energy home is to reduce the usage of the home. Most of a home's energy usage is devoted to heating the home, but appliances play a large role as well. During this project we looked very in depth

into how to light the home, a washer, and an oven. Also we learned more about energy star rating and would choose energy star appliances for all appliances that were not looked into in depth.

Lighting was a big consideration when deciding on reducing usage. There are three standard options for unnatural light. There is CFLs, incandescent, and LED lights. We chose LED lights because they have a longer lifetime than any of the other options and also used the least amount of energy. They were also the most expensive option, but the benefits outweighed the costs. We found bulbs as cheap as \$12 each for 8 watt bulbs which emitted the same amount of light as a 60 watt incandescent bulb.

The washer we chose for the house did not only need to be energy efficient, but also conserve water. The energy star rating for washers luckily considers both factors. As a team we found three washers and compared them, and found that Electrolux EIFL 55S was the superior option because of its low cost of \$800 and the other options having payback periods longer than the life of an average washer.

Lastly, we considered ovens for the home. Residential ovens are not rated by energy star. This made sourcing information on an energy efficient oven quite difficult. We ended up comparing three ovens that were claimed to be efficient. Comparing them by their price and energy usage we found that the LG 6.2 cu ft range was the best option for our needs.

## **Energy Analysis**

We calculated our energy usage to be 4,044 KWH / year. This was gathered through an online calculator after inputting our appliances and other information. This number is much lower than the standard for a home in the US. This is because of the fact that we focused heavily on reducing our usage. We did this through taking advantage of passive solar, and choosing the right appliances.

Reducing usage is only half of the equation. The other half is using active solar to make your home truly zero energy. By using active solar to meet your energy needs the home will not be dependent on the grid. Also, excess energy can be sold back to the electric company. Considering our usage and the specific values for State College, PA we concluded that we need a 3.83 KW or greater solar array in order to meet our energy needs. A 4 KW solar array seemed to run anywhere between \$4000 - \$7000. Another option would be to rent solar panels from Solar City which is a company designed to rent solar panels for a monthly cost in order to help individuals get over the upfront cost and instead pay as they go. Either way a solar array is needed to make this home truly zero energy.

## Prototype and Experiment

The experiment consist of the model home being under a light, which represented the sun for 8 mins while a thermometer collected the internal temperature. During the second part of the experiment the model would be in front of a fan blowing cold air for 8 mins to see how much heat the house would retain.

We built a model of concept 2 out of foam board, hot glue, a rubber mat,



clear plastic wrap, and black cloth. We initially drafted a design dimensioning out the model. We then built our model by using the foam board as the walls and ceilings. We used hot glue to assemble the model, and to make sure it would be sealed from the cold wind during the experiment. We set our roof angle at 45 degrees for maximum sunlight on our thermal mass slab, which was the rubber mat. On the walls we used the black cloth as insulation.

Our house did well in the experiment. During the sunlight time the house went up 5 degrees and during the cold wind lost 4 degrees. A critical mistake we made was having our windows too high. The sun didn't shine on our windows



but instead mostly on our roof. Though the windows were placed wrong we still obtained around the same internal temperature as most groups. If the sun hit our windows, our model would have heated up much more. Our model lost the least amount of heat during the cold wind portion of the experiment. Some groups used more insulation on the east wall where the wind was blowing from. If we were to build this model again we would incorporate that into our design and have the east wall be more insulated. Also, we would make our model smaller like the other groups in order for the sun to hit our windows directly on, instead of the sun mostly hitting the roof. Overall our model performed well, but if we made these adjustments it would do even better.

## **Conclusion**

Our design came from the early stages of defining the problem, and researching. We used that information to generate concepts. We used our knowledge we learned in class to make a decision using concept selection. We then researched more specific details like appliances, usage, and solar array size. With this information we figured out how feasible our design was on paper. Then we built the model and tested it in the experiment. We did fairly well and learned a lot. If we had to do this again we would make a few adjustments that were previously mentioned. A lot of these adjustments come from things we saw other teams do and incorporate that we thought may be useful. The problem presented for this design challenge is very relevant. We need to be more sustainable and reduce our ecological footprint in order to preserve our world. Homes play a large role in that. Designing a zero energy home made us aware of not only why to do this, but how. We learned a lot about reducing usage, passive solar, active solar, and appliances. We used this knowledge in order to design a zero energy home that worked out well both on paper, and in the experiment.