Zero Energy Home Report
Team O.S.M.
Intro to Engineering Design Section 005

Team 3 submitted to 10/16/15
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Executive Summary

In this economy, it is becoming increasingly necessary to build houses that are environmentally cleaner and more efficient. Over the past several years, this concern has been
addressed with the introduction of zero energy homes (ZEH), meaning they consume a net energy of zero annually. The objective is simple; design a house with such capabilities.

In developing concepts, specific requirements had to be met such as net zero energy consumption and accommodations for a family of four. The final concept will best accomplish these and do so in the most efficient way possible.

Risks for the prototype include going over budget, being inefficient, and not accommodating four people. The best aspects of all concepts will be combined to deliver a livable zero energy home by summer of 2016.

Team OSM’s Goal

Our goal is to build the most sufficient and self-sustaining zero energy home around. For starters, the zero energy home must input energy at an equal rate as it releases, creating a net energy of ‘zero.’ This net energy is achieved through energy conservation and proper technologies that provide maximized energy efficiencies. One way we approach this solution is the stress of active solar energy. Our solar panels and other energy efficient features optimize energy conservation, allowing the homeowner to save an incredible amount of money. Another way we create this net energy of zero is to use the most energy efficient appliances around. Appliances suck up unnecessary electricity, so energy-friendly appliances are pivotal in conserving energy. These, amongst other features, allow our goal of an efficient zero energy home to be possible. However, this house is not merely a box boasting the latest appliances; the sleek design with 21st century aesthetics allow our zero energy home to be outstanding in all categories of housing, regardless of energy relation.

Customer Needs Analysis

The first customer need was for the house be structurally sound. As a building that must provide a suitable dwelling for families for years to come, its structural stability must be unquestionable to produce a sense of safety for its inhabitants. The second customer need was that its aesthetics be satisfactory. In order to sell the house, it must look appealing to its suitors. Another customer need was that the house be affordable. While the house’s inhabitants will save a large amount of money by having drastically reduced electric and water bills, the price of the house must still be low enough that a middle class worker wouldn’t feel overwhelmed by the mortgage they would need to buy it. The next customer need is for the house to be energy efficient. This is vital to the idea of having a zero energy home, and is also the home’s main selling point. Potential buyers are willing to buy the house despite its low space because of the fact that an energy efficient, zero energy home will have much lower electrical costs than a typical home. Being energy efficient also goes along with the idea of the house being helpful to the environment, which is another big selling point of the house. The final customer need was that the house have enough room for a family of four. While conserving space is immensely important to cutting down energy use, there still needs to be enough space that an average small family could comfortably live. This meant that we had to incorporate at least two bedrooms, since anything less would leave the house’s inhabitants feeling cramped.
## External Research

The results of our group’s benchmarking assessments are shown below:

<table>
<thead>
<tr>
<th>Requirements *Values range from 1-5</th>
<th>Planned Rating</th>
<th>Actual Rating</th>
<th>Competitor A (Soleta)</th>
<th>Competitor B (TC Legend)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structurally sound</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Affordable</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Energy efficient</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Enough room for a family of four</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Damage/weather resistant</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Efficient circulation</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Long-term cost effective</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34</strong></td>
<td><strong>31</strong></td>
<td><strong>33</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>
Our actual design ended up falling a few points short of our planned rating. The factors causing this were that the aesthetics were slightly less appealing, there was not as much room as we had hoped, and its long-term cost effectiveness was not as high as anticipated. One point on which the design outperformed its planned rating was its circulation, which helped to make the gap between the planned rating and the actual rating not as wide. Our first competitor, the Soleta Zeroenergy home, had a total rating that was able to top ours. The Soleta home had better aesthetics, more room, and more efficient circulation. Soleta is able to achieve this by having a much larger budget, thus creating a much more expensive house as a result. All things considered, our design is a better fit for the targeted demographic, because our house’s much more affordable price is able to compensate for the fact that its features are marginally less favorable than Soleta’s. Our other competitor, TC Legend Homes, had a lower total rating than our design, indicating that its features are inferior. The TC Legend home’s main weaknesses were its aesthetics, energy efficiency, weather resistance, and circulation efficiency. It does offer a slightly more affordable price, but with so many features that fall short compared to ours, it would be fair to say that our design is better.

Concept Descriptions

Concept 1: Concept 1 is a simple rectangle with an acclivity of 45°. The south facing roof has only one side and will contain solar panels for sunlight to be collected. The house will be surrounded with windows, but most of them will be along the south side along with a door. Although it could be fully functional, the plans for this concept are very unappealing and an awkward distribution of ceiling height is present.

Concept 2: This concept takes inspiration from Concept 1, expanding upon them even more. This house has two sides to the roof, with solar panels only on the south side to obtain the maximum amount of sunlight. The layout for the second concept is the most aesthetically

Concept 3:
pleasing than the two competitors and will cost less because of the fewer solar panels placed on it.

Concept 3: The model for the third concept is conic in order to maximize solar collection at all angles. Also, thanks to its conic shape, the customer would be able to maintain a 360° view of their surroundings with some of the windows placed along the walls of the house. Although this would seem like the ideal model, the circular walls would prove very strange to put furniture near.

Concept Selection

- Values will range from 1-5

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Concept #1</th>
<th>Concept #2</th>
<th>Concept #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structurally sound</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Affordable</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Energy efficient</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Enough room for a family of 4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total:</td>
<td>18</td>
<td>22</td>
<td>15</td>
</tr>
</tbody>
</table>
Although Concept 1 had promise, when put into the selection matrix, it was concept 2 that ended up being the most favored. Concept 1 ended up losing mostly due to its unappealing looks, but also because of some structural issues that would arise with the construction of the house; Concept 2 is just more durable.

Concept 3 had a good ideal with the circular roof to maximize sunlight gathered due to varying angles of solar panel placements. However, since the house will be facing southward, solar panels placed all around the roof would end up costing more money for possibly less energy output. Also, the roundness of the walls creates a very hard environment in order to put family possessions in.

Concept 2 took the best qualities from concept 1 and 3, while also excluding the unnecessary aspects of them. In order to achieve the maximum amount of energy output from the solar panels, the roof from Concept 1 was taken into consideration while designing Concept 2. However, because Concept 1 had an awkward height space with the roof being at a 45° angle, we instead decided to make Concept 2 look like a more traditional house, and made two roofs with 28° angles. Thanks to the two roofs, there are no problems with the height of the house. When we were creating Concept 3, we made it conic in so the house could possibly look more aesthetically pleasing. However, once the concept was made, we realized that just because it was rounder, not only was it not as appealing as we thought it would be, but it also limited the amount of space in the house. Because Concept 2 is a rectangle, there are no weird round walls to maneuver furniture around, and the customer can fit more things in their house then they could in a round house. The traditional house style might not look like anything special, but that is the reason why it is special. A design does not need to be complex in order to obtain self-sustainability, and Concept 2 is the proof of this theory.
Design Description

The physical model is made out of cardboard, plastic wrap, aluminium foil, paint, marker, and hot glue. On the model, the scale used is 1/8 inch=1 foot

Features:
- 28° south facing roof with further angled solar panels
- Dark interior for heating purposes
- Ample south facing windows for thermal exchange
- Fireplace in order to heat up house
- Insulated carpeted flooring for heat conservation
- 1 story design for ease of moving furniture and storing heat better
- Fiber cement siding for less exterior maintenance and more stability

The materials used in the model of the project were chosen for their unique qualities. The paint used on the cardboard makes the material a little more thicker than just cardboard in general, so it was used on the exterior of the walls in order to represent the fiber cement used for the siding. The aluminium foil, with its reflective properties, was used to represent the solar panels on the roof. Since plastic wrap is clear, it made an excellent interpretation of a window, which is why it was chosen to do so.

The actual design of the house is more than just common household materials though. The rectangular shape of the house was used in order to provide maximum space for the maximum amount of space to be used. Both sides of the roof are slanted at a 28° angle, but only the south facing one has solar panels. This was an intentional decision, since the sun will always be south facing from where the house will be located, this will allow for maximum sunlight collection throughout the day for the PV system. The use of the solar water heater also connected to the roof allows for the use of warm water without the use of energy input from the house's electrical system. Geothermal heating is used throughout the house to maintain a constant temperature by using the grounds constant temperature in order to help sufficiently heat/cool the house. The space provided by the house not only provides ample living space for a family of four, but also helps contain heat and lets air travel freely. In order to make the house seem bigger then it is, the house contains the least amount of walls possible in order for a happy living environment. Most of the space in the house is used for the living room, which most of day to day activity will take place. The next major room in the house the master bedroom, which will be where the married couple will be sleeping in. The third room is the children's room, which is located on the south side of the house to the east. Finally, the bathroom is the last room. It will be a shared bathroom with a 5’ x 2.5’, one toilet and one sink. The doors to exit and
enter the house will be located on the southeast and northeast corners the house, so they can be opened in order to let air flow in depending on what side of the house the wind is flowing. The southeast door will lead into a small entryway with a shoe rack that will then immediately connect with the tiled kitchen for everyday cooking, food preparation, and food storage. The kitchen will then be open to the living room/dinning room area of the house, where the family would relax. The northeast door would connect directly with the dining room.

In order for the house to be livable for a family of four, everything mentioned above was taken into consideration to make the house self-sustainable while also being comfortable.
Appliances

Refrigerator – 283 kWh/yr (Thermador: T24IR800SP)
http://www.energystar.gov/productfinder/product/certified-residential-refrigerators/details/2219297

Dishwasher – 200 kWh/yr (Bosch: SHE9ER5*UC)
http://www.energystar.gov/productfinder/product/certified-residential-dishwashers/details/2192617

Clothes Washer – 84 kWh/yr (Bosch: WAT28400UC)
http://www.energystar.gov/productfinder/product/certified-clothes-washers/details/2234997

Clothes Dryer – 311 kWh/yr (Bosch: WTG86401UC)
http://www.energystar.gov/productfinder/product/certified-clothes-dryers/details/2238756
Showerhead – 1.25 GPM (Niagra: N2912CH)
http://www.amazon.com/Niagara-Earth-Massage-1-25GPM-showerhead/dp/B003UQ17O4

Toilet – 0.9 & 1.6 GPF (Toto: CST412MF.10-01)

All appliances used in the house are highly efficient in carrying out tasks they were designed to do. Each electrical appliance is EnergyStar Certified and exceed their respective federal standard guidelines. The showerhead and toilet were chosen due to their low water consumptions during average use. The toilet, specifically, has two flush
modes that allow for little water use of only 0.9 gallons when disposing of smaller waste or 1.25 gallons when extra motivation is needed. All these efforts combined will further improve our efforts in achieving a zero energy home.

Energy Analysis

Estimated Operating Costs with Solar Heat and Electricity Contributions

<table>
<thead>
<tr>
<th>Category</th>
<th>Net</th>
<th>Solar</th>
<th>PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lights</td>
<td>$57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major appliances</td>
<td>$164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. electric loads</td>
<td>$191</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot water</td>
<td>$74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td>$186</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>$46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>-$152</td>
<td>-$718</td>
<td></td>
</tr>
</tbody>
</table>
The estimated cost of our home is approximately a base cost of $137,884. Here is a breakdown of the statistical structure behind the cost:

Location: Philadelphia  
Stories: 1  
Floor area (sq. ft): 600  
Bedrooms: 2  
Ceiling Insulation: R40  
Size of PV system (kw): 5.35  
Heating/Cooling System: electrical geothermal heat pump  
Window Type: Triple Low-E  
Base House Cost: $93,129  
PV Cost: $26,739  
Upgrade Costs: $15,267

The upgrade cost of the house is used to incorporate a solar water heater, high thermal retentive materials and high efficiency appliances. All of these investments help to lower the energy consumption of the house to help achieve our overall net zero energy.

The solar panel grid used consists of 26 individual panels that present a total surface area of 408.6 square feet. Their average energy output is 5.35 kW/year which enough to cover the energy consumption of household appliances with enough energy “leftover” that can be returned to the grid if needed.

Conclusion

There are dozens of zero-energy home designs that are effective in certain areas, but of the three concepts that stood out, Concept 2 proved to be the most well-rounded. With adequate aesthetics, Concept 2 is simple but effective, providing the self-sustainability that a zero-energy house needs. The simple, sleek design of Concept 2 is not only appealing, but efficient in solar resourcing. The two roughly 28° angles of the roof allow for almost maximum reception of sunshine resulting in the most solar energy created of all concepts. This useful feature of Concept 2 made this concept the clear frontrunner for the aesthetic category. Another major category that Concept 2 stands out in is structure. The round walls of structure of Concept 3 and off-balanced roofing of Concept 1 are no match for the well-structured, well-founded design of Concept 2.

There are zero-energy homes that are indeed more efficient, better looking, or cheaper than ours; but, no house combines the best of all three worlds. The modest overall cost of $137,884 for a good looking, energy efficient home is the best on the market. If a family of four was to search for the best possible zero-energy around, the clear choice is ours. With the most energy efficient appliances, plenty of room for
everyone, and a handsome home design altogether, this house will be not only the boundary breaking home of the now, but the trend-setting powerhouse of the future.