Zero Energy Home Design & Passive Solar Design

Engineering Design Section 16

Team #1

Team Orkon Inc.

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Abstract: Our Mission

In this project, our mission was to create a home that was able to produce enough energy to negate the energy cost of maintaining the house; resulting in a home with net zero energy. This was to be completed through various active and passive designs. Active designs, such as solar power, were important for capturing energy and using it to power the house, while the passive strategies, such as large windows, were used to minimize the energy costs of the home. Using online tools, we were able to optimize our house to produce as much energy as possible while using devices that would minimize our energy use. These reports and designs allowed us to have a house that was truly zero energy.

Introduction:

After being given our goal, we started brainstorming characteristics that would help us accomplish our goal. Once we had a large list of items for our house, we each created a draft of our house and compared each house in various categories through a concept chart. Once we evaluated each house and decided on the best one, we started on the construction of the model. Using items such as foam core board, aluminium foil, a black t-shirt, and more, we were able to construct a house that resembled what our life size house would look like. We then tested our house against the other homes in tests involving heating the house with a large lamp and cooling it with a fan and cold air. Then, we used some online resources to retrieve data on our house, which allowed us to guarantee that our house was truly a zero energy house.
Clearly Defined Challenge:

Our challenge for this project was to build a model of a house that has a net zero or positive energy output while also being aesthetically pleasing to the resident. This includes the use of many passive and active solar designs such as solar panels, large windows, and energy saving appliances, while also including all of the essential parts to a house, like bedrooms, bathrooms, kitchen, and many other features. Having to include all of the features of the average house while adding appliances and devices to save energy was difficult for us, and this combination caused us to change our designs multiple times throughout the process.

List of Figures and Tables:

Model Multiview, Dimensions, and Photos

Online Active Solar Calculations, Graph
**Concept Generation:**

After discussing many different design possibilities and characteristics we wished to include in our home, we all individually created a layout for potential zero energy homes and we compared them in a concept chart shown below. After scoring all of our homes based on the passive solar features, active solar features, energy consumption, and aesthetics, we determined John’s overall design and layout was the most efficient and realistic and included all of the characteristics and attributes we all saw as necessary to include in our zero energy home project.

<table>
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<th>Weight</th>
<th>Zach’s House</th>
<th>Matt’s House</th>
<th>Hunter’s House</th>
<th>John’s House</th>
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<td>Rating</td>
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<td>Energy Consumption</td>
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</table>
Autodesk Home Styler Images:

First Story

Second Story/ Loft

← South

3 Dimensional Views:

First Story

Second Story/ Loft
Passive Solar Design

Passive solar features are a very important aspect of our design. We strategically placed every window and room accordingly to maximize its exposure to sunlight. Open concept living was the driving force behind our design. We wanted to limit any walls or structures that would inhibit the sunlights passage through the house allowing for more efficient heating. This provided each room with more heat in the winter, and the inclusion of automatic blinds in our design allow for us to maintain and control that same heat in the warm summer months where the sun's elevation angle is at its largest. To allow this home to function for a family of four, we decided to place two childrens bedrooms on a loft alongside a second bathroom to give the family the square footage they need, while still allowing us to add a large two story window on the southern end of the home to maximize the heat in our open concept living, kitchen, and dining room. This idea is incorporated in our bedrooms as well. Each bedroom has access to a southern facing exterior wall where we placed windows to attain the most heat possible. Thermal mass is yet another passive solar feature included in our design. We included dark slate tile floors to absorb heat so it can then distribute that heat at night when the sun is not out. In addition to our energy efficient design, we managed to keep our design aesthetically pleasing as well.

Active Solar Design:

Our active solar features were far less complicated. Placing solar panels on the roof angled at 45 degrees southward is how we intend on creating more energy to lessen the use of electrical power needed on the grid. Overall, this will contribute to less energy use in our home and is a simple yet very effective tactic.
Prototype

We constructed a prototype measuring 70 sq/in using memory foam board, a black t-shirt for thermal mass, tin foil, and plastic wrap. We were able to include a functioning solar panel as well that was able to light an LED light shown above.
# Prototype Testing

Prototype Held Under 200 Watt Lamp Simulating Daytime

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Prototype Placed in Front of Box Fan Simulating Nighttime

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Testing Results:

After constructing our prototype, we then tested it. We placed our prototype under both a lamp to simulate daytime, and a fan to simulate night time. Our home reached a high of 55 degrees in the daytime and a low of 24 degrees at night time. After testing, we determined a few minor adjustments and improvements were needed but our prototype was a success overall.

Appliances + descriptions of impact

We found that household appliances can greatly affect the overall energy use in a home. Keeping that in mind, we decided to incorporate specific brands of appliances to reduce the overall energy use. For our washing machine, we chose to include the Whirlpool WFW95HEX model due to its very low usage of only 114 kwh/yr. Also, it only uses an estimated 4,863 gallons of water compared to other brands exceeding 7,000 gallons. In the long run, this washing machine will prove to be a large factor in overall cost and energy use. In addition to using the whirlpool washing machine, we can reuse the water saved to water our outdoor garden. We will also include the Samsung LG LFC25776ST refrigerator in our home due to its low energy usage and low cost to keep it running. On average, this refrigerator will save you $769 over a 12 year period compared to other leading refrigerator brands. With these appliances included, our energy usage will continue to minimize.

Energy Analysis: Model 1

A normal house with the same square footage of our zero energy home:

Base House Cost: $228,298
PV Cost: $59,111
Upgrade Costs: $20,853
Total House Cost: $308,262
Electricity: 15,550 kwh

PV Output for house to be a Zero Energy Home: 15,500 kwh

Electronics: Personal items

Energy/Household: 2134 kwh/yr

Total Cost: $5,972

**Our Zero Energy Home:**

Base House Cost: $228,298

PV Cost: $25,032

Upgrade Costs: $43,827

Total House Cost: $297,157

Total Electric: 1497 kwh

PV output: 6578 kwh

PV Size: 5.01

Electronics Personal Items

Energy/Household: 1067 kwh/yr

Total Cost: $5,344

Due to our large windows, we do not need as much lighting in the house for the majority of the day. This, with the addition of energy saving device such as a low energy washing machine and a low energy dishwasher, makes the energy output relatively small.

We calculated Array Size through the equation: Annual Kwh/yr / 365 days/ Solar Hours/ derate factor (0.75)

6578/365/3.6/0.75=6.67 kW Array Size or 43.5 square meters worth of the ND-240QCJ solar panel model, which is approximately 27, 1.63 sq*m solar panels
Model Description

Our model was constructed from foam-core poster board, plastic sheeting, black cloth, aluminum foil, and hot glue. Also included was a small 6v solar panel and high-brightness white LED to be implemented as our active solar system. Our initial plan was to include a 10F supercapacitor to enable storage of the sunlight for later use to power the LED in darkness. However, due to a voltage issue with the capacitor, we were not able to successfully incorporate the capacitor into the circuit. Our roof was angled at 45 degrees maximize the light absorption by our solar panel. Our floor plan was open to allow for maximum heat circulation. One section of the house was separated to privately encompass the master bedroom on the first floor, and two other bedrooms on the second floor. However, both sections of the house have their own passive solar system, complete with large windows, open configuration, thermal mass, and insulation.

Conclusion

After defining the problem, addressing the issue, ideating a solution, creating a prototype, and testing it, our overall results proved to be successful. In the daytime simulation, the temperature in our home rose 38 degrees, more than any other model in the class. On average, our model gained heat at 3.9 degrees per minute. We found that our large windows and our functioning solar panel proved to be a very aesthetically pleasing, realistic, and effective solution to the problem. During the night time simulation, our model fell short of our expectations. Our home lost 31 degrees during the night simulation averaging a loss of 3.4 degrees per minute. This statistic was comparable to other prototypes in the class, but other models proved to hold heat better than ours did. Other teams included rubber into their homes as an attempt at creating thermal mass. We believe that our lack of including rubber could have led to our drastic drop in
temperature. Another issue was our roofing. Perhaps if we had sealed our roofing a little better the rising heat wouldn’t have been able to escape as easily. After making these few adjustments and improvements, we believe our model could have absorbed and retained heat far more effectively.

In addition to creating a prototype, we were to assume we were actually building a zero energy home. In creating an actual home, a lot more work goes into conserving energy beyond the passive and active solar features. Factors such as appliances and electronics all contribute to a homes energy use which shows the importance of purchasing energy efficient appliances such as the Whirlpool WFW95HEX washing machine and the Samsung LG LFC25776ST refrigerator. Overall, we found that on average our home will use 1,067 kwh/yr, costing us only $5,344 on average. Compared to a normal home, we save $628 per year and 1,067 kwh/yr. Based off of our energy requirements, we will need 43.5 sq meters of the ND-240QCJ solar panel model to successfully be considered a zero energy home.