

# **Zero-Energy House Report**

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With a \$200,000 budget, our goal was to design the most sustainable Zero-Energy House. To start, it must be located in Pennsylvania, and for that we chose Harrisburg. This is the

ideal place considering it is the region in Pennsylvania that received the most annual sunlight (58% per year). This is essential for our solar-panel energy implementations because we plan to use only solar panels to generate energy. Also, Harrisburg has been proven to be a good location for net-zero homes; it already has several energy efficient houses built and moved into! This means we, most likely, will not experience any difficulties, as it is not a foreign market for zero-energy houses.

One thing we did not neglect and always prioritized was the commodity of the customer: our main preoccupation and most focus went into meeting the customer's expectations. We designed a house suitable for a family of four, making sure every area in the house had enough space. Every material we used, from the bamboo floorings to the dishwasher, was of the best quality within our range. We made sure to create this house as energy efficient as possible by using several different technologies. The Zero Energy House was designed under very precise and well-thought specifications, and is very eco-friendly!

After the customer's needs and target specifications are found, the next step in the design process is generating concept ideas. Having never used the design process before, we used the classic method of brainstorming. We simply bounced ideas around and wrote all of them down. Through this process we didn't limit our thinking. Our thoughts ranged from basic ideas, like low pressure shower heads, to more complex ideas, like the house being placed next to a river to generate hydroelectric power. No one in our group dismissed thoughts and everyone had an open mind. Limitations, costs, and resource constraints weren't part of the equation in our concept generation. Without knowing much about this topic and clean energy generators, search engines were a great tool to us.

After gathering a plethora of ideas, we decided to set some structure by making categories of “energy creation” for how clean energy would be generated to sustain the house and “energy conservation” for how we would sustain the energy we had. Using the beautiful tool of pencil on paper, we made a web diagram consisting of those main categories and sub categories. For the category of sustaining energy, we jotted down ideas, such as, the size of the house, special appliances, motion-detecting lights, and whatever else came to mind. The main idea we focused on was the size and layout of the house; each member added their idea and opinion to this topic and we ended up with concepts, such as, one story, an open floor plan, and minimal piping. We also briefly discussed insulation and different appliances.

For our other main category, generating energy, we were ambitious. We brainstormed by listing ideas like solar panels, wind turbines, and hydroelectric power. Finally, the two ideas of a solar-panel driveway and a solar-panel rooftop were conceived. The solar-panel driveway was the most unique energy generator we thought of and it truly differentiated us from other zero-energy homes. We continued to write and expand our web diagram and ended up with an enormous entanglement of concepts to build upon, narrow down, and work with.

After generating ideas, it is necessary to filter through them and choose the best ones. There are several different methods that can be used to select final product concepts. Some include benchmarking and concept screening. We also used the House of Quality to increase the comfort and sustainability of our home.

Benchmarking is when an engineer compares products by researching and gathering information about each option. For example, we generated several ideas on how to produce the home’s energy, such as, solar-panel driveway and solar-panel roofing. In order to decide which was best for our house, we had to do further research. We discarded the idea of a solar-panel

driveway because we found that it took an abundance of work and money to install compared to solar-panel roofing. We also found that the solar-panel driveway would not efficiently generate all of the home's needed energy. Through benchmarking, we decided to generate 100% of our energy by installing a solar panel system on the roof.

We also used concept screening to help us make small decisions for things, such as, appliances. Concept screening works by scoring each different option and simply choosing the product with the "best" score. For example, we were unsure whether to use a solar water heater or a tankless water heater. We compared several aspects: upfront costs, efficiency, installation process, future management requirements and capacity of tank. After scoring each aspect for the two options, we came to a decision that a tankless water heater would be more beneficial to our zero-energy home.

The final tool that we used was the House of Quality (HOQ); in fact, you can find our template attached at the end of this report. The House of Quality organizes the main concepts of the generation period. It consists of several different scoring methods. For example, we compared our house to several other zero-energy homes in different locations based on the specifications. We used the results to find ways to increase our "score." Compared to the other houses, our comfort level was low because of our small square-footage. However, to make the home more comfortable, we decided to expand the area of our home and, thus, raised our "score."

The selected product concepts must then be tested. For this project, all of the testing was based upon the specifications: budget, location, comfort, and net-zero energy. The first test our concept design needed to pass was the budget (\$200,000). After gathering all of the approximate costs of constructing our house, the budget is as follows:

Cost to Build Home...	...\$163,800
Solar Panel Installation...	...\$10,000
Insulation...	...\$5,000
Energy Star Appliances...	... \$10,615
Unattached Garage...	...\$6,525
Total...	...\$195,940
<b>EXTRA...</b>	<b>...\$4,060</b>

The next tests that needs to be passed is the location (Pennsylvania). We chose Harrisburg, due to the high amount of annual sun, which is located in Pennsylvania. The third test that needs to be cleared is the comfort for a family of four. With three bedrooms, a two-car garage, and 1,400 square feet to raise a family, we have concluded that this home is more than suitable for four people. Finally, the home must be a “net-zero energy house.” This means that the house must produce 100% of the energy it consumes. Our house, including the Energy Star appliances, has an estimated annual energy use of 6000 kWh which can be produced by a 4.5kW solar panel system. Therefore, using approximately 110 square feet of our roof, we have decided to install a 4.5kW solar panel system. This meets the requirement of a net-zero energy home.

As we said before, an important part of the design process is benchmarking competitive products. If you don't know what the standard is for your product in the market, then you have nothing to compare your design against. We used this method to generate ideas for the overall structural design of our home.

We got our original design plan from a Zero Energy Home that has already been built at least once, and is qualified under the Credit for Construction of New Energy Efficient Homes of the Energy Policy Act of 2005. The original design was a one story, 3 bedroom, 2 bathroom, 1,941 square foot home that featured an attached two-car garage and front porch. The roof area could hold up to 18 kW of solar panels, to power the house and two cars for at least 20,000

total miles per year. After further research we discovered even more ways that we could make this home more energy efficient.

One change was deciding to make the garage unattached from the home. Detached garages can be used for all kinds of purposes, from parking a vehicle to doing hobbies such as woodworking, or gardening. Separating the garage from the main house ensures that windows can be maintained on all sides of the house, maximizing daylight and views. A detached garage also limits the amount of noise and pollution that filters into the house. Overall, a detached garage is more energy efficient because it cuts down on the costs of heating and cooling.

Another change was to cut down on the square footage of the house. We decided that reducing to a 1,400 square foot home would not only cut down on heating and cooling costs, but also be more sustainable for a family of four. Also, our roof will not come to a “point” but rather be somewhat flat and diagonal. This will maximize the amount of sunlight that the solar panels can be exposed to, no matter what direction the sun is hitting from.

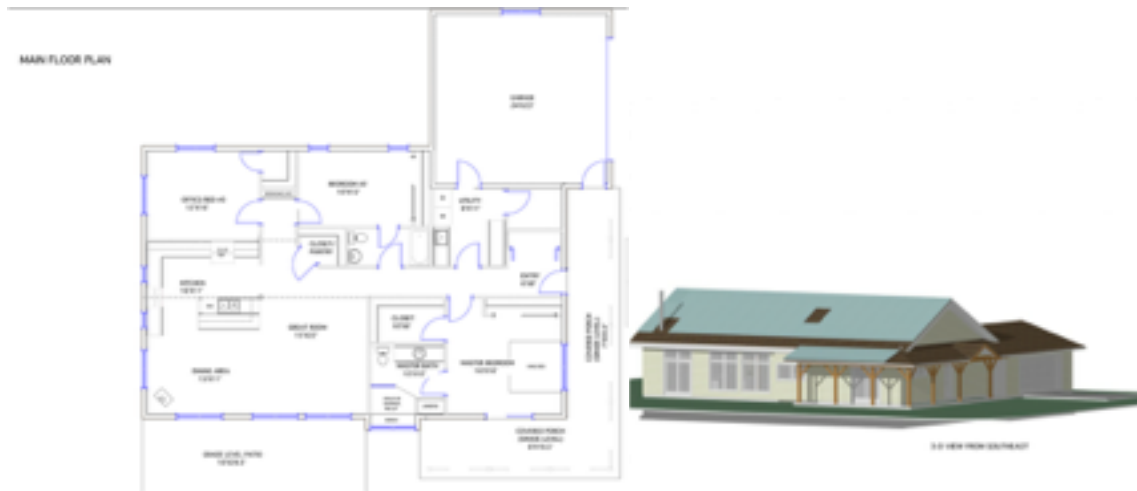
Another important aspect of our house was to have an open floor plan. Energy efficient house plans typically provide a modern style of open floor plans, with the living spaces connected with the kitchen and dining areas, thereby maximizing the space available. This is what we did for our home as well, and with fewer rooms to heat/cool, the family saves a significant amount of money on energy bills.

All in all, the efficiency of the house is completely in the family’s hands. It is up to them to understand how the house, and its appliances, work. Even when an appliance is labeled as “Energy Efficient” it should not be abused. For example, if the family left all of the lights on, it defeats the purpose of living in a zero-energy house. This is because they are abusing the

energy efficient lights and producing more energy than the house can manage. To ensure a zero-energy house success, a walkthrough instruction session will be provided upon move-in.

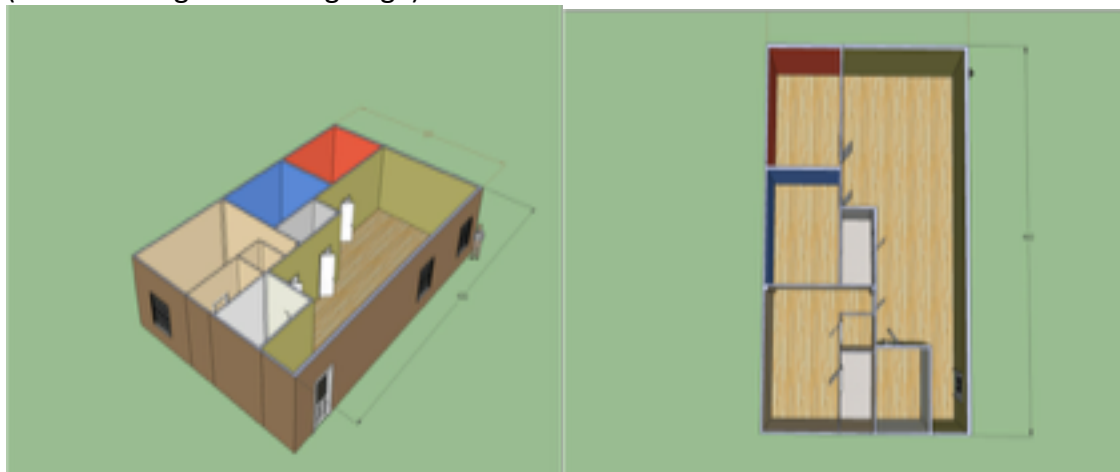
## **APPENDIX**

### **Original Plan:**



### Our Design Plan:

- 1400 square feet, large windows, open floor plan, one story, and garage.  
(Not including detached garage)



### Concept Screening

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House of Quality

## House of Quality

Direction of Improvement Design Requirements (How)							Customer Rating				
		Renewable Resources	Smart Lights	Large Windows	Open Floor Plan	Unattached Garage	Our Home	Harrisburg	Florida	Arizona	New York
Customer Requirements (What)	\$200,000	X	X		#	#	5	4	3	3	5
	Pennsylvania	#					5	5	1	1	1
	Family of Four	#		#	#	#	4	4	4	3	5
	Zero-Energy	#	#	#	#		5	5	5	5	5
	Sustainable	#		#			4	4	5	5	4
	Comfortable				#	#	4	5	5	4	5

### Our Home:

- The 4.5kWh Solar System, approximately 100 square-feet, produces an average of 6200 kWh/year.
- If the home is used properly, the family should generate approximately 6000kWh/year (give-or-take one hundred kWh/year)
- Energy Star Appliances (Total Cost of \$10,615) (Estimated Annual Energy Usage of 6000kWh):
  - Whirlpool Dishwasher
  - LG Stove
  - LG Refrigerator and Freezer
  - Two Vizio Televisions
  - DirectV Multi-Room Satellite Television Set
  - Energy Star Microwave
  - Five Harbor Breeze Fans
  - Five One-Zone Ductless Heating and Cooling Systems
  - Tankless Water Heater System
  - Whirlpool Washer and Dryer
  - Low-Flow Water Appliances
    - Two Toilets
    - Two Showerheads
    - Three Faucets
  - Motion Sensored Light System
    - With approximately twenty light bulbs throughout the house, each bulb is designed to automatically shut off when no motion is detected.