Zero Energy Home Report

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Introduction:

Designing a zero energy home is a process that incorporates all of the steps of the design process. A zero energy home is defined as a home that consumes zero net energy which is relevant in limiting the ever growing carbon footprint and also cutting energy bill costs for the customers. It is important to take into account that the home must use energy for heating and cooling that cannot be achieved passively, so the home must have a way to produce it's own energy. We looked at various ways to create a zero energy home, and through utilizing the basic engineering design process we found a way to accomplish this task. This will go on to help us understand how other systems (not just a zero energy home) work.

A major aspect of zero energy homes is sustainability. The three pillars of sustainability are economic, social, and environment. Sustainability is important in order for us to preserve the earth so it can be enjoyed by many more to come. Right now, we are nowhere near being completely sustainable so the importance for engineers to create better efficient designs is very high.

Customer Needs:

Customer Statements	Need Statements
"My home has to be located in Pennsylvania"	It is located in Pennsylvania
"My home has to be under $200,000"	The cost is under $200,000
"My home must be zero net energy"	The energy the home produces must equal to or greater than the energy consumed
"My home must be able to comfortably fit my family of four"	The home fits a family of four
"My home must be long lasting"	The home is long lasting
"My home must be appealing"	The home must be aesthetically pleasing

From the customer statements we created need statements. We then organized the need statements into a table and rated their importance from 1 to 5, with five being the most important and 1 being the least important.

Customer Needs	Rating (1 to 5)
It is located in Pennsylvania	5
The cost is under $200,000	5
The energy the home produces must be equal to or greater than the energy consumed	5
The home fits a family of four	3
The home is long lasting	4
The home is aesthetically appealing	2

The customer needs had to be viewed in a positive way so we saw them as features for the home as opposed to limitations. The family we were designing the home for consisted of two parents and two children with a $200,000 budget. This seemed like a lot of money to work with, but with the cost of building a house alone combined with the costs of heating and cooling systems left a limited amount of money for the selection of energy producing technologies. Another customer requirement was for the house to be built in Pennsylvania. This limits the passive qualities of a house that we can use because of the climate and terrain.

Our concepts from here on out are based on these specific customer needs and the needs are kept in mind throughout the whole design process. Throughout the whole process, we were striving to not only meet but go above the customer's needs and expectations.

Target Specifications:

1.Determine what you will measure
2. Examine your primary competition
3. Set values for your product specifications

We needed to find a basis for comparison in which items in our design could be evaluated from. Our research led us to a zero energy home in Asheville, North Carolina. We felt more confident incorporating a ground source heat pump, even though it was a large expense. This was mainly because the homeowners said that the high cost was offset by a lot of incentive money. We were also able to see that the homeowners didn't save any energy from radiant heat, so it would not be smart to spend a lot of money on that.

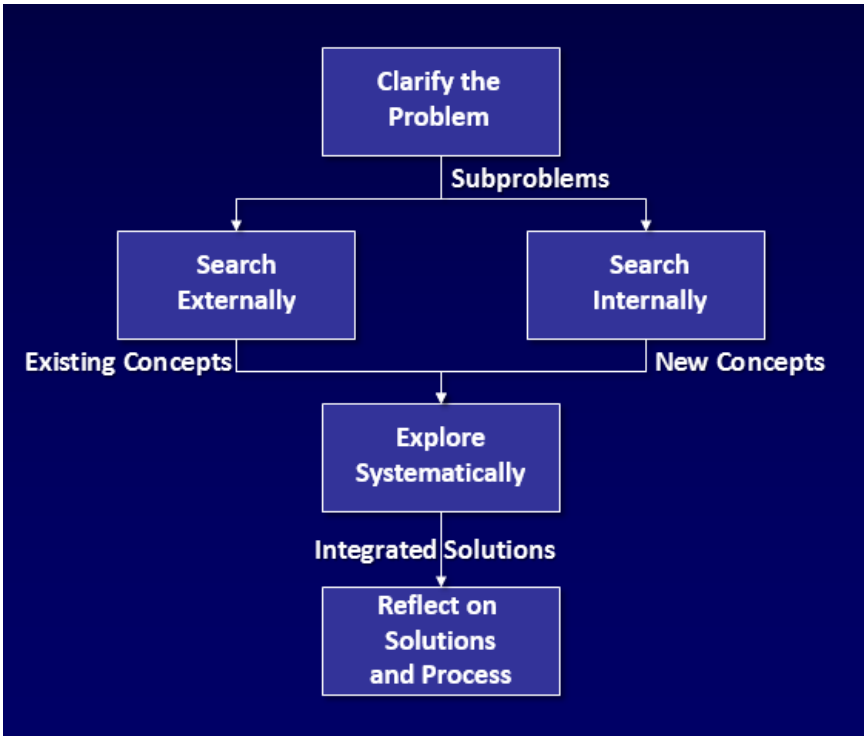
From the customer needs we developed the target specifications and organized them in the table below:

Need (number)
In Pennsylvania (1), Under $200,000 (2), Zero Net Energy (3), Comfortable (4), Aesthetically Appealing (5), Long Lasting (6)

Metric #	Need #	Metric	Importance
1	4	Well-insulated	5
2	3	Solar panels	5
3	3,4	Geothermal heating	4
4	3	Air-tight windows	4
5	2	Energy efficient appliances	4
6	2,5	Long single story	3
7	1,4	Mild weather	4
8	5,6	Modern materials	3
9	3	South facing	5
10	3	Large roof space	5

Concept Generation:

After clarifying the customer needs and deciding on the target specifications we decided to use the Elrich and Uppinger concept generation strategy. The illustration below outlines their strategy.



The next step in this process is to identify subproblems. The subproblems included Pennsylvania's minimal days of sunlight, overall low wind speeds, harsh weather conditions in some areas, reducing energy consumption, staying under budget, and a family friendly home. Once we identified the subproblems we were able to move forward and start with both external and internal research.

Search Internally

When we began the internal search our team decided to use the brainstorming process. We created a long list of ideas and organized them into categories as shown below.

Brainstorming Process

Ways to make Home Zero energy	**Beginning Design**
Collect and reuse water	Minimize room space
Energy efficient appliances	A lot of windows
Timer to automatically turn things off	Slanted Roof
Good insulation	Light Colored Flooring
High efficiency heat pump	LED lights
Small wind turbine	Use recycled material
Roof garden	Two story home
Solar hot water	

Thermal storage basement
Grid tied photovoltaic panels

Search Externally

Our external search began with the brochures and pamphlets that Dr. Etienne uploaded to angel. Our team quickly realized that there was a lot more to building a zero net energy home than was first thought. We began to research locations and immediately eliminated locations with extreme weather conditions such as Erie, PA. Then we compiled a list of our top three possible locations in the table shown below.

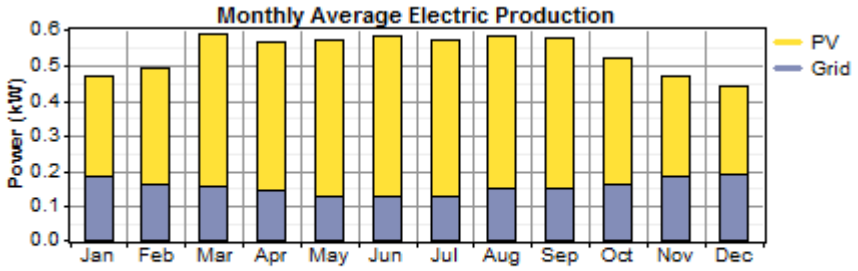
Location	Days of sun per year	Solar Radiation (ranked 1 = most - 3= least amount of radiation)	Wind Speed (mph)
Somerset	158	3	21
Allentown	204	2	3-14
Philadelphia	205	1	9.5

After finding the possible locations we decided to research different options that would reduce the energy consumption of the home. We considered a rainwater system that would recycle the rainwater and use it for the sewage and showers. We also researched a geothermal heating system, energy efficient appliances and and insulation. We used the excel to determine the appliances that were most commonly used and would best fit the needs of our family.

Small Appliances	ZEH Calculator	0.2 kwh/hr	1839.8 kwh/yr
Major Appliances	• Washing Machine • Refridgerator • 15 Led Lights	0.129 kwh/hr	1130.80 kwh/yr
Total MEL load		0.329 kwh/hr	2970.60 kwh/yr

Cost summary

Total net present cost	$ 20,360
Levelized cost of energy	$ 0.736/kWh
Operating cost	$ 75.1/yr



Load	Consumption (kWh/yr)	Fraction
AC primary load	2,164	46%
Grid sales	2,524	54%
Total	4,689	100%

Quantity	Value	Units
Excess electricity	0.00000159	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.373	

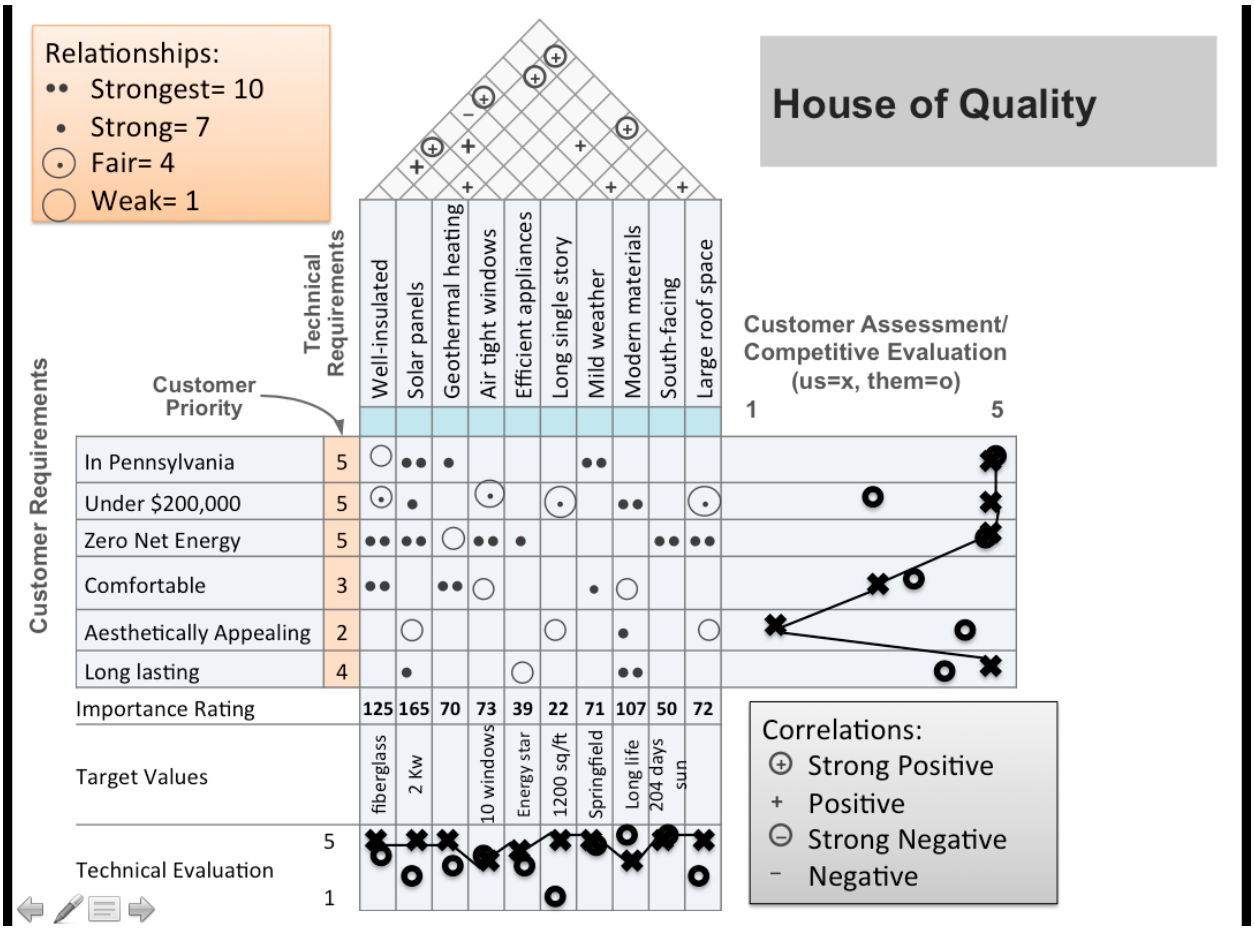
Explore Systematically

After much research, our group came to the conclusion that we could not include everything we thought of in the brainstorming process. We had to eliminate ideas that did not fit well with our design, location, or budget. We had to discard the usage of wind turbines because they did not produce a sufficient amount of energy for the price. We also terminated a roof garden from our design because they costed around $200 per square foot, and we could not make room for it in our $200,000 budget. Our group decided not to go with a two story home because a one story longer home gave more roof space for solar panels. Finally, we decided to locate our zero energy home in Springfield, PA because it is right outside of Allentown. We turned our attention to the area around Allentown because it had many sunny days per year, so more solar energy could be produced. It is very open, so more sunlight can hit the solar panels. Springfield is considered a suburb, so it would be good for a family of four raising kids. Overall, this process allowed us to formulate our final design.

House of Quality

The house of quality is a tool used in the design process to help organizing and determining the importance of each specification and where our house stands in comparison to others. For benchmarking, we compared our house to The Morning Star located in State College and also got ideas from other groups. It is not wrong to share ideas with other people and it really benefited us in areas that we were lacking and could not seem to solve on our own. It really made

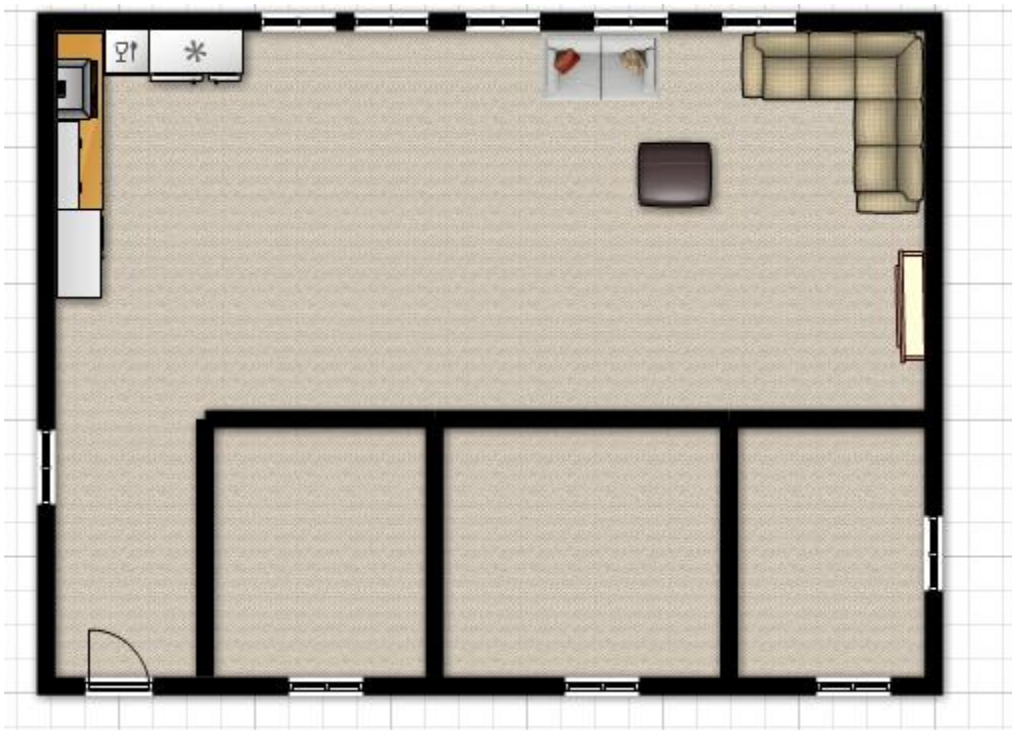
the practicality of each aspect known. We could see what worked and what did not work so well. The house of quality was used for this large system but can be used for any other system as well.



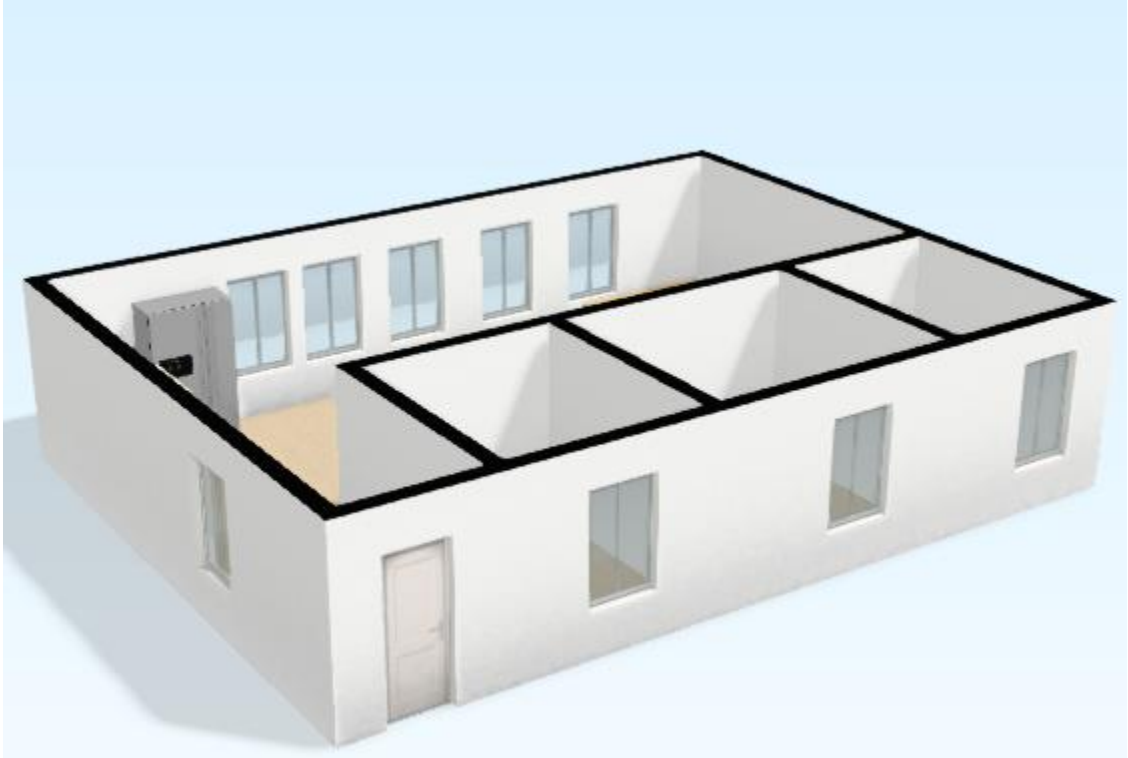
Design

We decided to design our house to be one story with south facing windows as well as the roof tilted towards the south so that the solar panels will be exposed to as much sunlight as possible. Then due to the latitude and longitude of Springfield the solar panels will be tilted at a 40 degree fixed angle. Then the roof will have to have a 46 degree overhang above the windows. This is due to the sun sitting lower in the sky in the winter than in the summer and will allow for maximum use of the warmth from the sun in the winter and avoidance of it in the summer. Our system is a 2.55 kW solar system and it requires 256 sq feet to install this system.

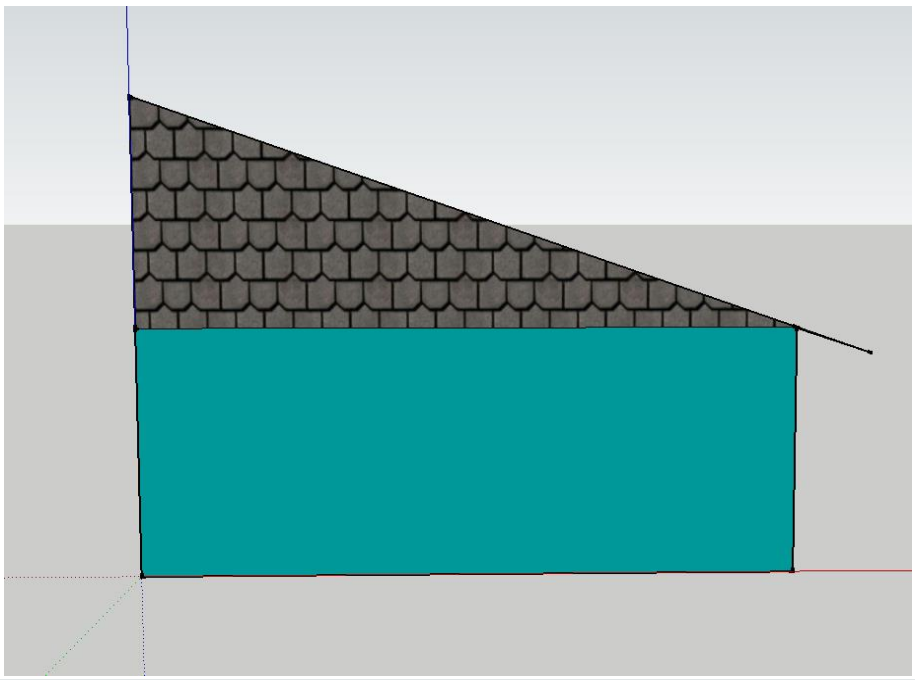
Our final design is depicted below, there is a total of 1200 sq. ft. and it is 30x40 ft.

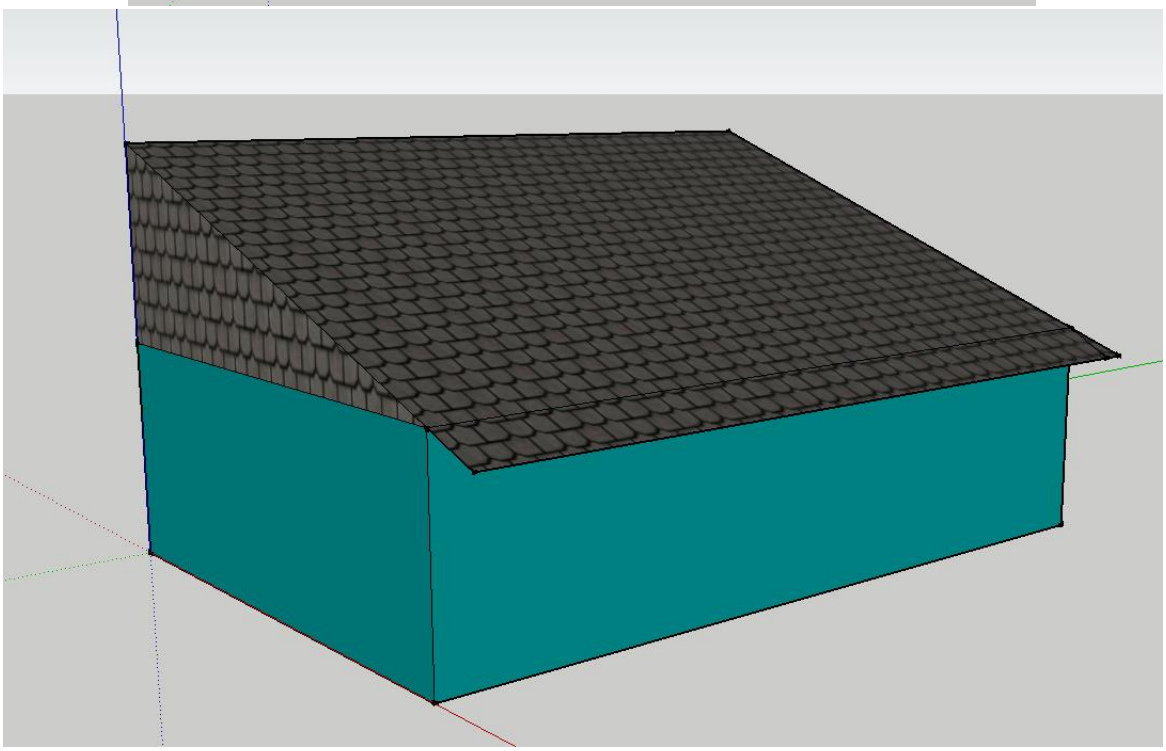


Floor plan



Entrance to house





Roof view

Citations

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