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Moving Towards Sustainable Energy: Zero Energy Home Project

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EDSGN 100: Zero Energy Home Project
Submitted to: Dr. Smita Bharti, Section 003, March, 4th 2016

Abstract:
The zero energy home is a home with zero energy consumption, which means that the output of energy is equal to the input of energy for the home. Our model is designed to comfortably fit a family of four. Generally, there are many energy-efficient concepts in the home to improve sustainability, such as solar panels and thermal mass. Our house contains both active and passive solar concepts. This project presents a great way to increase the sustainability in both State College, Pennsylvania, and the world.

Introduction:
In today’s day in age, there exists a desire to obtain sustainable energy use across the United States as well as in various other areas throughout the world. Historically on a global level,
energy consumption has continued to grow from just under 10,000 Mtoe (Million tonne of oil equivalent) in the year 2000 to almost 15,000 Mtoe in the year 2014 (Global).

https://yearbook.enerdata.net/

For this reason, many countries are trying to move closer to reusable energy sources such as hydroelectric energy or solar energy just to name a few. In the United States, the term “Zero Energy Consumption” was coined to illustrate how homes, offices, etc. can not only input less energy but also output or use less energy to provide sufficient power to sustain daily functions required for a home to function such as heating, lighting, and many more.

From a financial perspective, reducing energy consumption is allowing home/business owners to save on their energy bills at the end of the month. By doing something as simple as opening the blinds to let natural sunlight into a living space, home owners are able to turn off lamps and other lights which ultimately lead to spending less every month just in lighting a room. Statistically, current figures show that on average in the United States, people are spending roughly $3000 a year on their energy bill just to power their home (How Much). Dr. Smita Bharti, faculty member at The Pennsylvania State University, has made it a point to apply many passive and active sustainability techniques to her home and attests to the fact that applying these techniques has kept her energy bill at around $220 a year.

With this “zero energy consumption” idea in mind, the Department of Energy has initiated several builder challenges for companies to construct the most energy efficient home. These builder challenges have led to the development of over 14,000 energy efficient homes as well as million dollars in energy savings as of 2008 (Zero).

Indeed, future initiatives are conducive to retaining the world’s natural resources and finding more ways to develop sustainable energy usage for not only homes but businesses as well. Many companies are releasing products onto the market which are much more energy efficient. By utilizing natural sources of energy such as the sun and the wind as well as minimizing the need to
use very energy costly appliances, we as a world can move closer to sustainability for many generations to come.

**Customer Needs and Specifications:**

Our Zero Energy Home is located in State College, Pennsylvania where we find a fair amount of available sunlight, rain water as well as easterly winds. With this in mind, the customer has requested the following features for the exterior of the house:

Size and Structure of Home

*Area*: 2100 sq ft

*Material for Home*: Brick Siding, Insulated Vinyl on roof

Solar Panels

*Model*: GE 37150

*Area*: 1.28 sq m

*Rated Power*: 150W

*Efficiency*: 11.7%

*Number of Panels*: 33

Large Bay Windows

*Location*: On top level of home

*Type*: Double layered bay window

*Frame*: Fiberglass

*R Value*: 3.8

Smaller Windows

*Type*: Double low-e

*R value*: 2.9

To further obtain sustainability, as well as add comfort and aesthetic value to the home, the customer has requested the following specifications for the interior design of the home:

Wall Structure

*Material*: Double 2x4 with 10" foam
R Value: 36

Bedrooms
3 bedrooms

Bathrooms
2.5 bath

Kitchen
Stove: Kenmore stainless steel
Refrigerator: LG Counter Depth French Door

More Appliances
Washing Machine: Kenmore Front Load Washer
Dryer: Electric Dryer w/Sensor Dry

HVAC System:

Lighting
Lighting: LED light
Efficiency: 25%-80% more efficient than other incandescent bulbs

Our Findings:

1. Library/online/patent research
As the Zero Energy House becomes popular, it’s easier to build nowadays. Still, there are some factors we need to pay attention to when building the Zero Energy Home.

The Orientation:
In order to maximize the solar energy, the house needs to face true south, allowing roof overhangs to absorb sunlight in winter and provide shades in summer. Additional items to consider are, the placement of trees, nearby surroundings and porches that will all have effects on the house.

Windows and Doors:
For zero energy homes, it is important to have highly insulated windows and doors; remembering to choose high R-Value windows and small window frame profiles. Window size has a major impact on the house. It’s better to use 14% window-to-floor area for the house, and 50% of windows need to be located on the south side of the home (Twelve). In the northern parts, many people choose to use double 2×4” walls to provide for thorough insulation throughout the home.

Heating and Cooling:
For the interior, minimizing heating and cooling is the most important step in building a ZEH. In that case, increasing open spaces in the house could achieve better heating and cooling effects. It’s important to install a heating, ventilating, and air conditioning (HVAC) system to bring both heat and cool air to all parts of the house without additional ventilation such as house fans. For the energy source, heat pumps are one of the most efficient methods for heating and cooling due to their available energy output as well as their capacity to keep things heated for long durations of time.

**Efficient lighting and appliances:**
To reduce net energy use to zero, houses need to install energy efficient lighting as well as selecting energy efficient appliances are very necessary. For the lighting, it is better to increase natural lighting and use LED’s in the house, which require less electricity and have longer life. There are certain types of conditions that need to be considered when designing the lighting: the amount of luminance required, the location and number of lights needed and whether lights will be dimmed or not (Lighting). For the appliances, trying to view Energy Star rated appliances is a great place to start. In considering light sources, it is also a good practice to implement manual on and off switches which can prevent from phantom loads or unused leaking electricity.

**Morningstar Zero Energy Home: Penn State**

The Morningstar home is located in Penn State and is a very successful demonstration of Zero Energy Home. At first, the outside of the house has many features to increase sustainability, such as wind turbines, an electric car, and an ecological irrigation system all of which are very energy sustainable. The interior of the house also has numerous environmental-friendly concepts. For example, the table is made from the sick trees from the Penn State campus. Surely, it gives our team many inspirations for our own project. After viewing the Morningstar home, our team was inspired to use some similar concepts such as the use of sliding doors rather than normal doors in order to increase the open space and minimize heat loss. Also, our team is going to use the washer and dryer combo like the Morningstar did to save energy. The tour of the Morningstar was rewarding and was a great learning experience for developing our own ZEH.

**Manufacturer Design:**

**Our 3D Model**

![3D Model](image)
1. Geothermal heat pump: It’s a central heating system that transfers heat from the ground (Wikipedia). It provides clean, quiet heating and cooling while cutting utility bills up to 70 percent (Geothermal). With the help of geothermal heat pumps, the house could save a significant amount of electricity and requires no maintenance.

2. Rain harvesting system: For definition, the system converts rainwater into heating, irrigation or drinking water. The use of rain harvesting system could not only reduce water bills, but also reduce floods and soil erosion, which is great for the environment (Advantages).

3. Solar panels: Solar panels are very common to use. Basically they transfer light energy from sun to electricity through the photovoltaic effect (Wikipedia). The reason to install solar panels is that they provide reliable, secure energy source. For sustainability purpose, solar power helps to stop global warming (Advantage).

4. Bay windows: Firstly, the use of bay windows could enhance the artistic value of the house. Also, the windows could allow more sunlight shine into the room, reducing the use of lights. At last, bay windows save more spaces, so it’s very efficient to use.
Concept Selection:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Andrew: Rate/Weighted Score</th>
<th>John: Rate/Weighted Score</th>
<th>Steven: Rate/Weighted Score</th>
<th>Eliza: Rate/Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>10%</td>
<td>3: 3 x 0.1=0.3</td>
<td>4: 4 x 0.1=0.4</td>
<td>1: 1 x 0.1=0.1</td>
<td>4: 4 x 0.1=0.4</td>
</tr>
<tr>
<td>Design</td>
<td>20%</td>
<td>3: 3 x 0.2=0.6</td>
<td>5: 5 x 0.2=1.0</td>
<td>4: 4 x 0.2=0.8</td>
<td>5: 5 x 0.2=1.0</td>
</tr>
<tr>
<td>Energy Usage</td>
<td>40%</td>
<td>4: 4 x 0.4=1.6</td>
<td>4: 4 x 0.4=1.6</td>
<td>5: 5 x 0.4=2.0</td>
<td>4: 4 x 0.4=1.6</td>
</tr>
<tr>
<td>Cost</td>
<td>30%</td>
<td>3: 3 x 0.3=0.9</td>
<td>3: 3 x 0.3=0.9</td>
<td>2: 2 x 0.3=0.6</td>
<td>5: 5 x 0.3=1.5</td>
</tr>
<tr>
<td>Sum/Rank</td>
<td>100%</td>
<td>3.4</td>
<td>3.9</td>
<td>3.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

This concept matrix was used to identify what criteria will be used to determine the most energy efficient and cost effective zero energy home.

Just a quick introduction to how the matrix itself works: First it is important to make a list of what are the choices being considered as well as what criteria would judge the effectiveness of those choices. In the matrix above, four choices were based on four separate criteria (size, design, energy usage, and cost). Second, there must be assignment of importance to each criteria that are ultimately partitioned in such a way that their sum equals 100%. To decide which of the choices being considered is best, one must assign a numerical ranking system ranging from very poor to excellent (i.e. 1-5). Third, after assigning each choice a value from 1-5 for example, the weight of the criteria is then multiplies and eventually summed with the numerical assignment(s) given for each choice. The sum or rank decides which option from the ones listed is the optimal selection.

Conclusions:

Our group designed a zero energy house for a family of four. In order to provide for four people, our group designed three bedrooms. One master bedroom includes a bathroom for the parents, and two small bedrooms were constructed for the boy and the girl. The house also includes 2.5 bathrooms. In addition, the house has a large kitchen and a living which will both serve as the main living space in the home. Our objective during this project was to provide a comfortable and functional home for the family while promoting sustainability in the community. After extensive research in the subject, we decided to use solar panels as the main power source for the home, and an electric geothermal heat pump for most of the water and air heating in the home. Our group also put many features inside the house to achieve net zero energy, such as an open concept, sliding doors and bay windows. To simulate a real situation, our group built a model using black fabric, foam core board, aluminum foil, hot glue, and black insulating rubber. The model showcases the basic size, layout, and solar features of the home. Our house performed at an average level in the heat retention test. The house retained heat fairly well, however it could be improved through a better seal on the roof, and more insulation throughout the model. Overall, the house did meet our customer's specifications and includes many features that assist in the
achievement of sustainability. For future improvements, we may need to install a garage to compensate for the average American family. Most families own at least 2 cars in our modern society. To conclude, the Zero Energy Home project taught us much about living in a cleaner world and the measures we will have to take to achieve a more sustainable planet.
Appendix A: Cost Analysis for Home

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (in dollars)</th>
<th>Energy Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator/Fre</td>
<td>2,065.10</td>
<td>665 kWh/year</td>
</tr>
<tr>
<td>Freezer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stove/Oven</td>
<td>499.99</td>
<td>660 kWh/year</td>
</tr>
<tr>
<td>Microwave</td>
<td>179.99</td>
<td>130 kWh/year</td>
</tr>
<tr>
<td>Television</td>
<td>1100</td>
<td>65 kWh/year</td>
</tr>
<tr>
<td>Dryer</td>
<td>359.99</td>
<td>416 kWh/year</td>
</tr>
<tr>
<td>Fan</td>
<td>50</td>
<td>15 kWh/year</td>
</tr>
<tr>
<td>Laptop</td>
<td>500</td>
<td>50 kWh/year</td>
</tr>
<tr>
<td>Printer</td>
<td>150</td>
<td>90 kWh/year</td>
</tr>
</tbody>
</table>

Listed above is a very brief assessment of general appliances that may be used by a typical family during an average day and how their monetary cost is associated with a particular energy output.

<table>
<thead>
<tr>
<th>Base House Cost</th>
<th>$ 193,828</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost</td>
<td>$ 24,750</td>
</tr>
<tr>
<td>Upgrade Costs</td>
<td>$ 19,596</td>
</tr>
<tr>
<td>Total House Cost</td>
<td>$ 238,173</td>
</tr>
</tbody>
</table>

Above us a basic cost breakdown for the home.
Appendix B: References


Dr. Smita Bharti, 29 Feb. 2016.


