Zero Energy Home

Team Lion 2/25/16

Members:

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Abstract:

The Earth provides many resources for us. Many of these resources are renewable, but some that we have become dependent on are impossible to renew. The resources that are nonrenewable have been used to the point that we may soon run out of them. The use of these resources as fuel also produces large amounts of greenhouse gases, which have contributed to the problem of global warming. The need for clean energy, especially for domestic use, was the driving force behind the design of the zero energy home. The house will use clean energy technology to meet or exceed its energy needs, while also having all the amenities a family of four needs to live comfortably.

Executive Summary:

The customer has a need for a Zero Energy Home in the North Eastern part of the United States. Over the past couple of years the amount of energy that people use in our daily lives has gone up and this is causing concerns. This is where a Zero Energy Home comes in because it allows people to live in a house that uses energy that it makes on its own. The objective of this project is to design and build a home that makes as much if not more energy than it consumes. The house should also be aesthetically pleasing, and able to comfortably fit a family of four. It must also be built using green technologies and materials.
In developing the design for the Zero Energy Home, several different designs will be evaluated. Initial patent and market surveys were conducted. This process helped us to narrow down the design of our house according to our customer’s needs. After ranking our customer needs and target engineering specifications, our options will be scored using the Pugh scoring matrix. Two of the initial designs were based on were based on a green roof along with using solar panels and a geothermal pump. The other three designs involved everything the initial two designs without the green roofs. Based on our concept scoring exercise, our preliminary design will be based off of a two story house that is about 1600 square feet with solar panels, geothermal pump, and also a green roof.

There are multiple risks involved in creating a Zero Energy Home. The first that arises stems from the two floor concept. Since much of the energy generated is done so by photovoltaics, a two story home is much more difficult to achieve net-zero than a single story home. In order to fix this problem, more roof space must be used, thus generating more energy to combat the double story house. Other risks include staying within the budget as well as assembling the right team in the right place to create this home. Additionally, using the correct the materials is paramount and weekly meetings will be held to keep proper organization in these areas. The final date by which construction must be finished will be March 4, 2016.

Introduction:

This project is based on the development of an idea for a zero energy home. The reason why this project is so relevant is because today’s society uses far more energy than what the Earth has to offer. For this project, the customer requires that the home produce as much if not more than the energy it consumes. Also the house must be aesthetically pleasing, and fit a family of four comfortably. In this project, we are going to select an appropriate city in the North Eastern part of the United States, we need to decide on what materials and systems that we are going to use so that the project ends up being as efficient as possible.

Customer Analysis:

The most strikingly important design that our zero energy home must be centered around is its sustainability. It is imperative that the home not only be able to use a net zero energy each year, but also give some energy back to the grid. The idea behind this is to conserve natural resources and cut back carbon emissions to create a greener planet. This also creates a lower cost to maintain a home which is an added bonus. The next most important concept of this home is whether or not it is a home. The house must be aesthetically pleasing otherwise it is a zero energy living space. This is not our goal. We want our customers to feel a sense of comfort and family when they go to bed at night, which is as important as feeling a sense of pride that one is doing all that they can to help create a greener planet. The next two ideas behind our zero energy home are less important, but still vital to get right. The cost of the home must not be too steep to discourage one from taking the leap to create a zero energy home. This plays directly into the final concept of the difficulty to build. We want to see this home planned and built without issues, as making our customers lives stress free is of the
upmost importance to us. All of these needs have the ability to be met and more, and that is our plan.

**External Research:**

- **Patent Search:**
  Geothermal Heat Pump System and Installation
  Publication Type: Grant
  Publication Date: June 3, 1997
  Invented by: Kenneth W. Lambert
  The geothermal heat transfer system comprises a plurality of heat exchange loops placed in the ground at an angle of less than a 20 degrees, but greater than a 5 degrees

![Diagram of geothermal heat pump system]

- **Solar Panel (solar power)**
  Publication Type: Grant
  Publication Date: December 11, 2001
  Invented by: John Wing-Yan Tang and Tai-Yan Tang
  Solar cells are embedded in a window pane and generate an electrical current that is converted.
Wind Turbine (wind power)
Publication Type- Grant
Publication Date- October 17, 1944
Invented by: Putnam Palmer Cossett

Solar Water Heating System
Publication Type- Grant
Publication Date- June 10, 1958
Invented by: Raymond W. Bliss Jr.
Double Pane Window
Publication Type- Grant
Publication Date- June 24, 1967
Invented by: Hubert Woelk

- **Benchmarking:**
  - **Existing Structures:**
    - Massachusetts
    - Vermont
○ **Existing Renewable Energy Resources:**
  - Geothermal Heat
  - Solar Power
  - Wind Power
  - Solar water Heater
  - Energy Star Appliances
  - Insulations
  - Double Pane Windows
  - Smart Power Strip
  - Hydrogen Power

○ **Cost Model:**
The following table shows the cost for certain items that we could use when designing a home to be zero energy.

<table>
<thead>
<tr>
<th>Items</th>
<th>Average Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Heat</td>
<td>$7,500 to buy and $0.08/kWh to run</td>
</tr>
<tr>
<td>Solar Power</td>
<td>$19,500 to install and $0.10/kWh to run</td>
</tr>
<tr>
<td>Wind Power</td>
<td>Average $30,000 to install</td>
</tr>
<tr>
<td>Solar Water Heater</td>
<td>$6,000 - $17,000 and about $175 per year to run</td>
</tr>
<tr>
<td>Energy Star Appliances</td>
<td>Around $2,000 and saves $2,000 per year</td>
</tr>
<tr>
<td>Insulations(cellulose)</td>
<td>About $0.41 per square foot</td>
</tr>
<tr>
<td>Double Pane Window</td>
<td>Around $850 per window and saves about 50% on heating/cooling</td>
</tr>
<tr>
<td>Green Roof</td>
<td>About $11 per square foot, saves approx. 75% on cooling costs</td>
</tr>
</tbody>
</table>
**Product Dissection:**
Our house is going to be a two story zero energy home with dimensions of 40x40x40 ft. and with a garage 24x24x24 ft. The house’s electricity is going to be supplied by a 60 ft. windmill, solar panels, a geothermal heating system, and solar water heater. The house is going to be occupied by a family of 4, and it is going to have a total livable area of 2800 square feet. The roof is 8 feet wider in both dimensions than the rest of the house, and it is going to be accessible by a spiral stairs located in a corner of the house. The roof will be a green roof and have space for multiple plants and a garden, and also include a table and benches. While the first floor uses all the area provided by the house’s dimensions, the second floor is going to have a 20x20 ft. empty space to enhance the heat flow throughout the house.

**Global Marketplace:**
According to the ZEH Calculator, our house is going to need a windmill that can generate about 6 kW of power. According to the cost model, the estimated cost of the windmill is going to be about $22,000, not including installation. We will also be using solar panels to supplement the power generation of the windmill. The 3kW solar panel will cost about $7,000 with installation. Both of these are eligible for up to a 30% tax credit.

**Concept Generation:**

```
<table>
<thead>
<tr>
<th>Energy</th>
<th>Water</th>
<th>Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Store or accept</td>
<td>Store water from</td>
<td>Store external heat</td>
</tr>
<tr>
<td>external energy</td>
<td>outside</td>
<td></td>
</tr>
<tr>
<td>Convert energy to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>translational energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply electricity</td>
<td>Supply heated water</td>
<td>Supply heat to house</td>
</tr>
<tr>
<td>to house</td>
<td>to house</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

ZEH
The following matrix outlines the needs of the customers and the aspects of the house that fulfill, or exceed, the needs.

### Metrics

- In Pittsburgh, PA
- Uses solar panels and a windmill to make electricity
- Modern design
- Stucco exterior
- Green roof
- 1600 square feet of living space
- Attached 2 car garage, including storage space
- Large windows and open space for passive heating
- Energy star appliances

### Needs

- House must fit 4 people comfortably
- House must be good looking
- House must make all or more energy than it needs
- House must be in the NE united states
- House must use green materials


<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Chris's Design</th>
<th>Ryan's Design</th>
<th>Woobin's Design</th>
<th>Glenn's Design</th>
<th>Anil's Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Aesthetically Pleasing</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Fit 4 people comfortably</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Green Material</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Sum +’s</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>sum 0’s</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>sum -’s</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Net Score</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
The conclusion we got from the concept screening was that Ryan’s and Chris’s designs for the house were the two best designs.

The following table is called a concept scoring which will allow us to pick the best overall design between Chris’s and Ryan’s design.

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Weight</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>50</td>
<td>5</td>
<td>2.5</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>Aesthetically Pleasing</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Fit 4 People Comfortably</td>
<td>10</td>
<td>3</td>
<td>0.3</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Green Material</td>
<td>30</td>
<td>4</td>
<td>1.2</td>
<td>3</td>
<td>0.9</td>
</tr>
<tr>
<td>Total Score</td>
<td></td>
<td></td>
<td>4.5</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Rank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

The concept scoring allowed us to pick Ryan’s design as our best design and we will be using his design for the house.

**Embodiment Design:**
Energy Calculator:

According to the energy calculator the solar panels and water heater will supply much of the energy needed, and an additional 6kW wind turbine will likely lead to a surplus of energy, which can be put into the grid and sold to power companies. This will make the home not only a zero net energy home, but a positive net energy home.

The cooling model predicted in the calculator will be offset by the potential 75% reduction of cooling costs from the green roof. This will make the estimated cooling cost $28.25.
**Final Design Description:**

The house is a cube that has dimensions of 40x40x40 ft. It has an attached two car garage, which includes a lofted storage space with room for appliances, that is a 24x24x24 ft. cube. The exterior of the house is stone and stucco, and the interior has a modern design. There is a large window in the southwest corner of the house to aid in heating the house, the window has cellular shades to control the amount of sunlight let in. The floorplan is very open and includes a large open space on the second floor to allow passive heat flow throughout the house. The first floor has a large kitchen, a dining area, living room, and a half bath. The second floor has two bedrooms, a full bath, and a master suite that has a private bath. There is a spiral staircase...
in a corner of the house that connects the floors and provides roof access. The roof is a green roof which includes large areas for plants or a garden with a gravel walkway leading to a table with benches to enjoy the roof. The roof of the garage has a solar panel and solar water heating system. Both yards of the house are large and the backyard contains a 60ft. tall windmill which will provide most of the house’s electricity.
Conclusion:
Our Zero Energy Home was a success due to the fact that it was aesthetically pleasing and also it produces the same amount if not more energy than it uses in a month.

References:

- **Patent Search (in order):**
  - https://www.google.com/patents/US6329589
  - https://www.google.com/patents/US3299591
  - http://www.google.com/patents/US7954301

- **Existing Structures (In Order):**
  - http://www.solartoday-digital.org/solartoday/20111112/?pg=40#pg40

**Cost Model:**
- [http://geo-energy.org/geo_basics_plant_cost.aspx](http://geo-energy.org/geo_basics_plant_cost.aspx) (geothermal pump)

**Energy Calculator**