Pennsylvania Zero Energy Home

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Introduction:

A zero energy home doesn't really use zero energy. Instead the total energy used and produced by the home created is net zero. The home is optimized for the use of renewable resources as well as other features to save energy from the average home. Using the houses innovative features and the energy from renewable resources the house is able to generate enough energy to cover the energy used. After research and looking into other zero energy houses, many factors lead to a practical design. Some of the major contributing factors being orientation and location. All of this without compromising the safety of the family whether it be toxins or asthma related issues. Are home creates a minimizes its impact on the environment and provides insight to the future of what homes will be built.

Mission Statement:

Tony Pajamas and the Engineering Mafia's mission is to design an aesthetically appealing zero energy home for a family of four. We strive to make the best home possible within our budget range while still retaining eco-friendly qualities, with no carbon footprint. Sustainability and energy efficiency are key to achieving satisfaction with our customers. We take pride in our work and the effect we will have on the world.

Abstract:

The task of building a net zero energy home can bring quite a challenge for any engineer. This is why Dr. Etienne called upon Tony Pajamas and the Engineering Mafia to create a home using important ideas we learned in class. In class we were taught extensively about the engineering design process as well resources we could use to complete such a substantial project. One of the first things we looked at was location for the home. Originally we thought that a location near a body of water could provide many beneficial options for the house. We found a larger creek in between State College and Pittsburgh for what we thought would be used for drinking water as well as water power. After extensive research about the technology we came to the conclusion these were not economically and environmentally feasible. However, at this location we found some of the cheapest land and standard of living in all of Pennsylvania. Looking at zero net energy homes on line we knew that it would be optimal to have more than one floor and use of passive solar energy as a main component of the design. We would then combine and refine our ideas and create the design we have now.

Customer's Requirements:

- Create a net zero energy home in Pennsylvania
- Able to house a family of four
- Environmental impact is the backing of every design feature
- Make the house have good curb appeal
- Use solar energy as well as other valuable renewable resources
- Environment suitable for asthma and illnesses
- Budget of $160,000

Customer Needs Analysis:

Customer Statements	Needs Statements
Suitable home for a family of four.	The ZEH is 2 bedroom, 1 bath in a 1.5 story layout with 1000 sq ft of living space.
Demonstrates the requirements needed to be classified as a zero energy home.	The ZEH produces enough energy through solar panels to cover the amount of energy used by the home.
Above average air quality for child with asthma.	-The ZEH has a dehumidifier. -The ZEH has an air purifying filtration system.
The home utilizes the renewable energy produced from the sun.	-The ZEH has solar panels are placed on a sloped roof. -The ZEH has windows on the east, south, and west walls allow natural light and heat to enter the home.
Located in Pennsylvania.	-The ZEH is in Clymer, PA located in Indiana County.
Uses green engineering principles.	-The ZEH has energy efficient appliances implemented where possible. -The ZEH has products selected to allow maximum sustainability and efficiency.
Home is aesthetically pleasing.	-The ZEH has curb appeal with a landscaping design to optimize shading and natural sunlight.

Location Information:

Adams St. Clymer, Indiana County, PA 15728

Latitude: 40°40′08″ N

Longitude: 79°00′43″ W

Elevation: 1216.286 feet

Along Two Lick Creek

Temperate forest & river systems

Average Amount of Sun: 4.00 kWh/m^2

Wind Speed:

Snowfall: 75.6 in/year

Rainfall: 47.8 in/year

High temp: 80 F

Low temp: 15.1 F

Total temp: 51.4

Background Info:

Clymer was a prosperous coal town located along Two lick Creek. The town of Clymer was incorporated as a Borough in 1908 with an area of 304.78 acres. The streets were named after the signers of the Declaration of Independence. Clymer has approximately 1,500 residents and 400 buildings. Clearfield Bituminous Coal Corporation was the main employer, however in 1907 Clymer Brick and Fire Clay Company was formed and became a major contributor to the employment scene.

Demographics According to the 2000 Census:

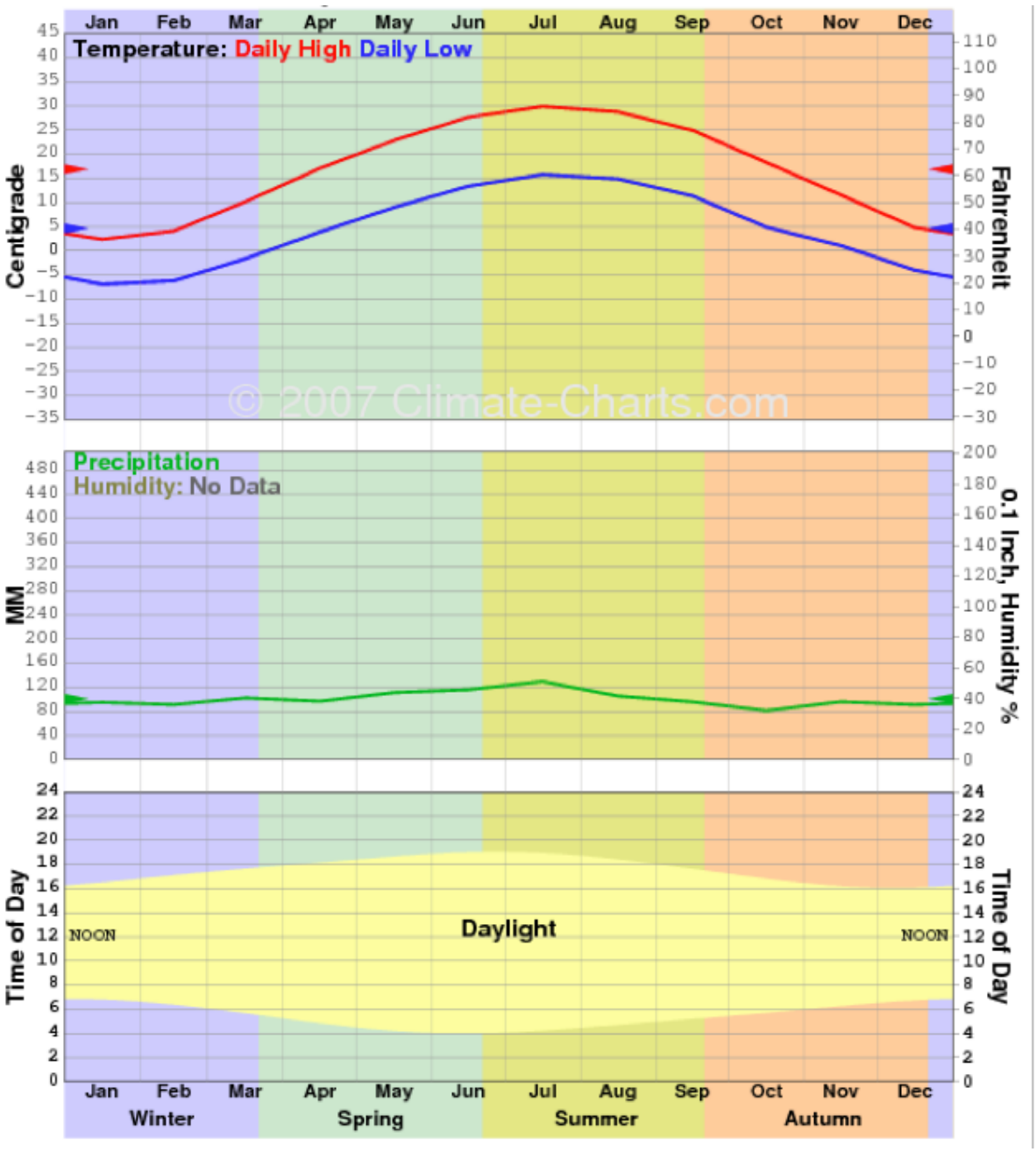
1,547 people, 679 households, and 418 families reside in the borough.
In the 679 households...

- 27.0% had children under the age of 18 living with them
- 44.9% were married couples living together
- 38.3% were non-families
- 35.1% of all households were made up of individuals
- Median income for a family was $36,688
- 18% of the population are below the poverty line
- Including 25% of those under age 18 and 16% of those age 65 or over.

Average Temperatures:

Statistic	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Temp.	F	28	30.2	39.7	50.9	60.8	69.1	73.2	71.4	64.8	52.9	43.5	32.7	51.4
High Temp.	F	36.3	39.4	50.4	62.8	73.2	81.9	85.8	83.8	77	64.9	52.9	40.6	62.4
Low Temp.	F	19.6	20.8	29.1	39	48.2	56.1	60.4	58.8	52.5	40.8	34	24.8	40.4

Weather Graphs:



Concept Generation:

Our initial concept generation was disorganized; We placed all our ideas on small pieces of paper and then organized them in different piles and discussed the reasoning for each one. After this initial brainstorming, we began to research more into zero energy homes, and what makes them more efficient and sustainable.

	Concept Screning							
		Startup Cost	Energy Efficient	Long Term Cost (heating/cooling)	Availability	Asthetics	Net Score	Rank
	One Floor	0	0	0	1.5	1.5	3	3
HOUSE DESIGN	Two Floors	2	1	1	1.5	1.5	7	2
	1.5 Floors	1	2	2	1.5	1.5	8	1
		Cost	Energy	Long Term Cost	Availability	Asthetics		
	Two Bedrooms	1	0	1	1	1	4	Yes
	Three Bedrooms	0	0	0	1	1	2	No
House Elements	Open Floor plan	1	0	0	1	1	3	Yes
	Huge Windows	0	1	1	1	1	4	No
	Multiple small windows	1	1	1	1	1	5	Yes
	Low ceilings	1	1	1	1	0	4	Yes
	high ceilings	0	0	0	1	1	2	No
	Buffer rooms	1	1	1	1	1	5	Yes
	Cheap appliances	1	0	0	1	1	3	No
	Energy Efficient appliances	0	1	1	1	1	4	Yes
	Wood floor	0	0	1	1	1	3	Yes
	carpeted floor	1	1	0	1	0	3	No
	Fireplace	0	1	0	1	1	3	No
	Insulation	1	1	1	1	1	5	Yes
Power	Soar power	1	1	1	1	1	5	Yes
	hydro power	0	1	1	1	1	4	No

External Research:

Zero Energy Home Research:

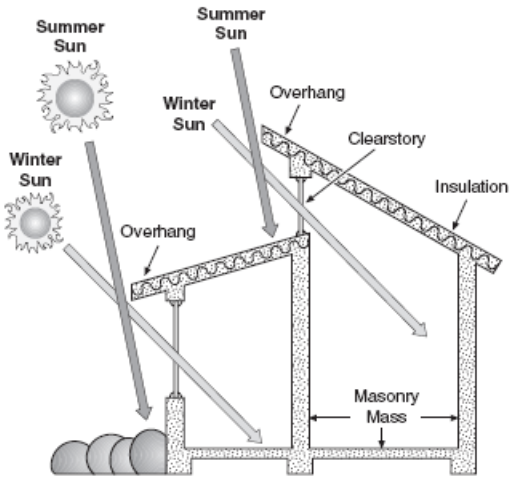
We looked at some solar decathlon zero energy homes, and tried to understand what their reasoning was for building their houses. They had an extra constraint, it is about the same amount of dollars, but they have to be very mobile houses so that they can get to the competition, which takes place on the national mall. The majority of the houses used some sort of sloping roof, was built with sustainable materials, and had an open floor plan. They were mostly 1 story, but that was only because they had to be portable.

Literature Review:

One major website provided us with excellent insight to energy efficient features of homes and how to implement them was house-energy.com. This helped us and backed up our ideas of what is efficient and provides the house with renewable energy. One of the major designs of our house was backed up by this website. This provided us with many extra ideas that were not very difficult or costly to implement.

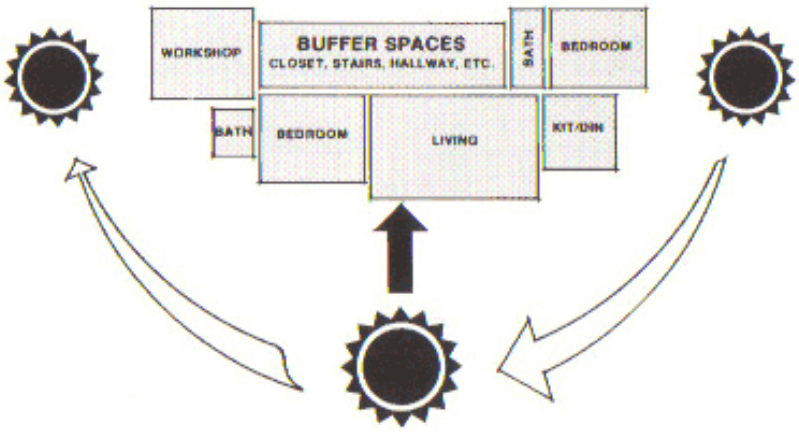
Overhangs Depth and Sun Angle for Shade and Energy:

Overhangs that are tilted and shaped can be very effective in cooling and heating the house in summer and winter respectively. As shown in the picture below the overhangs prevent direct 12pm summer sun from entering through the windows while allowing all of the 12pm winter sun into the house. This creates a very impactful heating and heat prevention effect on the home. Based on the elevation as well as number of cooling/heating degree days we were able to calculate close to the optimum overhang angle/size.



Layout of our floor plans:

In our design and on the website all rooms were and are suppose to be placed in very specific locations to maximize the effectiveness of the passive solar power. To start the majority of windows are facing the south due to the cold climate in Pennsylvania. In the bottom floor the buffer rooms are the utility, bathroom, and kitchen. These rooms are not in need of any direct sunlight for any time period during the year. However surrounding these rooms or sun facing rooms are the ones that benefit from being heated such as the living room. In order to benefit from the morning and afternoon sun we placed the kids and parents bedrooms on the west and east facing sides of the house respectively. This way, in the cold winter months they are heated during the dawn and dusk hours of the day with direct light in order to save in energy costs.

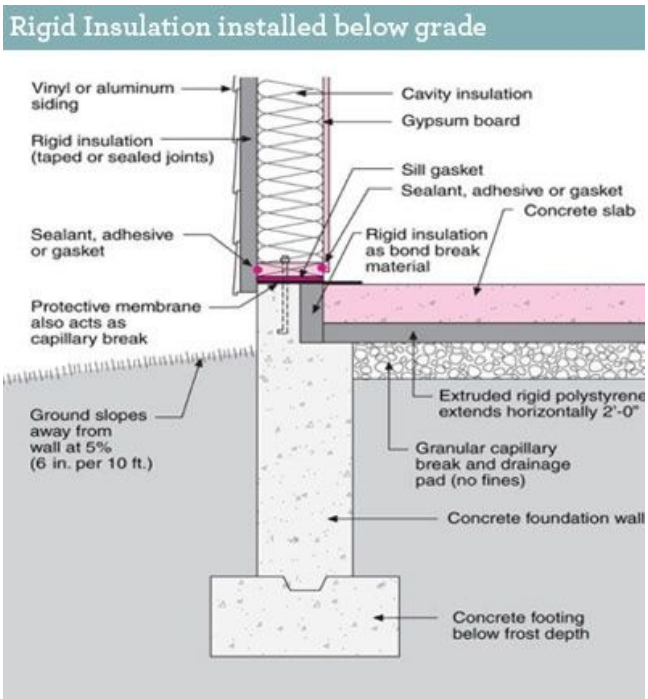


Ceiling Fans And Air Conditioners Can Work In Conjunction:

Another small but impactful energy saving technique is optimizing ceiling fans together with air conditioners. Each one degree increase (F°) in your air conditioner thermostat setting can decrease your air conditioner bills by 5%. And ceiling fans make that possible. Just turn your ceiling fan and raise the AC setting by 4°F or slightly more during the summer months. You will not notice any loss of comfort and you get massive energy savings.

Concrete Slab Insulation For Energy Efficiency:

Insulated floors are a great way to keep energy efficiency in the house. Floor insulation may be not as important as attic or wall insulation, however it is still very important. Concrete under slab insulation can reduce heating bills by 10%–20% in cold and moderate climates. Also in the summer a un-insulated slab can create a unwanted heat gain. This concrete slab insulation reverses its effective behavior during the summer to save energy all year round.



Storm Windows:

Storm windows can be very effective in cold climates. Exterior storm windows can reduce energy losses through windows up to 50%, if equipped with Low-E glass. This provides a great benefit of making the home air tight and reducing the cost of heating the house during the winter months.

Benchmarking:

Other Energy Efficient Builders in the Country:

Tommy Williams Homes - Zero Energy Home - Longleaf

Gainesville, FL - 2,250 square feet - 3 Bedrooms - 2.5 bathrooms

More information at:

http://www.ba-pirc.org/casestud/pdf/BA_BuildersChallengeSpotlight_TWH-ZEH.pdf

Performance Features:

Thermal Shell-

- R-30 ceiling insulation (R-19 knee wall Insulation), vented attic with radiant barrier
- 10" heel trusses for improved insulation coverage
- R-15 formaldehyde-free blown fiberglass wall Insulation
- Double pane, Low-e vinyl frame windows (U=0.35, SHGC=0.25)
- ENERGY STAR® Certified including
- Thermal Bypass Checklist Compliance

Efficient Appliances & Renewable Energy-

- 100% Compact Fluorescent Bulbs
- 6.75kWp Sunpower 225 PV System (inverter avg. eff. = 0.97)
- ENERGYSTAR® rated dishwasher, clothes washer and refrigerator
- Very efficient ceiling fans

O'Neil Zero Energy Prototype Homes

Montgomery County

Project Overview:

- Location: Perkiomenville, PA
- Owner/Developer: Jackie O'Neil
- Building type: Single-family residential
- New construction, 2 houses
- Size: 2016 sq ft and 2216 sq ft
- LEED for Homes Gold certified

Description: *Two energy efficient, passive/active solar single family residences, integrated climate responsive design, energy modeling, daylighting, radon resistant construction, slab on grade, structural insulated panels, fiber cement siding, 50 yr shingle roof, clad wood ENERGY STAR windows, stained concrete floors, no-VOC finishes, site-harvested wood floors & millwork, salvaged interior doors, geothermal heating system & radiant floor heat, tankless on-demand water heating, energy recovery ventilation & humidity control, passive cooling & geothermal air conditioning, 5.25 kW grid connected photovoltaic system, ENERGY STAR appliances & lighting, high efficiency water saving plumbing fixtures, native landscaping, permeable pavement, rainwater harvesting, non-toxic pest control*

More information at:

http://www.citilogs.com/pdfs/consillience_philadelphia_sustainability_awards.pdf

Concept Selection:

After identifying what was important for building a net-zero energy home, we deciding the final items that would be prioritized and implemented in the home that would satisfy the needs identified by the customers.

	Metric	Clymer PA	Open Floor Plan	Windows	Enegy Star Apliances	Wood Floor	Insulation	Passive Solar	Solar Pannels	Two Bedrooms	Dehumidifier	Air Filter	Cost
	Need	1	2	3	4	5	6	7	8	9	10	11	12
1	Designed for a family of 4									x			
2	Located in PA	x											
3	Includes solar component							x	x				
4	Above average air quality					x					x	x	
5	Produces at least as much energy as it uses				x		x	x	x				
6	Energy efficient appliances				x								
7	Aesthetically pleasing		x	x		x				x			
8	Under Budget												x

Final Specifications:

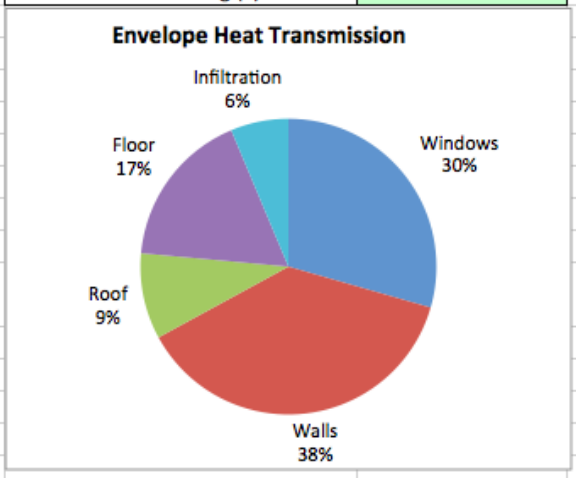
After research was done and we had the specifications that would go into our final design for the ZEH. Subscribing to all of the customer's needs, we entered our final data into the "Zero Energy Calculator" provided to us by Dr. Etienne. We then used this information to finish research and decide the exact materials that would go into our net-zero energy home. We found out that we needed the most energy efficient products we could use, and the home needed to be properly insulated and air-tight in order to truly sustainable and efficient. With the proper dimensions inputted, the following results were obtained:

Penn State Center for Sustainability

General Info	
Location	Pittsburgh
Electricity cost ($/kwh)	0.1
House type	1.5 story
Conditioned floor area (sq.ft.)	1000
Number of bedrooms	2
Envelope Details	
Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	600
North wall area (gross) (sq.ft.)	400
East wall area (sq.ft.)	510
South wall area (sq.ft.)	340
West wall area (sq.ft.)	510
North window area (sq.ft.)	0
East window area (sq.ft.)	56
South window area (sq.ft.)	98
West window area (sq.ft.)	36
Air tightness	Tight with heat recovery
Appliances	
Refrigerator	Energy Star
Clothes Washer	Energy Star
Dishwasher	Energy Star

Zero Energy Home Calculator

Heating & Cooling	
Type of heating & cooling system	Electric geothermal heat pump
Solar Technologies	
Size of PV system (kw)	3.89
Solar water heater	Yes
Behavior	
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	68
Cool thermostat setting (F)	78



Appliance and Materials Specifications:

Wherever possible in the home we chose to use energy efficient products. Including most large appliances, the items chosen are a necessary for the home and by purchasing the most energy efficient products, we are reducing the amount of energy that will be used, and therefore the amount of energy we will need to produce ourselves. This will also make the home more sustainable and have less of a carbon footprint.

Item	Quantity	Price Per Unit ($)	Cost ($)	Energy Efficient?
Bamboo Flooring	1000 sq. ft.	4.69	4690	x
Larson Exterior Storm Windows	16	84.94	1360	x
Larson Storm Door	1	199	199	x
Benchmark Entry Door	1	189	189	x
Harbor Breeze Ceiling Fan	2	99.98	199.96	x
Frigidaire Stainless Steel Refrigerator	1	899.1	899.1	x
Whirlpool Duet Front Loading Washer (Stackable)	1	719.1	719.1	x
Whirlpool Duet Front Load Dryer	1	809.1	809.1	x
GE Stainless Steel Dishwasher	1	629.1	629.1	x
WinixTrue HEPA Air Cleaner	1	169	169	x
GE 50-Pint Dehumidifier	1	215.71	215.71	x

- As bamboo flooring is more durable than other woods, we chose an engineered bamboo flooring for the home. Carpet holds dust and allergens, which may not be the best option for a home that houses a child with asthma, so the bamboo flooring will be throughout the entire home.
- Storm windows and doors help reduce heat loss, so we selected Larson Exterior Windows and a Larson Storm Door for our home which add an extra layer of insulation barrier to reduce energy loss by up to 80%.
- Ceiling fans can help reduce the need for air conditioning, and by choosing the energy efficient Harbor Breeze Ceiling Fan we will be cutting the energy required to cool the home.
- The kitchen is home to many appliances. We decided to go with stainless steel products for their durability, and where available, energy efficient products were also chosen. The refrigerator will automatically enter energy saving mode if not opened for a certain period of time. The dishwasher is also energy star qualified and will require less utility input, thus reducing costs.

- The family will no longer need to go to the laundromat and can now do laundry at home with their energy efficient washer and dryers that require less energy and water per load. The set is stackable as well, reducing the space needed for the appliances.
- As one child has asthma, it is important to include appliances that will reduce the chances of an asthma attack at home. A dehumidifier and HEPA air filtration system will do just this. The models selected are also energy efficient and will not require as much added electricity to support these types of systems. Built in timers also reduce the energy consumption.
- The bathroom and kitchen fixtures, such as the sinks and bathtub, were also chosen to be water conserving. WaterSense products reduce the water flow to fixtures so less water goes to waste when leaving the water running.
- For insulation, the higher the R-value the more energy efficient. To achieve insulating the home to the best of our abilities, we chose a Pactiv Extruded Polystyrene Insulated Sheet that has an R-value of 10. The insulation is a little more expensive, but it will reduce energy loss which will make the home more sustainable in the long run.

*All the materials listed above can be purchased from Lowe's and Home Depot

Solar Panel System Specifications:

Based on our "Zero Energy Calculator" provided by Professor Etienne, our annual electric usage will be 4,620 kwh based on the specifications we decided to use in our home. In order to have a system that will provide this much energy for the home, we will install a system that produces approximately 4,622 kwh of electricity. The solar rating for the area we have chosen to build our home is good, providing 4.00 kWh/m^2 per day. Our roof will be sufficient to hold this system, requiring 432 sq ft of the 685 sq ft available. The solar system capacity required is 4.32 kW of peak power (DC watts).

ESTIMATED NET COST:	**$ 12,544**
ESTIMATED NET COST AT INSTALLATION:	**$ 14,394**

Your Solar Electric Estimate by the Numbers

Building Type:	Residential
State & County:	PA - Indiana
Utility:	Pennsylvania Electric Co (FirstEnergy)
Utility Type:	Investor-Owned Utility
Your Average Monthly Electricity Bill: (Assumed rate x average monthly useage)	$ 65 / Month
Tiered Rates Apply:	No
Time-of-Use Metering Offered:	No
Net-Metering Available:	Yes - See Notes, below!

ESTIMATED SYSTEM SIZE

The system size best for your situation will vary based upon product, building, geographic and other variables. We encourage you to work with a Solar Pro who can better estimate the system size best for your situation. We estimate your building will need a system sized between 3.46 kW and 5.18 kW of peak power. This estimate assumes the mid-point of this range.

Solar Rating:	**Good** 4.00 kWh/sq-m/day
Solar System Capacity Required:	4.32 kW of peak power (DC watts)
Roof Area Needed:	432 sq-ft
Equivalent Annual Production:	4,622 kWh electricity

SAVINGS & BENEFITS	
First-year Utility Savings:	
Your utility offers Tiered rates and/or TOU metering. Therefore, the electricity savings you realize may exceed the annual electricity needs of your building. See the Notes, below, about why you may want to choose a smaller system.	**$726**
Average Monthly Utility Savings: *over 25-year expected life of system*	**$102**
Average Annual Utility Savings: *over 25-year expected life of system*	**$1,219**
25-year Utility Savings:	**$30,464**
Levelized Cost of your Solar Energy: $12,544 cost / 115,550 kWh electricity replaced by solar	**$0.11 per kWh**
Utility savings shown above do not take income tax effects into account (they use "Post-Tax" dollars). The financial ratios shown below are based upon the cash flow values shown in the Cash Flow table, below, which include income tax effects, as noted.	
Appreciation (Increase) in Property Value:	**$14,520**
Return on Investment (ROI):	**186%**
Internal Rate of Return (IRR):	**9.2%**
Net Present Value (NPV):	**$7,343**
Profitability Index:	**1.5**
Greenhouse Gas (CO_2) Saved:	**95 tons**
over 25-year system life	**190,000 auto miles**

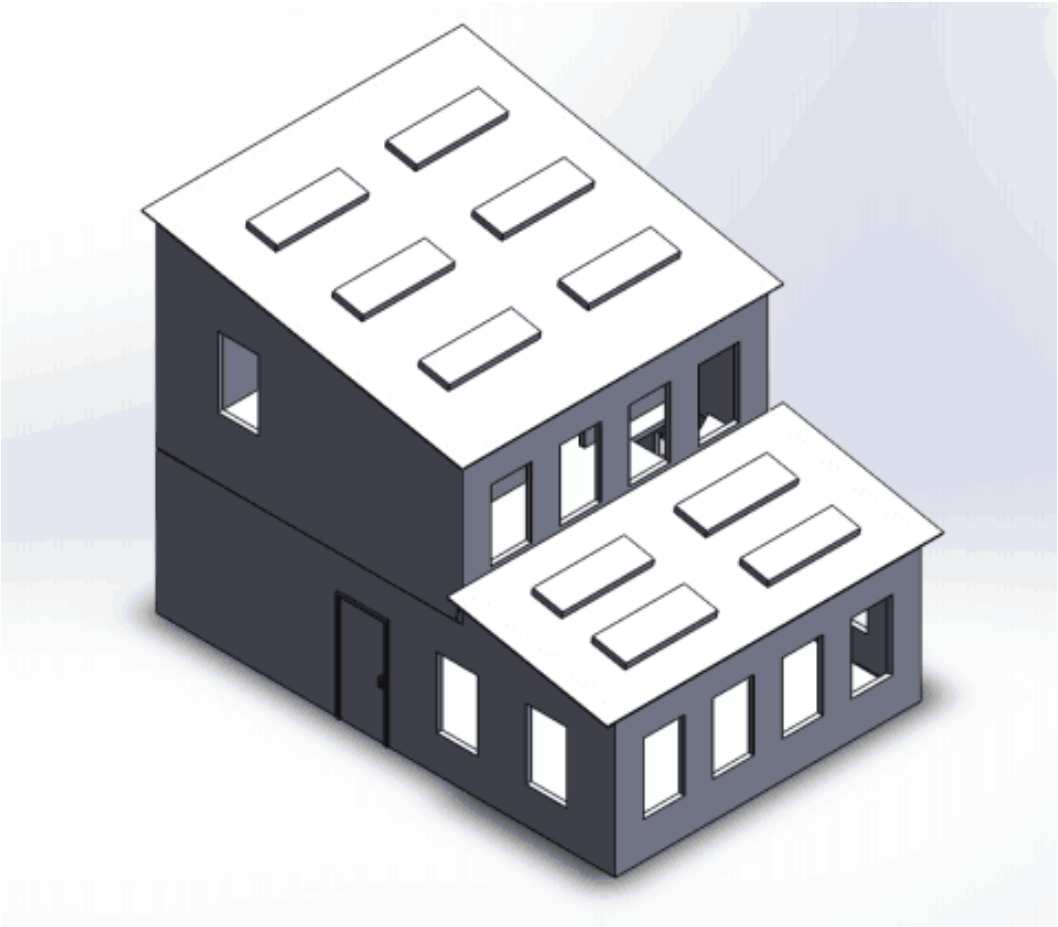
Final Budget Model:

Item Name	Material	Labor	Equipment	Total
Foundation, Piers, Flatwork	2,963.00	3,164.00	764	6,891.00
Rough Hardware	289	309	75	673.00
Rough Carpentry	9,581.00	7,602.00	--	17,183.00
Insulation	2,394.00	833	--	3,227.00
Exterior Finish	7,486.00	2,963.00	537	10,986.00
Exterior Trim	469	501	122	1,092.00
Doors	668.00	677	--	1,345.00
Windows	1,360.00	945	--	2,305.00
Finish Hardware	198	113	--	311.00
Roofing, Flashing, Fascia	3,706.00	2,281.00	--	5,987.00
Finish Carpentry	532	1,818.00	--	2,350.00
Interior Wall Finish	2,552.00	2,176.00	--	4,728.00
Painting	1,525.00	2,417.00	--	3,942.00
Wiring	1,548.00	1,984.00	--	3,532.00
Lighting Fixtures	1,161.00	248	--	1,409.00
Flooring	4,690.00	1,099.00	--	5,789.00
Bath Accessories	722	150	--	872.00
Shower & Tub Enclosure	399	131	--	530.00
Countertops	1,085.00	618	--	1,703.00
Cabinets	3,568.00	762	--	4,330.00
Built In Appliances	1,736.00	165	--	1,901.00
Plumbing Rough-in and Connection	2,212.00	3,647.00	336	6,195.00
Plumbing Fixtures	2,280.00	966	--	3,246.00
Heating and Cooling Systems	3,805.00	3,046.00	--	6,851.00
Fireplace and Chimney	2,272.00	3,408.00	--	5,680.00
Building Materials Subtotal	**59,201.00**	**42023**	**2210**	**103,058.00**
Final Cleanup	--	--	--	
Insurance	3,827.00	--	--	
Permits & Utilities	2,323.00	--	--	
Necessary Costs Subtotal	**6,150.00**	**--**		**6,150.00**
Total Bulding Costs	**$65,793.00**	**$42,023.00**	**$2,210.00**	**$110,026.00**
Solar Panels				$12,544
Panel Installation				$1,850
Asthma Control Products				$384.71
Customer Needs Total				**$14,778.71**
Total Cost of ZEH				**$124,804.71**

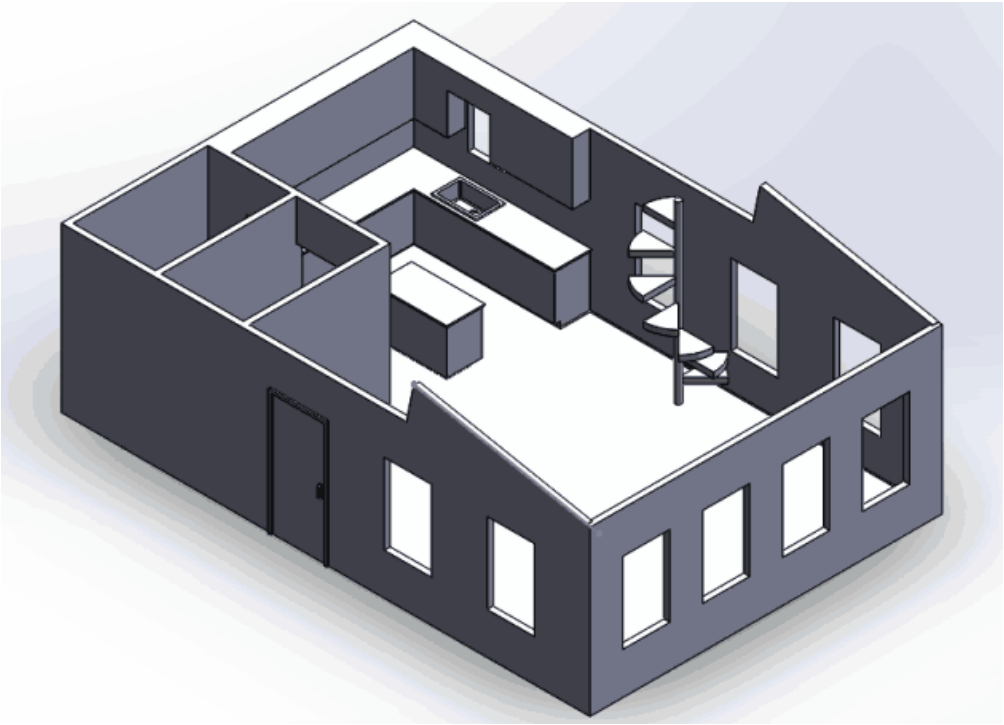
Final ZEH Design:

SolidWorks Model:

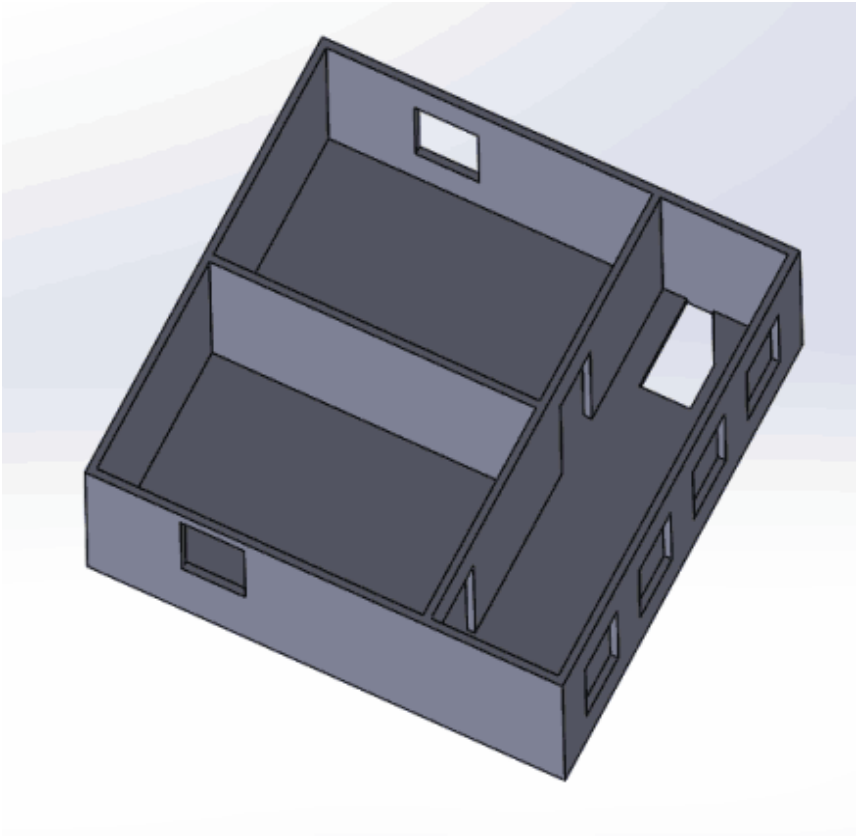
Entire Home:



Ground Floor:

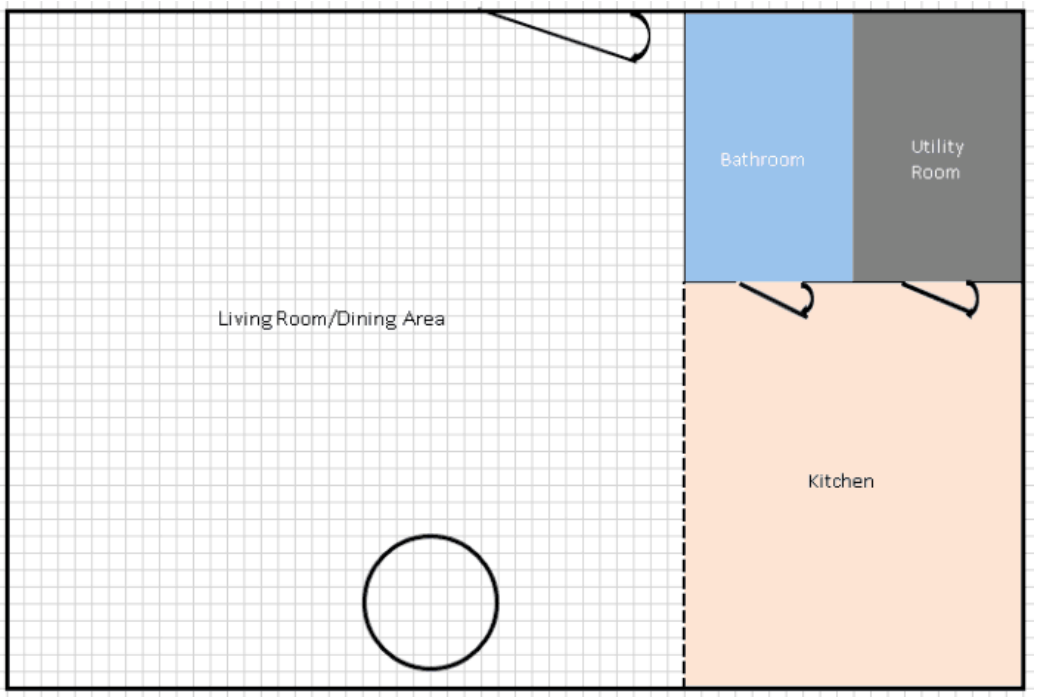


Top Floor:



Floor Plans with Dimensions:

Ground Floor:



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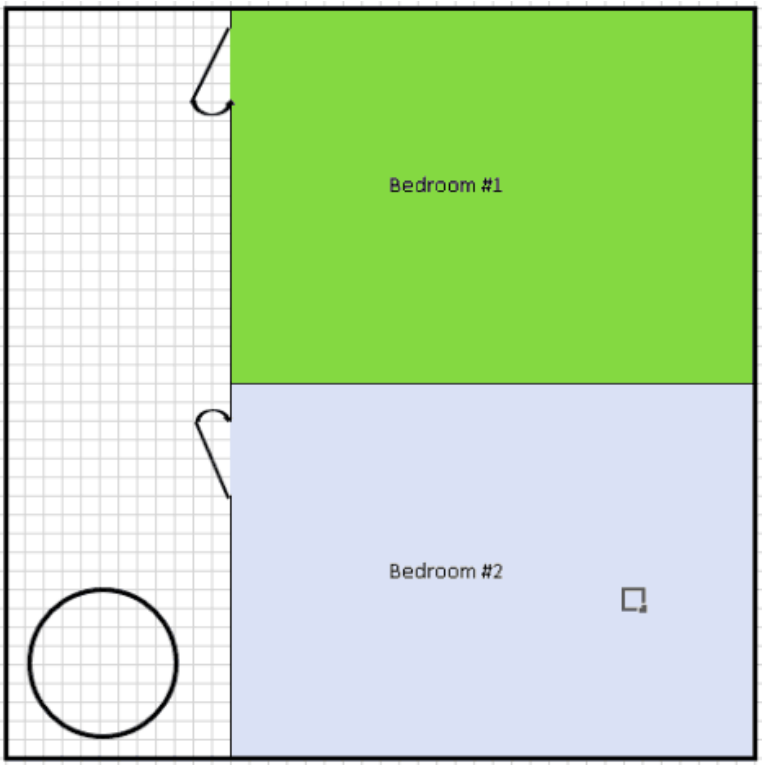

Cardboard Model:

Entire Home:

Ground Floor:

Top Floor

Conclusion:

After many hours of diligent work and collaboration, our zero-energy home finally came together. We found that making a zero-energy home with a $160,000 budget is an achievable goal. We discovered that there are numerous ways to bring energy to a home and store the energy that is generated. Both the storage and usage processes are equally important. Our home design took both into consideration. While working on this project, we made sure that we were using all aspects of the design process to make our home as effective as possible. It is essential to take every step into consideration in order to maximize the abilities and efficiency of your home. When given full freedom to create a home, there was some disagreements at first but collaboration is important to the engineer so we worked through them. No ideas were shunned and all were considered to try to make this house as creative as possible. Although we constantly altered our original designs, we finally reached a model that pleased everyone. Then, the more detailed specifications for the house were made and the home was really starting to look like what we desired. Our CAD and cardboard models were both made precisely to scale with these specifications. After we finished these, we calculated both the energy that our home required and how much energy we would produce. After doing finishing our powerpoint and final report, we realized what it was like to be an engineering team and are proud of what we created.

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