Zero Energy Home

By: Team DiggyWithIt (8)

Engineering Design 100

Section 207

Submitted to Wallace Catanach on August 13, 2015

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</tr>
</tbody>
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Executive Summary

For the EDSGN 100 class at Penn State University, Team *DiggyWithIt* plans to address the issues and the challenges of designing and modeling a Zero Energy Home. A Zero Energy Home is a home that is essentially self-sufficient. Over the course of a year the house produces either an equal amount or an excess amount of energy than it consumes. In order to meet this goal, the house uses solar energy and other green building principles to produce its energy. Other zero energy staples include south-facing windows, strong emphasis on recycling along with composting, geothermal heating, acceptable insulation, and wind turbines. In addition to the home being completely self-sufficient, it also needs to meet some average home requirements, including state regulations. The home must be able to comfortably house a family of four, as well as have an attractive design that any potential owner can take pride in.

While brainstorming the design of the Zero Energy home, multiple factors became accounted for after a vast period of preliminary research. During this time frame, homes were carefully studied and information was collected in order to get a firm understanding of the functionality and appearance of existing designs. Many of the design principles were implemented to make the home functional for a family of four, while at the same time improving the wealth and well-being of the residents. The owner will take pride in the home because of its beautiful look and positive footprint on the environment. The design ideas decided on were chosen through a process of multivoting, a process of ranking the importance of ideas, after the initial brainstorming.

The project will be completed within the design budget of $140,000. Some possible issues could arise while trying to stay within this budget. This risk will be avoided by using the most cost effective and green building materials and by keeping the size of the house in a reasonable range. An additional risk in regards to the house is that the sources of energy may not produce the energy required to live comfortably and meet all the needs of the occupants of the home. This possible problem will be avoided by including a large enough photovoltaic system and wind turbine system to produce more than the required energy for the house and its denizens. The final project will be turned in and presented on August 11th 2015.
Introduction

In this project report we have included each step that we went through to develop our home. The steps are in chronological order, so as the report goes on the reader will be able to follow through the process we went through as a team. We first started out by defining our customer needs. Then we did some preliminary research to better understand how to construct a zero energy home that would satisfy our customer needs. After we understood how to do that we started to think of concepts that we could use for our home that would meet our customer needs at the same time. After we had multiple concepts we worked to combine the best parts of each concept and we selected an idea that we believed incorporated all those ideas. This became our model. From there we developed a cost model to ensure that our home was under budget. Finally after we developed a model that met every one of these needs, we developed a floor plan and then generated that into a 3D model, both physical and in a CAD program called SolidWorks.
## Customer Needs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The home produces more than a sufficient amount of energy to cover all of the average consumer's needs.</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Energy Homes can be built and function in the commonwealth</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Energy Homes can meet the needs of a family of four.</td>
<td>5</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home is built using green building materials/principles.</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home is attractive to the consumer</td>
<td>3</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The house does no harm to the community in the present and future.</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home’s efficiency improves the health and welfare of its residents and the community it’s in.</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The consumer can be proud to live in this house.</td>
<td>4</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The house is beautiful and functional.</td>
<td>3</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Importance: 10 9 7 5 7 3 4 2 6
Customer Needs Analysis

The function of our zero energy is to have a house which is completely self-sustaining. Solar panels and other top notch conservative energy systems help create this environment. It will be built in the commonwealth of Pennsylvania in an area with adequate resources for consumption. Green building practices will help reduce the consumption and allow for the house to do no harm to its habitants and community. The house is built to accommodate a family of four and provide enough space for them to accomplish their daily activities. The house will maximize the allowed floor space of the home and create multiple bedrooms and bathrooms. Exterior and interior amenities will allow for the family to be proud of living in their new zero energy home. Such amenities could include top of the line appliances and technologies which limit energy use as well as an attractive exterior like stucco or vinyl. Those who come into contact with the habitants and those who have a chance to live their will show that the houses efficiency improves the health and welfare of everyone. Essentially people will feel like this home is increasing the quality of their life and relives them of the stresses of provided electric, oil, or gas services.
# Research

<table>
<thead>
<tr>
<th>Zero Energy Homes</th>
<th>Location</th>
<th>Size</th>
<th>Floors</th>
<th>Occupants</th>
<th>Bedrooms</th>
<th>Heating System</th>
<th>Heating Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom</td>
<td>Truro, Massachusetts</td>
<td>6200</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>Geothermal</td>
<td>Electricity</td>
</tr>
<tr>
<td>Tom</td>
<td>Farmstead, Vermont</td>
<td>2700</td>
<td>2</td>
<td>~</td>
<td>3</td>
<td>Electric Floor</td>
<td>Wood Stove</td>
</tr>
<tr>
<td>Dan</td>
<td>Cape May, New Jersey</td>
<td>1871</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>Heat Pump</td>
<td>Electricity</td>
</tr>
<tr>
<td>Dan</td>
<td>New Paltz, New York</td>
<td>2288</td>
<td>2</td>
<td>NA</td>
<td>3</td>
<td>Ground Source Pump</td>
<td>Electricity</td>
</tr>
<tr>
<td>Mike</td>
<td>Charlotte, Vermont</td>
<td>2800</td>
<td>2</td>
<td>3+</td>
<td>3+</td>
<td>Heat Pump</td>
<td>Electricity</td>
</tr>
<tr>
<td>Mike</td>
<td>Turners Falls, Massachusetts</td>
<td>1152</td>
<td>1</td>
<td>3+</td>
<td>3</td>
<td>Heating Pump</td>
<td>Electricity</td>
</tr>
<tr>
<td>Ashley</td>
<td>Gaithersburg, Maryland</td>
<td>2709</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>Geothermal</td>
<td>Electricity</td>
</tr>
<tr>
<td>Ashley</td>
<td>Frederick, Maryland</td>
<td>4516</td>
<td>4</td>
<td>3</td>
<td></td>
<td>Ground Source Pump</td>
<td>Electricity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zero Energy Homes</th>
<th>Size of PV System</th>
<th>Solar Water Heater</th>
<th>R-value W</th>
<th>R-value C</th>
<th>Air Recovery</th>
<th>Annual Energy Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom</td>
<td>~</td>
<td>No</td>
<td>~</td>
<td>~</td>
<td>Yes</td>
<td>~</td>
</tr>
<tr>
<td>Tom</td>
<td>~</td>
<td>Yes</td>
<td>60</td>
<td>87</td>
<td>Yes</td>
<td>Net Zero Energy</td>
</tr>
<tr>
<td>Dan</td>
<td>6.5</td>
<td>Yes</td>
<td>23</td>
<td>30</td>
<td>Yes</td>
<td>11324kWh</td>
</tr>
<tr>
<td>Dan</td>
<td>7.26kW</td>
<td>Yes</td>
<td>22</td>
<td>60</td>
<td>Yes</td>
<td>1733kWh</td>
</tr>
<tr>
<td>Mike</td>
<td>~</td>
<td>No</td>
<td>40</td>
<td>56</td>
<td>Yes</td>
<td>5999kWh</td>
</tr>
<tr>
<td>Mike</td>
<td>4.94kW</td>
<td>No</td>
<td>42</td>
<td>100</td>
<td>~</td>
<td>1949kWh</td>
</tr>
<tr>
<td>Ashley</td>
<td>19577</td>
<td>Yes</td>
<td>2x</td>
<td>2x</td>
<td>~</td>
<td>13086kWh</td>
</tr>
<tr>
<td>Ashley</td>
<td>~</td>
<td>No</td>
<td>24</td>
<td>50/55</td>
<td>Yes</td>
<td>Savings-22759</td>
</tr>
</tbody>
</table>
Below are images of a couple of the houses that we used for benchmarking.

Charlotte, Vermont

Turner Falls, Massachusetts
<table>
<thead>
<tr>
<th>House Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>( \text{Competitive Analysis} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Score</strong></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>( \text{Tally} )</td>
</tr>
<tr>
<td><strong>Comment</strong></td>
<td>The house is balanced and functional.</td>
<td>The consumer can be proud to live in the house.</td>
<td>The house promotes the health and welfare of its occupants and the community.</td>
<td>The house produces more than a sufficient amount of energy to meet all the average consumer’s needs.</td>
<td>The house does no harm to the community in the present and future.</td>
<td>The house promotes and supports the community’s objectives.</td>
<td>The house can meet the needs of a family of three.</td>
<td>The house is maintaining green building principles.</td>
<td>The house is attractive to the consumer.</td>
<td>( \text{Competitive Analysis} )</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Target or Limit Value</strong></th>
<th>( \text{High} )</th>
<th>( \text{Maximum} )</th>
<th>( \text{High} )</th>
<th>( \text{Maximum} )</th>
<th>( \text{High} )</th>
<th>( \text{Maximum} )</th>
<th>( \text{High} )</th>
<th>( \text{Maximum} )</th>
<th>( \text{High} )</th>
<th>( \text{Maximum} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Difficulty</strong></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Max Relationship Value in Column</strong></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Weight Importance</strong></td>
<td>150</td>
<td>121</td>
<td>131.8</td>
<td>131.8</td>
<td>188.9</td>
<td>188.9</td>
<td>239.8</td>
<td>239.8</td>
<td>284.2</td>
<td>284.2</td>
</tr>
<tr>
<td><strong>Relative Weight</strong></td>
<td>8%</td>
<td>8%</td>
<td>7%</td>
<td>7%</td>
<td>9%</td>
<td>9%</td>
<td>12.8%</td>
<td>12.8%</td>
<td>16%</td>
<td>16%</td>
</tr>
</tbody>
</table>

\[ \text{Note:} \text{Score values range from 1 to 10, with 10 being the highest.} \]
## Concept Generation

We started off our concept generation by each individually writing down some ideas that we believed were essential for our home design. After that we individually voted on all of the ideas. Some ideas had to be cut, even though they received some votes, simply because they were not possible with our design requirements.

<table>
<thead>
<tr>
<th>4 Votes</th>
<th>3 Votes</th>
<th>2 Votes</th>
<th>1 Vote</th>
<th>0 Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Porch</td>
<td>Hard Wood Floors</td>
<td>Plenty of Windows</td>
<td>Bay Window</td>
<td>Fire Place</td>
</tr>
<tr>
<td>Two Stories</td>
<td>Wraparound Couch in Living Room</td>
<td>No Green Carpets</td>
<td>Island in Kitchen</td>
<td>Flat screen TV</td>
</tr>
<tr>
<td>Large Kitchen</td>
<td>Solar Panels on Roof</td>
<td>Light Colors on Walls</td>
<td>Backyard</td>
<td>Dark Colored Walls</td>
</tr>
<tr>
<td>Vinyl</td>
<td>Skylight</td>
<td>Trees</td>
<td>Reading Benches Below Windows</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back porch with built in grill and fire pit</td>
<td>Front Yard</td>
<td>Granite Countertops</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upstairs Balcony</td>
<td>Marble Flooring in Kitchen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Acres of Land</td>
<td>Sliding Glass Door</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stucco</td>
<td>Large Garden</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brick</td>
<td>Plaster Ceiling</td>
</tr>
</tbody>
</table>
## Concept Selection

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Solar panels</th>
<th>Aperture</th>
<th>Top line appliances</th>
<th>Vinyl siding</th>
<th>Slab</th>
<th>Overhang</th>
<th>Wood floor</th>
<th>Laminate Floor</th>
<th>Bay windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>The home produces more than a sufficient amount of energy to cover all of the average consumer's needs.</td>
<td>X</td>
<td>0</td>
<td>/</td>
<td>0</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>x</td>
</tr>
<tr>
<td>Zero Energy Homes can be built and function in the commonwealth</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>x</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Zero Energy Homes can meet the needs of a family of four.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>The home is built using green building materials/principles.</td>
<td>X</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>0</td>
<td>x</td>
</tr>
<tr>
<td>The home is attractive to the consumer</td>
<td>/</td>
<td>X</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>/</td>
<td>x</td>
</tr>
<tr>
<td>The house does no harm to the community in the present and future.</td>
<td>X</td>
<td>0</td>
<td>/</td>
<td>0</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>x</td>
</tr>
<tr>
<td>The homes efficiency improves the health and welfare of its residents and the community it’s in.</td>
<td>X</td>
<td>0</td>
<td>/</td>
<td>0</td>
<td>x</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>x</td>
</tr>
<tr>
<td>The consumer can be proud to live in this house.</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>The house is beautiful and functional.</td>
<td>0</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Sum &quot;x&quot; (+)</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>9</td>
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<tr>
<td>Sum &quot;0&quot;</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Sum &quot;/&quot; (-)</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>Net Score</td>
<td>5</td>
<td>6</td>
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<td>6</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>9</td>
</tr>
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<td>Rank</td>
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<td>4</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Selection Criteria</td>
<td>Southern facing windows</td>
<td>East &amp; West facing windows</td>
<td>Triple pane windows</td>
<td>r30 insulation</td>
<td>r-60 insulation</td>
<td>Crappy Appliances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home produces more than a sufficient amount of energy to cover all of the average consumer’s needs.</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Energy Homes can be built and function in the commonwealth</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Energy Homes can meet the needs of a family of four.</td>
<td>x</td>
<td>X</td>
<td>0</td>
<td>x</td>
<td>x</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home is built using green building materials/principles.</td>
<td>x</td>
<td>/</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The home is attractive to the consumer</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td>/</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The house does no harm to the community in the present and future.</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The homes efficiency improves the health and welfare of its residents and the community it’s in.</td>
<td>x</td>
<td>/</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The consumer can be proud to live in this house.</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The house is beautiful and functional.</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sum "x" (+)                      9 4 8 5 7 2
Sum "0"                          0 3 1 3 2 2
Sum "/" (-)                      0 2 0 1 0 5
Net Score                       9 2 8 4 7 -3
Rank                            1 8 2 6 3 10
# Cost Model

## General Info

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Location</td>
<td>Philadelphia</td>
</tr>
<tr>
<td>Electricity cost ($/kwh)</td>
<td>0.1</td>
</tr>
<tr>
<td>House type</td>
<td>1 story</td>
</tr>
<tr>
<td>Conditioned floor area (sq.ft.)</td>
<td>680</td>
</tr>
<tr>
<td>Number of bedrooms</td>
<td>3</td>
</tr>
</tbody>
</table>

## Heating & Cooling

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Type of heating &amp; cooling system</td>
<td>Electric geothermal heat pump</td>
</tr>
<tr>
<td>Solar Technologies</td>
<td></td>
</tr>
<tr>
<td>Size of PV system (kw)</td>
<td>4.10</td>
</tr>
<tr>
<td>Solar water heater</td>
<td>Yes</td>
</tr>
</tbody>
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## Envelope Details

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Wall construction</td>
<td>Double 2x4 with 10&quot; foam</td>
</tr>
<tr>
<td>Ceiling Insulation</td>
<td>R60</td>
</tr>
<tr>
<td>Window type</td>
<td>Triple low-e</td>
</tr>
<tr>
<td>Upper floor ceiling area (sq.ft.)</td>
<td>680</td>
</tr>
<tr>
<td>North wall area (gross) (sq.ft.)</td>
<td>340</td>
</tr>
<tr>
<td>East wall area (sq.ft.)</td>
<td>200</td>
</tr>
<tr>
<td>South wall area (sq.ft.)</td>
<td>340</td>
</tr>
<tr>
<td>West wall area (sq.ft.)</td>
<td>200</td>
</tr>
<tr>
<td>North window area (sq.ft.)</td>
<td>0</td>
</tr>
<tr>
<td>East window area (sq.ft.)</td>
<td>48</td>
</tr>
<tr>
<td>South window area (sq.ft.)</td>
<td>144</td>
</tr>
<tr>
<td>West window area (sq.ft.)</td>
<td>48</td>
</tr>
</tbody>
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## Behavior

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<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water conservation</td>
<td>A lot</td>
</tr>
<tr>
<td>Uses clothesline</td>
<td>Some</td>
</tr>
<tr>
<td>Thermostat setback</td>
<td>Some</td>
</tr>
<tr>
<td>Heat thermostat setting (F)</td>
<td>70</td>
</tr>
<tr>
<td>Cool thermostat setting (F)</td>
<td>77</td>
</tr>
</tbody>
</table>

## Appliances

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td>Best</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>Best</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>Best</td>
</tr>
</tbody>
</table>

## Small Appliance Input

<p>| | |</p>
<table>
<thead>
<tr>
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</table>

## Extras

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Garage</td>
<td>a. None</td>
</tr>
<tr>
<td>Hot Tub</td>
<td>a. None</td>
</tr>
<tr>
<td>Pool</td>
<td>a. None</td>
</tr>
</tbody>
</table>

## Results

<p>| | |</p>
<table>
<thead>
<tr>
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<table>
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<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope Heat Transmission</td>
<td></td>
</tr>
<tr>
<td>Infiltration</td>
<td>5%</td>
</tr>
<tr>
<td>Windows</td>
<td>40%</td>
</tr>
<tr>
<td>Walls</td>
<td>22%</td>
</tr>
<tr>
<td>Roof</td>
<td>12%</td>
</tr>
<tr>
<td>Floor</td>
<td>21%</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Base House Cost</td>
<td>$ 98,418</td>
</tr>
<tr>
<td>PV Cost</td>
<td>$ 20,500</td>
</tr>
<tr>
<td>Upgrade Costs</td>
<td>$ 20,873</td>
</tr>
<tr>
<td>Total House Cost</td>
<td>$ 139,791</td>
</tr>
</tbody>
</table>
Estimated Operating Costs with Solar Heat and Electricity Contributions

Annual Cost ($)

- Lights
- Major appliances
- Misc electric loads
- Hot water
- Heating
- Cooling
- TOTAL

Net  Solar  PV

Estimated Operating Costs with Solar Heat and Electricity Contributions

Net  Solar  PV

- Lights
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- Hot water
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- Cooling
- TOTAL

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Cost Model Analysis

The cost model was one of the most integral tools in the design of our zero energy house. Due to our small budget of about $140,000 we ran into some issues adding features to our house without going over budget. However after fidgeting with the model itself we managed to fit into our budget without sacrificing what we truly wanted in our home. Our photovoltaic panel system used for our solar power generation ran us about $20,000 and was easily the most costly part of our house. The 4.10 KW system was chosen based on performance and price to be our best fit. Another challenge in the building and design of our house through the cost model was the determination of our square footage. For about every 100 square feet the price of the house increases about $7,000 so ultimately we settled for a slightly smaller house around the size of 680 square feet. We determined that a majority of southern facing windows would also be a more cost efficient feature of our house considering sunlight radiates from the south most of the day. This would allow our house to receive higher amounts of natural light as well as heat. Windows were also chosen to be triple pane as they retain the most heat. When it came to the heating of the house a Geothermal electric heat pump was chosen although it is the priciest model costing us about $6,000 more than the lower tiered heat pump. Such a system has a low operating cost, low use of electricity, as well as no carbon emissions, and are long lasting for up to 15 plus years.
House Design

Functional Diagram of House

- Solar panels
- Energy (back to the grid)
- Waste water
- Heat
- Lighting
- Slab
- Water
- Sunlight
- Appliances
- Bathroom
Final Floor Plan

Kitchen

Master Bedroom

Full Bath

Living Room

Bedroom 2

Half Bath

Bedroom 1
This is the top view of our zero energy home.

This is the front (south) view of our zero energy home.
This is the isometric view of our zero energy home.

This is the right (east) side view of our zero energy home.
This is the drawing of our zero energy home with all four views from above.
House Specifications

Team Diggywithit’s zero energy home design incorporates some of the most forward thinking and newest green building principles seen in the field today. Starting from the base then going up toward the roof we have the slab. A concrete slab was incorporated into the foundation of our one story rancher style ZEH home. The benefits of using a slab in the foundation of numerous and they include that they are easier to install compared to a crawl space, they retain heat better, and are more durable. When it comes to heating the house an electric geothermal heat pump was chosen for its benefits in heating and cooling as well as its limited energy use. The system itself functions by pumping liquid in pipes through the ground and uses the heat transfer from the ground into the liquid to heat the home through circulation after the heat itself is extracted from the liquid. A solar water heater is also incorporated into our house due to its low cost for one of the most important systems of residential life, hot water which is terrible to live without. The house is insulated with the best insulation we could get on the market. Walls are built with 2x4 with 10 inches of foam inside to keep in the maximum amount of heat in the winter. The ceiling insulation is R-60 and triple low e windows are used throughout the house. The windows allow for the highest transfer of radiant heat from the sun as well as let in the most light. The house will also include a tight air and heat recovery system which allows for the highest amount of heat to remain in the home and not be lost due to leaky seals and drafty windows. We are installing a 4.1 KW photovoltaic system into our home to reduce energy costs and to help follow green energy guidelines. This system includes Canadian Solar CS6K-M panels that are fixed on the south facing roof. In terms of our appliances, specifically our clothes washer and dryer, we decided to invest in Maytag appliances because they were the most energy efficient option. They were also sold at an affordable price.
Conclusion

In conclusion, we feel that our research has led to the development of a practical model of a zero energy home. The home comfortably houses a family of four, while at the same time abiding by green energy principles. We accurately analyzed our customer needs and developed a final product that satisfied all of the consumer’s wishes. We were able to do all of this while staying under the $140,000 budget, ultimately, constructing an aesthetically pleasing, self-sufficient house.
References

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