Zero Energy Home

Engineering Design Section 16

Team #8

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Abstract

Zero Energy Homes are homes that are able to create most of the energy that it needs thus making the net change of energy input and output almost zero. In order to design this type of house one must do a lot of careful planning. For this project, our house focused on obtaining its energy from the sun, therefore, we had to consider how to properly use both active and passive solar features. The ZEH house that our team designed uses these active and solar features to maximize the energy input of the house from the sun. After seeing many sample ZEH houses both in class and out of class, our team was able to learn how to best use these features. We learned guidelines and rules of thumb that could maximize our energy input. ZEH houses are important for the future as we continue to find new ways of reducing our human impact on the environment.

Introduction

Over the past several weeks, we have learned about the benefits of Zero Energy Homes and how to best design one for ourselves. In our team of four group members, we each used the lessons we learned to design our own ZEH houses and then shared our ideas with the rest of our team. We found many pros and cons to each house and compared the houses in a concept selection chart to decide which house was the most energy efficient. After selecting a design we constructed a model of it in class, we measured this model’s change in temperature when exposed to a hot lamp and then a cold fan, and we estimated the cost of the house if it were to actually be constructed. All of our results can be found below.

Challenge

Many people believe that Zero Energy Homes can be expensive to build or uncomfortable to live in. The challenge of this project is to prove that this does not have to be the case. By designing a house that can maximize heat absorption from the sun and minimize heat loss during the cold nights, we can reduce the amount of energy the house consumes thus saving a lot of money. This was the main goal for the model we constructed in class. When experimenting on the house, however, we used a large heat lamp instead of the sun and a fan with ice water to simulate the cold weather.

Concept Generation:

Each member of our group contributed one design for consideration, and while the final design was mostly modeled after our best design, it played off components from all four ideas.

<table>
<thead>
<tr>
<th>Design Concept</th>
<th>Concept Weight</th>
<th>Home Design: #1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Solar</td>
<td>45%</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Active Solar</td>
<td>25%</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Energy Efficient</td>
<td>30%</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
Naturally, our team chose to model our prototype after the 4th design concept. It maximized each concept possible to make the home as efficient as possible.

<table>
<thead>
<tr>
<th>Concept 1:</th>
<th>Concept 2:</th>
<th>Concept 3:</th>
<th>Concept 4:</th>
</tr>
</thead>
</table>

Concept 1 designated a large amount of design to maximizing active solar retention. Unfortunately, this compromised some of the capabilities of the building for passive solar efficiency and the awkward design of the home made it impractically energy inefficient. While concept 2 utilized a large amount of design processes to maximize passive solar efficiency, it left little room to gain active solar power. The third concept design was well thought out in energy savings. Appliances and interior design were a much larger factor of energy efficiency in this model. Unfortunately, concept 3 barely took passive solar into consideration. The fourth concept was a mix of each of the previous three, and scored the highest on the project matrix. It utilized active solar to an equivalent extent of concept 1, and was as keen on passive solar output as concept 2. Finally, there were several energy saving principles applied from concept three to the final design.

**Design Concept:**

Since our team wanted the home to rely mostly on passive solar energy, many design components of the home were specific to this concept. Most importantly, the large, south facing windows on the home were put in place to let in a maximum amount of sunlight onto the dark, absorbent floor on the first story. The layout of the first floor was also very open to allow heat to flow freely between the living, kitchen, and dining space. The second story windows were designed with the same process in mind, however an overhang was put in place to shade from the high, summer sun, but allow the lower sun in winter months to shine through. Behind these windows, our team put several supports in place to add thermal mass and retain heat (these are not seen in the blueprint, but are visible on the prototype). The Second story was designed as the first with an open floor plan to permit easy airflow, and is actually a loft above the first floor to allow excess heat from the large first floor windows to rise to the second
floor. This not only heats the second story, but prevents overheating of the first floor in the hot summer sun.

Exterior design also contributed to minimizing the energy input to the home. On the southernmost roof, solar panels would be put in place to maximize the amount of active solar power retained by the home. Continually, this roof would be aligned at a 45 degree angle to maximize the efficiency of the panels. We replicated this in our prototype by coating this panel with absorbent aluminum foil. Finally, the area of this roof is very large compared to the area of the northernmost roof. It was specifically designed as such to maximize the solar energy picked up on this roof, while still enabling a lofted second story and second floor windows.

One last design aspect of the house not included in the blueprint is a long trough running along the northernmost wall of the home where the roof meets the first story wall. This is then funneled into a basin at the northwestern-most corner of the home to collect and reuse rainwater. While this will not decrease the energy of the home, it will decrease the overall cost to manage the home.

<table>
<thead>
<tr>
<th>Layout Design</th>
<th>First Story</th>
<th>Second Story</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blueprint Concept</strong></td>
<td><img src="image1" alt="Blueprint Concept - First Story" /></td>
<td><img src="image2" alt="Blueprint Concept - Second Story" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3D Scape</th>
<th>3D Scape</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="3D Scape - First Story" /></td>
<td><img src="image4" alt="3D Scape - Second Story" /></td>
</tr>
</tbody>
</table>
The Model and the Experiment

We used white cardboard as the main material for the construction of our house model. Windows were made with plastic bags, the carpet was made with black fabric and everything was attached with hot glue. Each inch of our model represented two feet.

As can be seen from the pictures above, we had large windows on the south facing side of the house to maximize the heat and light that could enter the house. On the inside, the black fabric that carpeted the floors worked to absorb much of this heat that came in. A one inch overhang hung above the house to add shade on those hot summer days when the sun is directly above the house. The roof on the south facing side was covered in aluminum foil to represent the solar panels that would be installed there. This roof was angled at 45 degrees to maximize the direct light it would receive from the sun. On the inside, the floor plan is open to allow heat to flow freely within the house. For the experiment, our house was placed 6 inches away from a hot lamp for 8 minutes and then in front of a cold fan for 7 minutes. The temperature of the house was measured after each minute and can be seen below:

<table>
<thead>
<tr>
<th>“Day” Time (min)</th>
<th>Temp (degrees)</th>
<th>“Night” Time (min)</th>
<th>Temp (degrees)</th>
</tr>
</thead>
</table>

Multiview Images

As can be seen from the pictures above, we had large windows on the south facing side of the house to maximize the heat and light that could enter the house. On the inside, the black fabric that carpeted the floors worked to absorb much of this heat that came in. A one inch overhang hung above the house to add shade on those hot summer days when the sun is directly above the house. The roof on the south facing side was covered in aluminum foil to represent the solar panels that would be installed there. This roof was angled at 45 degrees to maximize the direct light it would receive from the sun. On the inside, the floor plan is open to allow heat to flow freely within the house. For the experiment, our house was placed 6 inches away from a hot lamp for 8 minutes and then in front of a cold fan for 7 minutes. The temperature of the house was measured after each minute and can be seen below:
What we learned from this experiment is that our house model is excellent at absorbing heat, but very poor at retaining this heat when exposed to cold weather. This is most likely due to the many cracks along the side of our house that were caused from not cutting our cardboard straight enough. Additionally we did not use enough absorbing material. We only used black fabric but should have tried to use black rubber as well. When comparing our house to other in the class we found that ours was the best at absorbing heat but the worst at retaining it. After seeing the projects of other group members it is most obvious that our flaw was in absorbent material. The more successful houses were the ones with dark colors and black rubber.

**House Cost**

Using the website [http://www.cpi.coop/my-account/online-usage-calculator/](http://www.cpi.coop/my-account/online-usage-calculator/) we were able to come up with rough estimates of the cost of our house assuming that it holds a four person family using energy efficient appliances.

<table>
<thead>
<tr>
<th>Monthly KW Usage</th>
<th>Appliances</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Cost (Dollars)</td>
<td>0</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3000</td>
</tr>
</tbody>
</table>
Energy Analysis

Energy Analysis: Model 1
A normal house with the same square footage as the Model 1: Base Cost of the Home: $200,000
Total House Cost: $285,500
Electricity: 11,280 kW
PV Output if we were to make this a Zero Energy Home: 11,280 kW PV Size: 11.5 kW
Electronics: Personal items
Energy/Household: 2,018 Kwh/yr
Total Cost: $5,720

ZEH Model 1 with optimal upgrades and solar panels Base Cost: $200,000
PV Cost: $28,500
Upgrade Cost: $33,500
Total House Cost: $262,000
Electricity: 6,250 kwh
PV Output: 6,250 kwh
PV size: 4.75 kW

Electronics: Personal items
Energy Household: 2,000 kwh/yr
Total Cost: $5,500

Upgrade cost increased by a significant amount due to the installation of an entire roof section being solar panel layered, also the new rain collecting system and lining the roof from gutters to collect the rain run off.
Array size: 6kW

Heat Loss Diagram

- Floor: 33%
- Windows: 13%
- Roof: 2%
- Walls: 52%
Conclusion

Our ZEH model was a fairly effective model of a real life Zero Energy Home. In the simulation, our house led all other homes in heat absorption, reaching a maximum heat of 56 degrees Celsius. We believe that our house was able to reach such great temperatures because of the area of our solar panels. Instead of taking the traditional route of a few strategically placed panels, we instead made the entirety of our south facing roof solar panels. This added more area of higher heat absorption resulting in the high heat gain within our model. However, our downfall came in the cold weather portion of the test, where our home lost a majority of its heat, dropping to 19 degrees Celsius. This drastic change in temperature is believed to have come from certain design flaws such as gaps where walls met and unsealed edges along the home.

Overall, our ZEH model proved to be an effective and energy efficient method of house design. As you have read in the data above, our model, if built in a real life scenario, would cost approximately $285,000. While this does not seem like a major discount as compared to a non-ZEH home, when evaluating prices over the course of the homes lifetime, residents of a ZEH home are likely to save a substantial amount of money annually.