

Large Noodle Squad's Zero Energy Home

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Abstract

The purpose of this project was to design a home that produces zero net energy(ZEH). The most significant aspect of this project was the practice and application of the design process. The aspect of sustainability was also introduced and the fact that the earth is capable of providing a limited amount of resources was brought to our attention. We were encouraged to reflect on our own use of resources and were given the opportunity to design a home that would use resources efficiently and produce a responsible ecological footprint.

Introduction

As a team we were tasked with designing a zero energy home, under the guidelines of a 200,000 dollar budget, a location in Pennsylvania, sized to fit a family of four, and to be physically appealing as well as energy efficient. A zero energy home must incorporate energy efficiency and renewable energy production. This means reliable insulation, airtight walls, and efficient appliances, as well as any combination of renewable energy. While the goal of this design is to attain zero net energy, energy must still be purchased off of the grid due to the fact that renewable energy is not available 24/7. However, any extra energy produced by the home can be sold back to the electric company. In addition to the obvious efficiency standards and use of renewable energy needed, the incorporation of passive design is also extremely important. This includes structural design and orientation of the house, which will be highlighted in the concept generation/selection portion of this report.

Mission Statement

As previously stated, the goal of this project was to design a home that makes use of renewable energy as well as maximum energy efficiency in order to attain a zero net energy home.

Customer Needs

Our zero energy home was limited to a budget of 200,000 dollars, was required to be located in PA, and had to be sized large enough to fit a family of four. In addition to being energy efficient, the customer also wanted the home to be visually appealing. The most important aspect of our design was obviously attaining the goal of zero net energy, however, the budget could not be spent strictly on energy efficient appliances and renewable energy technology, we had to also allot enough money to attain an aesthetically appealing home that was relatively large.

Concept Generation

After evaluating and considering all of the customers' needs, we needed to conceptualize ideas and solutions that would solve the problem. The first step in generating these concepts was to brainstorm. This meant a judge free environment that we recorded any and every idea that came to mind, no matter how absurd. As a team, we thought of several ideas for renewable energy, including, solar panels, wind turbines, hydroelectric energy, geothermal energy, hydrogen energy, and even mechanical energy produced by exercise machines. We also thought of the idea of a Saltbox roof style in order to maximize the area for solar panels. In addition to

having a large area of the roof facing south, we thought it would be a good idea to have a large wall area facing the south in order to further take advantage of passive heat energy from the sun. We knew that including LED lightbulbs and energy star windows in our design was also a good idea in order to keep our house as efficient as possible. For the construction of our house, we thought designing a 2000 square foot home located in Montgomery County PA would be adequate, as well as facing the windows south to take advantage of passive solar energy.

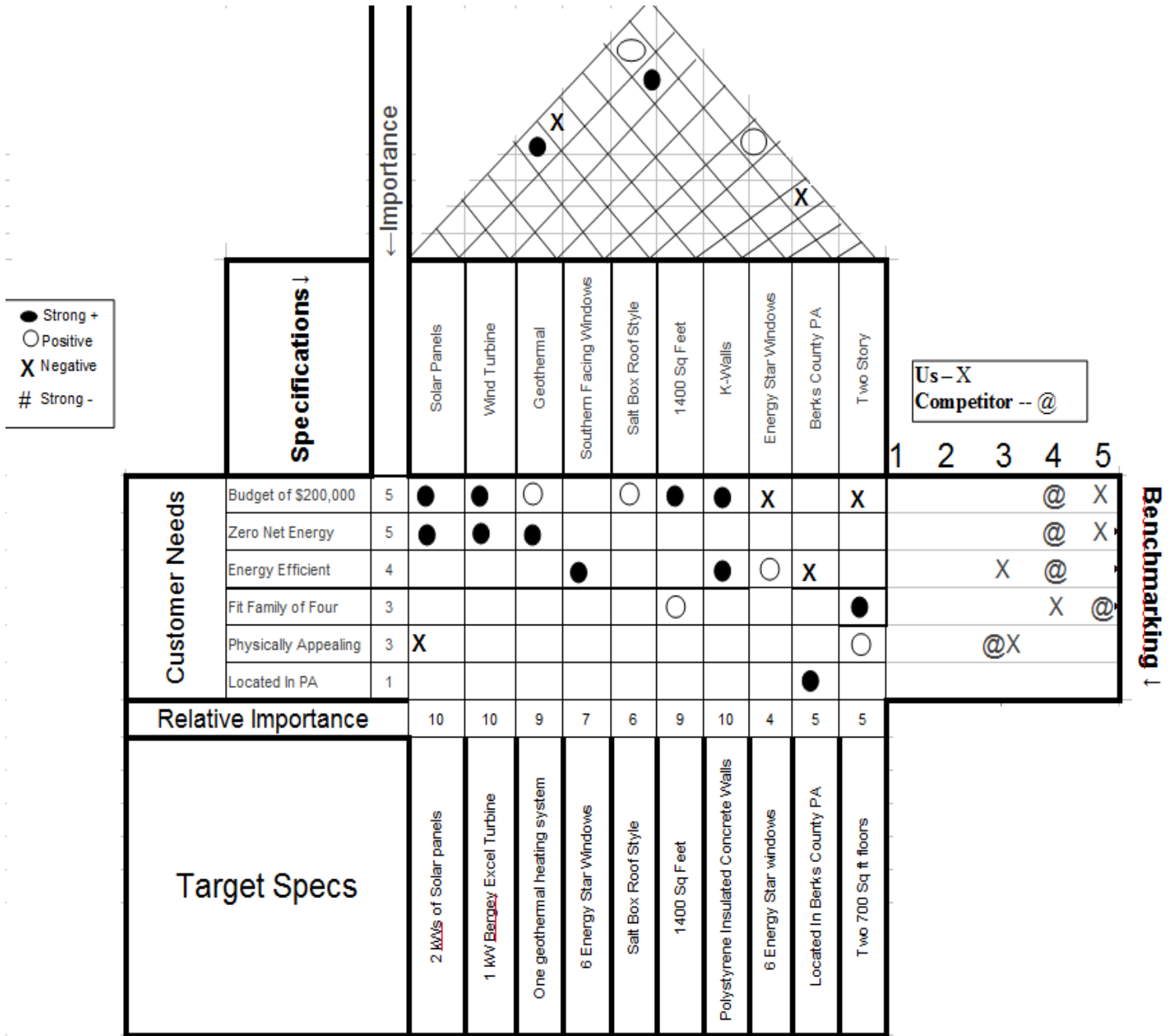
The next step was to conduct external research in order to evaluate and refine our concepts. First, we researched the different forms of renewable energy that we had brainstormed. After researching mainly the costs and energy output of these different forms of energy production, we organized them and compared them as seen below:

Energy Production	Cost Efficiency	Benefit
*Solar Power	High	High
*Wind Power	High	Medium
Biomass	Low	Medium
Hydro-Power	Low	Medium
Hydrogen Power (Through Electrolysis)	Low	High
*Geothermal	Medium	High

We found that only solar, wind, and geothermal energy were realistic and attainable, given our budget of 200,000 dollars. While hydro-power, hydrogen power through electrolysis, and biomass all had potential energy benefit, the prices and attainability of these technologies were not realistic. In addition to researching the forms of renewable energy, we researched the specific availability of each form specific to our location. We looked up topographic maps from the Renewable Energy Defence Council's webpage and found that while solar and geothermal energy was available in our current location, wind energy in Montgomery County was not realistically attainable. Instead of simply eliminating wind energy, we decided to conduct more research, and found on the National Weather Service's webpage that Berk's County had decent solar radiation of 4 hours of usable light per day, as well as the highest average wind speeds in Pennsylvania, which was 22 mph. After research, we also found that a 2000 square foot home would simply cost too much to construct, so using the resources and spreadsheets available on angel, we found that a 1400 square foot home would cost about 152,000 dollars to construct, which would leave us with adequate budget for renewable energy technologies. We researched multiple miscellaneous concepts for energy efficiency. We found that "K-walls", were concrete walls sheathed in a polystyrene insulation that were very good at insulating the house, as well as cutting back on construction costs of the house.

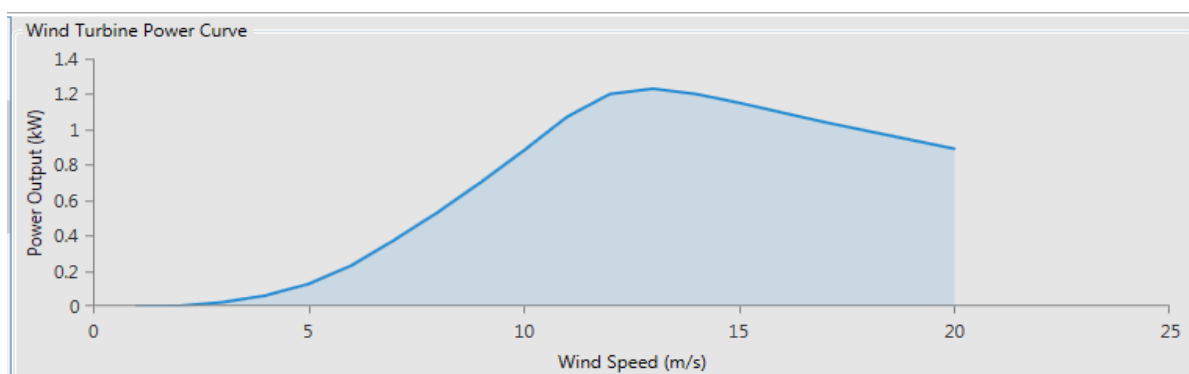
After conducting research concerning our specific location and concepts, we conducted benchmarking and compared our concepts to the design of a different zero energy house. We used a home constructed in Gainesville, Florida. (Images and Specifications of ZEH in Gainesville: <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1792-09.pdf>).

We used all of this external research to complete a template of a house of quality, as seen below:

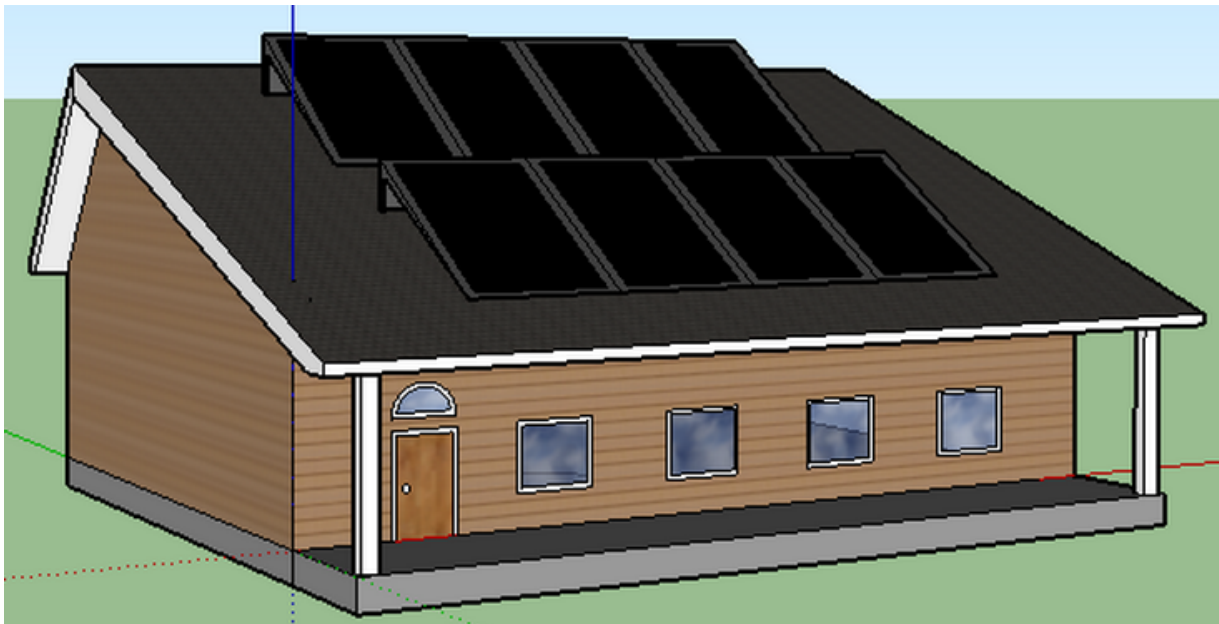


Concept Selection

After we had conducted enough research, we were able to refine and select our final concepts. As a great way of harnessing the area's naturally windy climate using the alternative source of energy of wind, seemed only logical. So we chose to go with the Bergey Excel 1 kW wind turbine; as one of the major components incorporated into our zero energy home's design, the wind turbine will be an effective tool in lowering the cost of the houses total energy. Solar energy is a relatively inexpensive form of alternative energy from purchase to installation, which is not a real issue compared to its effectiveness for producing energy. With little to no argument, we decided to invest in eight 250 watt solar panels, for a total energy rating of 2 kW, which was made one of the major components in the design of our zero energy home. Geothermal energy was introduced as an alternative means of heating and cooling our home, compared to traditional fossil fuel based heating and cooling. When our group researched further into the idea, we found that it was very effective source of alternative energy with a fair price for buying and installing it. With this new insight our group incorporated the idea of geothermal heating into our house design. In addition to the technologies used to harness renewable energy, we decided on including k-walls in the construction of the house, as well as a saltbox roof style, and a large wall area facing south. We decided to invest in LED lighting and energy star windows as well. Locating our house in Berk's County was a no brainer after researching the wind speeds.

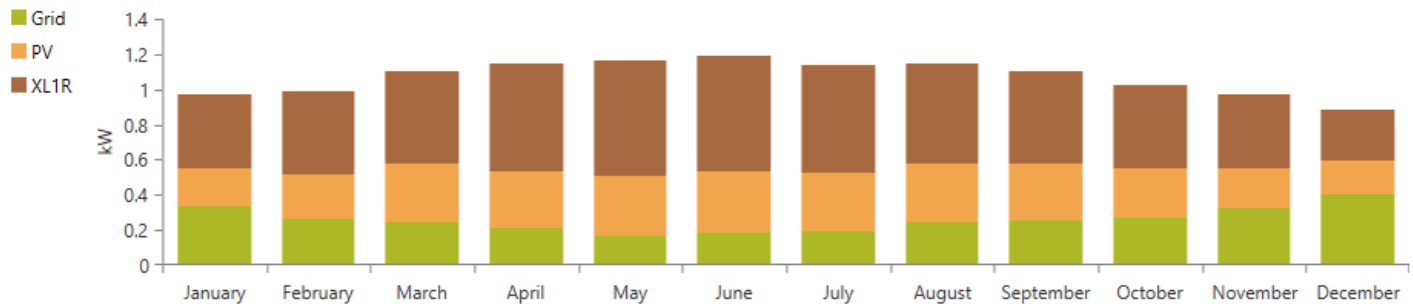


Final Specifications and Design



A model of our design can be seen above with the southern facing windows and saltbox roof style. We also entered all of our information into Homer in order to get exact numbers, concerning energy usage and production. We decided to allot 6275 kWh's of energy yearly. This may seem high considering the money and effort put into making our house energy efficient, however, there are other factors we had to take into account. For example, since we chose a location with high wind speeds, the temperature in the winter could drop dramatically, meaning more energy would need to be used to heat the house despite the geothermal heating system. We also had to consider the fact that even though we designed the house to be efficient, the family of four may not live in the house efficiently and may use more energy than anticipated. After entering our information into Homer, we found that our solar panels produced 2561 kWh per year, our Bergey Excel wind turbine produced 4550 kWh per year, and it was estimated that we

would buy 2258 kWh worth of energy off of the grid annually. This all adds up to a net energy usage of negative 125 kWh per year. A diagram of the energy output from Homer can be seen below:



Our final cost for the zero energy home was \$195,000. The cost for building the home itself was \$152,000. For appliances, our LED lights cost \$9 per 60 watt equivalent bulb. Our energy star windows cost \$5,600. The use of K-Wall technology for increased air tightness costs \$1,500. Our last appliance cost was \$2,300 for R19 1” foam wall insulation. For our energy resources, the eight 250 watt solar panels cost \$8,000. The Bergey Excel 1kW wind turbine cost \$9,000 and our Geothermal heating system cost \$16,000. After all these expenses, \$5,000 is still left in case the homeowner desires other products, and over time the energy not used by the homeowners will be sold back through the grid to have the house pay itself off over time. But in order to do this, the homeowners must be as efficient as possible. Things like using as little water as possible, turning lights off when not in use and not leaving the fridge/door open too long are all small parts of being as efficient as possible.

Conclusion

The purpose of creating a zero energy home is to economically construct a structure that will produce more energy than it consumes. In order to accomplish such a task, one must consider what devices will be used to supply the energy, how the structure will be built, where it will be built, how much it will cost, and with what materials it will be constructed. Each element of the home is important when it comes to reaching maximum energy efficiency. As a whole, we believe that we were successful in designing a house that meets the standards of a true zero energy home. We chose to use solar panels, wind turbines, and a geothermal heating system because each made sense from an energy efficient and economic standpoint. By utilizing these systems, we were able to use approximately 4,000 kwh less per year for a fraction of the cost. Additionally, the materials used to build the home also helped us reach maximum energy efficiency. In our design we used K-walls, special foam insulation, and energy star windows and doors to make sure that heat was not escaping and outside air was not getting inside. With everything said and done, we designed a home that would theoretically cost \$195,000 to construct. Thus, we were able to stay within the customers budget and create a product that met their needs and desires. By satisfying the customer, we truly met our goal of creating a usable zero energy home.

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