Design and Analysis of a Zero-Energy Building: Team Solution

Team #: 02

Instructions:

- Save this file with the file name **Energy3D_TeamSolution_*<teamnum>*.docx**, where *teamnum* is your ENGR 131 team number.
- Submit this team solution in Blackboard to the assignment **Energy3D: Team Solution Specification Sheet** by the start of the class **Design 5** (one submission per team).
- On your own, complete and submit the **Energy3D Reflection #2**, available in the **Assignments** area in Blackboard, by the start of the class **Design 5**.

EXECUTIVE SUMMARY

Write an executive summary (no longer than two pages) that addresses the topics listed in the Energy3D Design Challenge Team Solution Rubric.

There is an energy crisis in the world today. According to the U.S. Energy Information Administration, the U.S.'s energy consumption in 2010 was 98 quadrillion Btu (British Thermal Units), nearly 19% of the world's total primary energy consumption. It is imperative that the United States does everything in its power to reduce its energy consumption; first, it is becoming increasingly difficult to provide this gargantuan amount of energy to the citizens of the US. Second, our current method of production of energy is extremely harmful to the environment, so now we must take action to reduce this energy consumption. One such way is to construct energy efficient homes. After being assigned the task of completing plans for an energy efficient house, we first composed a course of action to follow when developing the plans for the home within the constraints provided. We set out to provide a cheap, energy efficient, comfortable, and aesthetically pleasing home design while simultaneously making construction of the structure simple. These factors not only produce high consumer appeal, but they will also produce large profits. After we established our plan, we began the task to accomplish our goal by making plans for a rudimentary structure. Using an iterative technique that involved construction, evaluation, and improvement, we reached a solution that satisfied every criterion beyond reproach; your consumers will be desperate to own these energy efficient homes, which benefits you, the people who will own these homes, and the environment.

The first criterion that must be analyzed is the energy production of our solution. The annual net energy consumption for our solution is -2530 kWh; this implies that our design generates 2530 kWh more than it uses. The greatest amount of energy loss is due to the windows, with 3118 kWh lost annually and the maximum energy loss occurring in the month of June. The AC is the next substantial contributor to energy loss at 1695 kWh lost annually. Again, the greatest energy loss occurs during the summer months, with a maximum occurring in July. There is far less energy used during the winter months, as only 952 kWh are used by the heater during the colder periods of the year. Yet, despite these energy losses, the solar panels generate about 5178 kWh annually. This energy generation offsets the losses incurred by a wide margin, and this building produces more energy than it uses. In brief, this residence is incredibly energy efficient, and this structure actually does not need energy provided from an outside source; it is capable of providing its own energy needs.

The next criterion to be examined is the cost and the contributors to cost of our solution. The final cost of the residence is $49, 819. We found this price acceptable given the constraints and the parameters of our benchmarking process, as this house was given a four out of five. Doing an analysis of the building, one can clearly see that the biggest contributors to cost were the walls, the solar panels, the roof, at 33.9%, 32.1%, and 26.6%, respectively.

The major sacrifice we made in designing this home was simplicity. Compared to our alternatives, this house was the most complex; however, we believe that this trade off will reward your company in attracting buyers. In order to motivate the people to move in on the advantages of a zero energy home, appearances must be up to a standard to which they are accustomed. We will gladly take input from your company on improvements to this design in order to make your construction process simpler. We will then handle any smaller adjustments to maintain the zero energy goal.

Perhaps the most important factor in choosing this design are the aesthetics of this house. In the process of drafting options to fit all criteria, we found a way to quantify a houses' curb appeal. We believe the ratio of window

surface area to wall surface area on the exterior of the house is related to how appealing a home is. The team agreed that by simply counting the number of windows and dividing by the number of walls gave an inaccurate representation of the house's aesthetics, which is why we decided on a method that focused on exterior surface area. In order to translate this into a figure that can be compared between all four house alternatives, we divided the sum of the window area by the area of the walls. We found that by comparing the ratio of window to wall area of several different homes, a ratio above .14 qualifies the house as relatively attractive. The model we have finalized surpasses that mark, achieving a ratio of .1599.

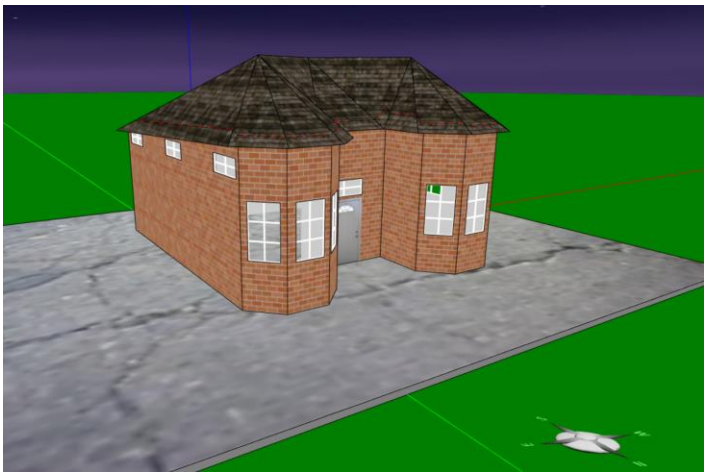
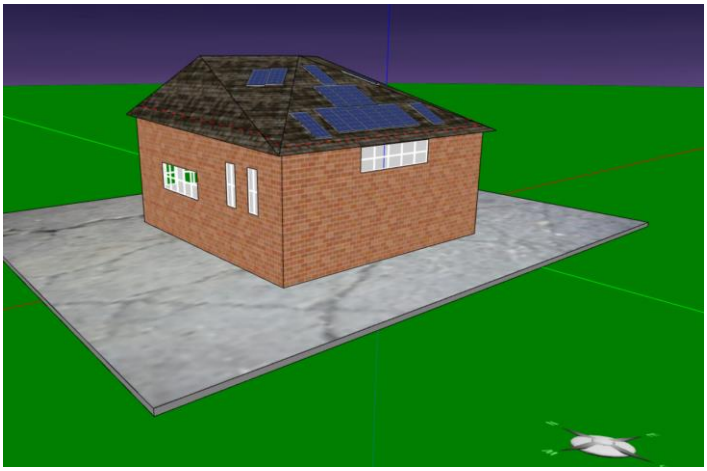
Lastly, this house is not only comfortable for four people, but it is spacious. The area of the house is 113.5 m^2, larger than the constraint provided. The average size of a master bedroom, according to House Plan Helpers, a group dedicated to helping families build comfortable homes, is approximately 9 m^2. Thus, one could easily fit four such bedrooms along with a kitchen and other miscellaneous rooms within the area provided. In addition, the height of the building is a roomy 7.5 m, while the average height of a person is 1.9 m. Therefore, these two aspects prove that the area and height of the house are more than enough to support four people.

Given the energy crisis that plagues the world today, it is imperative that we find a way to reduce energy consumption. The construction of an energy neutral home is a large step towards this goal. However, homeowners should not be forced to sacrifice a comfortable lifestyle, an attractive design, or a large amount of money in order to live in one of these homes. The house we have designed surpasses the zero annual energy criterion by a whopping 2530 kWh. It stays under the price limit we were given by $181. Given our decision matrix, we are certain that this home has curb appeal that will attract multitudes of customers. There is even enough space in the house to comfortably fit a family of four people. The only problem is how difficult the home is to construct. However, we believe the other aspects of this house make up for this difficulty. As the goal is to produce as much energy as the energy used, some of the solar panels could be taken off, making the house less expensive. Enough solar panels would be left on so that the house would produce at least as much energy as it uses; then, the cash surplus could be used to improve other aspects of the house. it could be left out making the house less expensive overall, but it could also go into expanding the house as well as making it more uniform and symmetric. This would reduce the number of oddly shaped parts, thereby increasing the simplicity of construction. The panels could also be left on and the windows extended, causing more heat to be let in but adding to the curb appeal of the house. Nevertheless, this is a cheap, energy efficient, comfortable, and aesthetically pleasing home design that will earn profits and provide homes for those who need them, while simultaneously benefiting the environment and the state of the energy industry.

APPENDICES

Design Specifications for FINAL Solutions

I. Solution Images – *Use the software's compass to help orient your house to the required views.*

Figure 1. Northeast View	Figure 2. Southwest View
	

II. BUILDING SPECIFICS

Total area (m^2): 113.5

Average height of walls (m): 4.96

Total number of windows: 14

Total number of solar panels: 16

Download the Energy3D Software at: http://energy.concord.org/energy3d/
Purdue University Contact: Senay Purzer, email: spurzer@purdue.edu

U-Factors: *For each feature, select the material you choose to use on your house.*

Walls
0.04

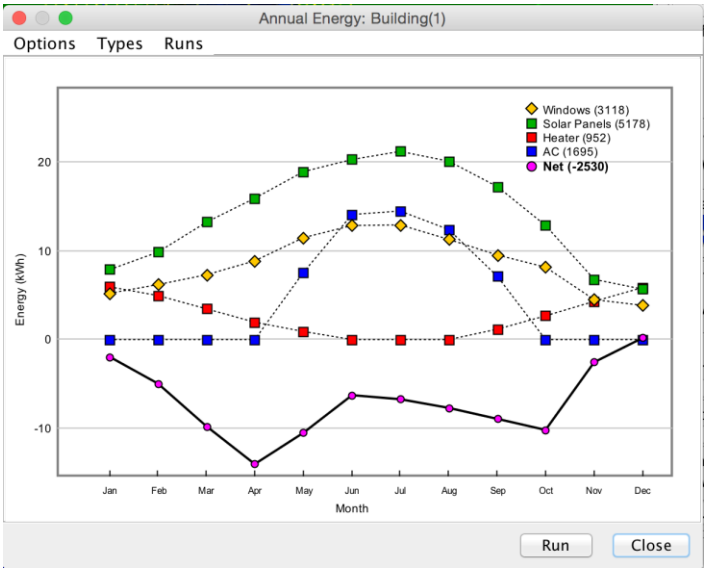
Doors
0.35

Windows
0.15

Roof
0.02

III. ENERGY DATA

Figure 3. Image of Annual Energy Analysis



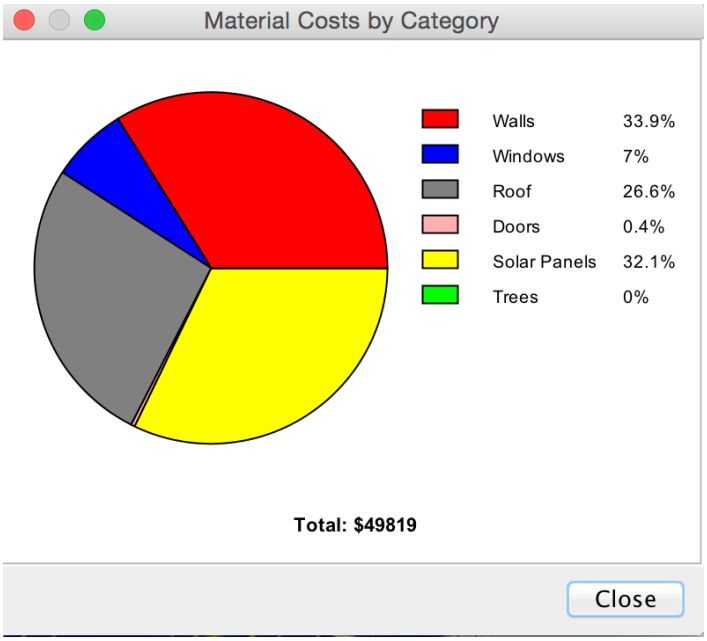
Annual Net Energy (kWh): **-2,530**

Explain what the analysis communicates about this solution's energy use. What is the biggest impact to the annual energy values? How could you reduce annual energy?

The solution generates 2,530 kWh more than it uses every year. Running the air conditioner during the summer required the most amount of energy. The annual energy used could be reduced by reducing the size or amount of windows on the solution, letting in less heat by doing so. Reducing the size of the windows would also result in less loss of heat due to a temperature difference between the interior of the house and the environment.

IV. COST DATA

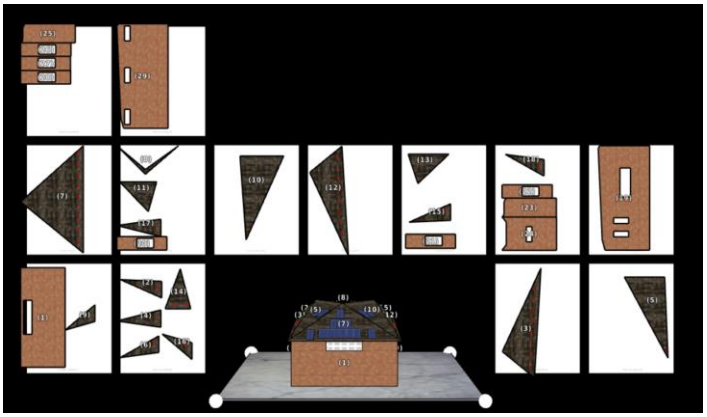
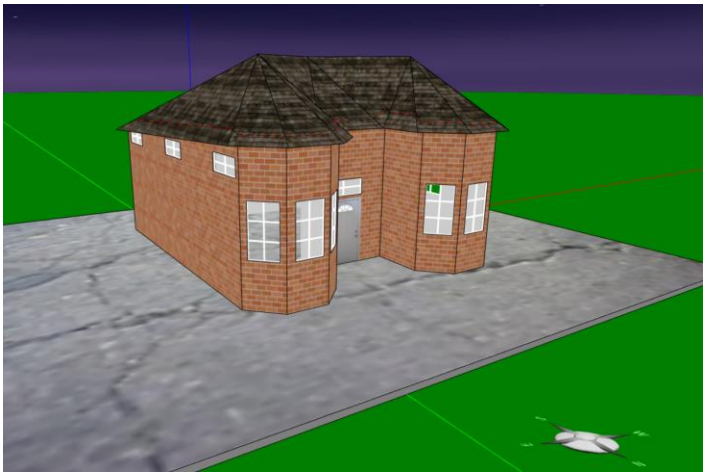
Figure 4. Image of Material Cost by Category



Total Cost ($): **49,819**

Interpret the cost data. What has the biggest impact on cost? Looking at your data, how could you reduce overall costs?

Materials for the walls amount for the largest portion of the total cost of the building. Walls represent about 34% of total cost. Coming in a close second is the cost of solar panels which account for about 32% of the total cost. Obviously, to reduce overall costs, one should reduce the height or size of the walls or reduce the total number of solar panels.

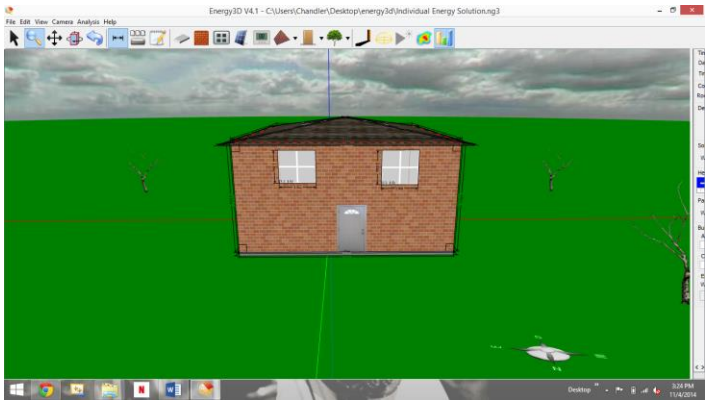
V. DATA ON HOW EASY IT IS TO CONSTRUCT	
Figure 5. Preview of Printable Parts	Number of Printable Parts: **29**
	Using the "preview printable parts" feature, count how many separate components your design have. Explain how this information communicates how easy it is to build your solution. What features make your design difficult to build? How could you improve your design in this aspect? This solution has 29 printable parts meaning that this solution is difficult to build. This is a substantial number of pieces; however, many of the pieces of the roof are very similar, which certainly increases the simplicity of the construction of the home. Making the house more uniform instead of such a unique shape would improve the simplicity of construction.
VI. DATA ON CURB APPEAL	
Figure 6. Image of Window/Wall Ratio	**Curb Appeal: .15987**
	There are many ways to measure curb appeal (or attractiveness of the exterior). One way is the ratio of windows to walls. Another way is the landscape (number of trees). Looking at your data, how could you improve curb appeal of this solution? In order to calculate curb appeal we used the suggested window to wall ratio. In order to calculate this, we used the formula: (Area of Windows)/(Area of Wall - (Area of Windows + Area of Door)). According to this, the best way to improve curb appeal would be to increase the size of the windows or decrease the size of the walls. Both would cause the ratio to increase. To improve the curb appeal, we might try to make the house more uniform.

VII. ALTERNATIVE SOLUTION COMPARISON TABLE

In the table below, summarize your three top alternatives **not selected as your final solution.**

	House 3	House 1	House 4
Annual net energy	-3 kWh	-6335 kWh	6056 kWh
Total cost	$47,600	$49,233	$42,000
Number of printable parts	8	8	21
Curb appeal (ratio)	.04098	.08011	.13973

In the spaces provided below, insert front views of your three alternatives.

Front of Alternative House 3	Front of Alternative House 1
	
Front of Alternative House 4	
	

Download the Energy3D Software at: http://energy.concord.org/energy3d/
Purdue University Contact: Senay Purzer, email: spurzer@purdue.edu

Works Cited

Bedroom Size. (n.d.). Retrieved November 6, 2014, from http://www.houseplanshelper.com/bedroom-size.html

How much of the world's energy does the United States use? (n.d.). Retrieved November 6, 2014, from http://www.eia.gov/tools/faqs/faq.cfm?id=87&t=1