Zero Energy Home Project

Team 3-Awesome

EDSGN100 Section 016
Submitted to: Wallace Catanach
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Introduction

The topic of sustainability is the most important long-term issue for the human race as a whole. At its most basic concept, sustainability means meeting the needs of the current generation without compromising those of future generations. After a long period of reckless consumption, society is starting to accept the reality that our planet has limited resources, and that our lifetime on this planet will not last if our current rate of consumption of does not change. The overall challenge is to get common people to embrace the idea of sustainable living as a realistic and moderate way of life, not as a drastic departure from ordinary life or an inconvenient chore. To do this, our design team developed a home which uses a net-zero amount of energy, while at the same time accommodates a normal family of four in a seasonal, Pennsylvania climate.

Abstract

The house produces all of the energy it needs annually through a roof-mounted photovoltaic system. The floor itself is a thermal slab which absorbs heat through high-efficiency thermal windows and distributes it throughout the home. The open floor plan of this home also accommodates passive solar heating. The exterior walls are highly insulated and air-tight to prevent heat loss. The comfort and functionality of this home were most important to our group during the design process.

Mission Statement

To demonstrate the realistic goal of sustainable living through the design of a home that eliminates the burning of fossil fuels, the excess consumption of energy, and the waste of non-renewable resources. The alternative energy methods used by this house, such as passive solar heating, heat pumps, and photovoltaic electricity generation, will not burden the design/aesthetics of the home, so as to show customers that sustainable living can be marketable and affordable. This will benefit the current community effort of sustainability at the residential level. Furthermore, the functionality of the home will not be compromised, as residents can still utilize many home appliances that have become a part of the everyday life of our generation. The energy consumption of this home will be less than or equal to the energy this home produces annually, thus earning the title of a “zero-energy home”. Energy and water consumption/production will be measured and recorded in order to properly monitor daily levels. Research, attention to detail, and cost-effectiveness will be key values throughout the design process of the home.

Customer Needs

Through research and verbal surveys, our group identified the following criteria as customer needs.

Customer Needs
The home not only produces all of the energy it needs over a year, but also puts some excess into the grid.
The home demonstrates that solar-powered Zero Energy Homes can be made to work well in the Commonwealth.
Meets the needs of a typical family of four.
The use of alternative energy sources does not hinder the common family lifestyle.
Residents have access to hot water.
Residents have access to common electrical appliances.
The use of alternative energy sources does not compromise safety, health, or comfort.
The home can produce energy year-round in the Pennsylvania climate.
Little to no extra maintenance is required for the operation of energy sources.
The home complies with local building codes and regulations.
The design of the home will be aesthetically pleasing.

Background Information on Location

We decided for our home to be located in Philadelphia, PA because of several key factors. Being in a moderate climate with hot summers and cold winters, a Zero Energy Home in Philadelphia demonstrates that sustainability can be available for the masses. The city still receives 80%-85% of the solar energy that Miami, FL receives; making our energy sources a realistic effort (http://www.maximussolar.com/faq/faq.htm).

Additionally, the city of Philadelphia is a hub for green building. In his 2007 inaugural address, the mayor of Philadelphia pledged to make this city the number one green city in America, and launched a comprehensive agenda of legislation and programs to promote sustainable living. This applies most to a residential homeowner in the form of tax incentives for the use of solar panels, solar water heaters, and heat pumps.

A list of local tax credits can be found here http://www.phila.gov/green/payForSolar.html .

Preliminary Research

Research of existing Zero Energy Homes, and the technology they use, was crucial to the generation of our concepts. Shown below are examples of many homes we researched.

Montague Urban Homestead

Location (city, state)	Turners Falls, MA
House size (floor area in square feet)	1152
Number of floors	1
URL of web site where info is found	http://www.builditsolar.com/Projects/SolarHomes/MAZeroEnergy/MAZeroEnergy.htm
Number of occupants	Single family
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Passive heating (insulation and thermal mass) HRV Heat Pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	4.94
Solar water heater (yes or no)	no
R-value of wall insulation	42
R-value of ceiling insulation	100
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	1949 kilowatt-hours

Charlotte Vermont House

Location (city, state)	Charlotte, VT
House size (floor area in square feet)	2800
Number of floors	2 + attic
URL of web site where info is found	http://www.wbdg.org/references/cs_ch.php
Number of occupants	4
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Passive heating (insulation and thermal mass) Heat Pump Heat Recovery Unit
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity (Wind)
Size of photovoltaic system (kilowatts)	N/A
Solar water heater (yes or no)	no
R-value of wall insulation	40
R-value of ceiling insulation	56
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	5999 kilowatt-hours
Any other pertinent info	Additional energy is produced by a 10 kWh wind turbine, which produced 6222 kWh annually

Through our research, we identified key concepts that seemed to be common in all zero-energy homes.

Air Heating

Uses passive solar heating to gain heat from sunlight. A large area of high-efficiency thermal windows, oriented toward solar south, increase the transfer of solar energy to heat inside the home. The floor is made of a concrete thermal slab which absorbs heat, as well as provides aesthetic appeal as shown in the home above. A heat pump is also an efficient source of additional heat recovery.

Water Heating

Can be heated by a solar water heater or a heat pump. Solar water heaters require a roof-mounted collector which cycles heat through the water supply using various methods.

Power

Generated by a photovoltaic system on almost every home. Some homes can additionally use a turbine where wind conditions are optimum.

Appliances

All home appliances carry an Energy Star rating. Low-flow sinks and toilets are also preferred.

Shading

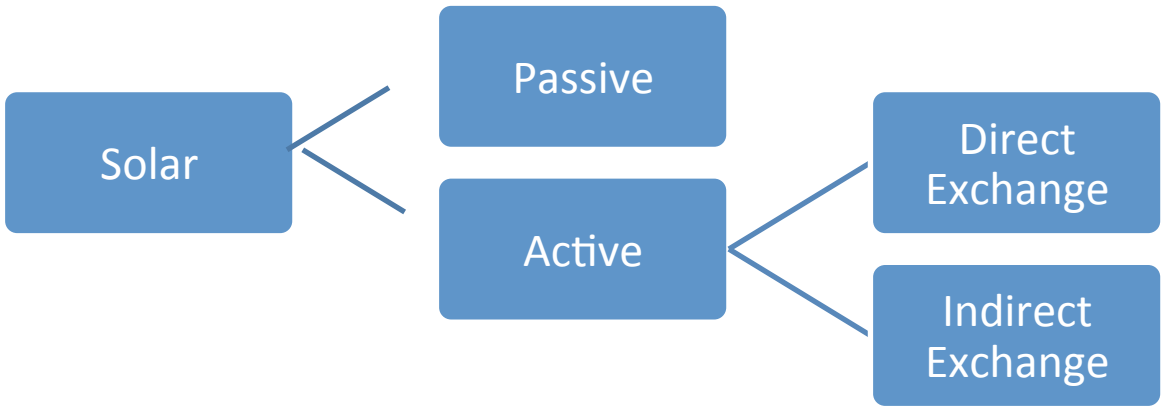
The windows are shaded from the angle of the sun during summer months by an overhang of the edge of the roof, effectively cooling the home.

Layout

An open floor plan will promote heat transfer to all areas of the house, as well as maximize interior space.

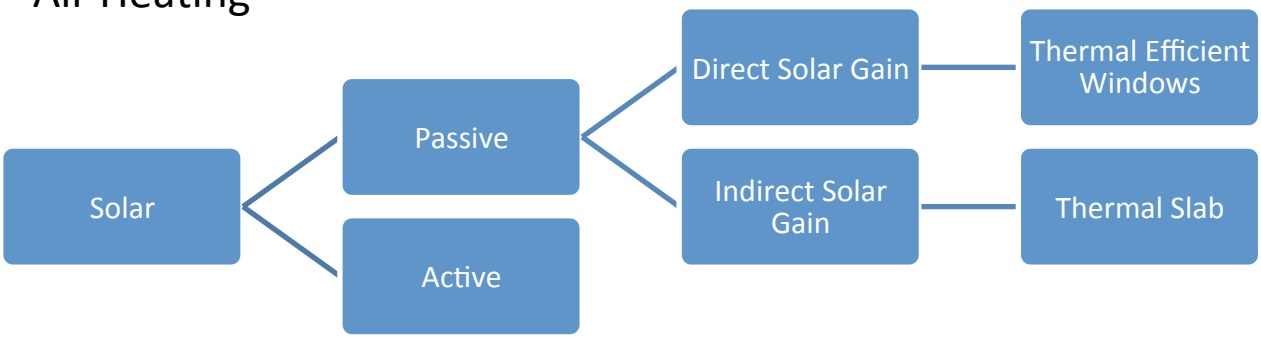
Concept Generation

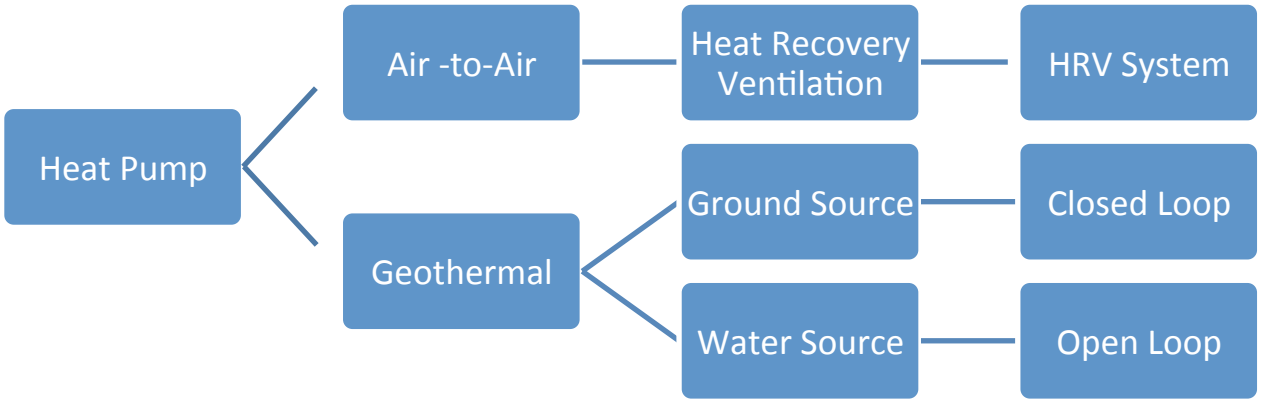
Water Heating



Concept Generation

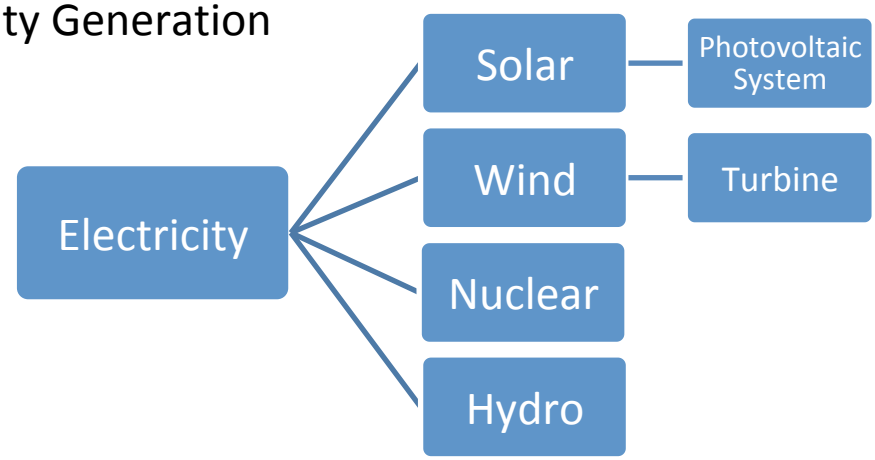
Air Heating





Concept Generation

Electricity Generation



Customer Needs Analysis

	Concepts	Thermal Slab Floor	High Insulation	Thermal Efficient Windows	Roof Overhang	Solar Water Heater	Heat Pump	Photovoltaic System	Energy Star Appliances	Water-conserving faucets and toilets	Open, spacious layout	Three bedrooms
Needs		1	2	3	4	5	6	7	8	9	10	11
The home not only produces all of the energy it needs over a year, but also puts some excess into the grid	1	o	o	o	o	o	o	o	o	o		
The home demonstrates that solar-powered Zero Energy Homes can be made to work well in the Commonwealth.	2	o	o		o				o		o	o
Meets the needs of a typical family of four.	3			o		o		o	o	o	o	o
The use of alternative energy sources does not hinder the common family lifestyle.	4	o	o	o	o	o	o	o	o	o	o	o
Residents have access to hot water.	5					o						
Residents have access to common electrical appliances.	6							o	o			
The use of alternative energy sources does not compromise safety, health, or comfort.	7	o	o	o	o	o	o	o	o	o	o	o
The home can produce energy year-round in the Pennsylvania climate.	8	o	o	o	o	o	o	o			o	
Little to no extra maintenance is required for the operation of energy sources.	9	o				o	o	o				
The home complies with local building codes and regulations.	10	o	o	o	o	o	o	o	o	o	o	o
The design of the home will be aesthetically pleasing.	11	o			o				o		o	o

Based on the above Needs-Concepts matrix, we were able to attribute concepts of the house to needs given by the customer. We felt that these aspects were necessary not only to fulfill the challenge of completing a zero-energy home, but also to keep the home as marketable and attractive to future buyers as possible. As a result, all of our concepts satisfied the need for not compromising the safety, health and comfort of the home and owners.

Concept Selection

	Concepts	Passive Solar Heating	High Insulation	Thermal Efficient Windows	Wind Power	Solar Water Heater	Heat Pump	Photovoltaic System	Energy Star Appliances	Water-conserving faucets and toilets	Open, spacious layout	Regular Home
Selection Criteria		1	2	3	4	5	6	7	8	9	10	11
Cost	1	+	+	-	-	o	-	-	o	o	+	o
Saves/Creates Energy	2	+	+	o	+	+	o	+	o	o	o	o
Aesthetically Pleasing	3	+	o	o	o	-	o	-	o	o	+	o
Maintenance	4	+	+	+	-	-	-	-	o	o	o	o
Totals		4	3	0	-1	-1	-2	-3	0	0	2	0

Although many of our concepts tend to have lower scores in the cost and maintenance categories, this is a common aspect of zero energy homes. While there is high upfront cost, over time you are able to break even and make your money back. Also, maintenance largely depends upon the specific unit, and thus was a huge deciding factor in our research for solar water heaters, photovoltaic systems, and heat pumps.

We collectively chose not to include the concept of the wind turbine because it constrains the location of the home and thus decreases marketability. This reason is also why we did not choose to include nuclear or hydroelectric power as well as a groundwater-source heat pump.

Embodiment Design

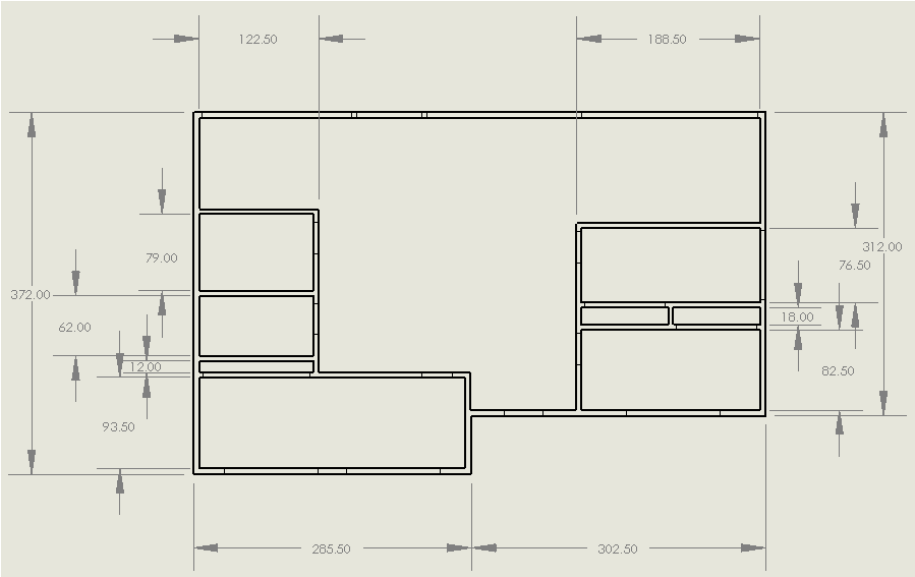


Figure 1 Top View Dimensioned

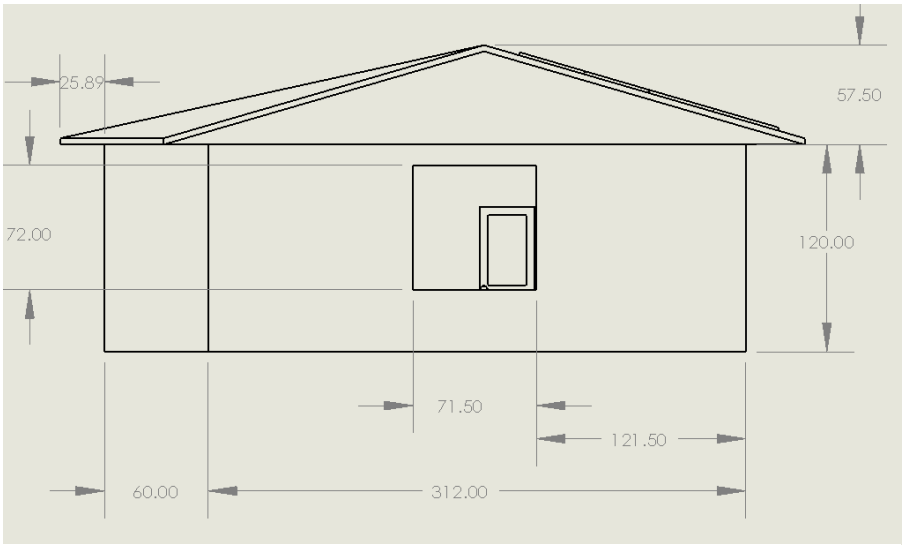


Figure 2 West Side Dimensioned

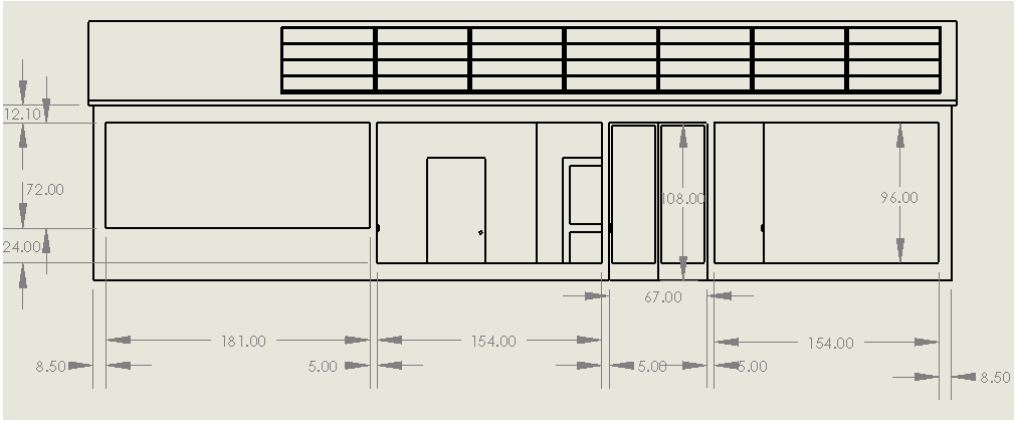


Figure 3 Rear View Dimensioned

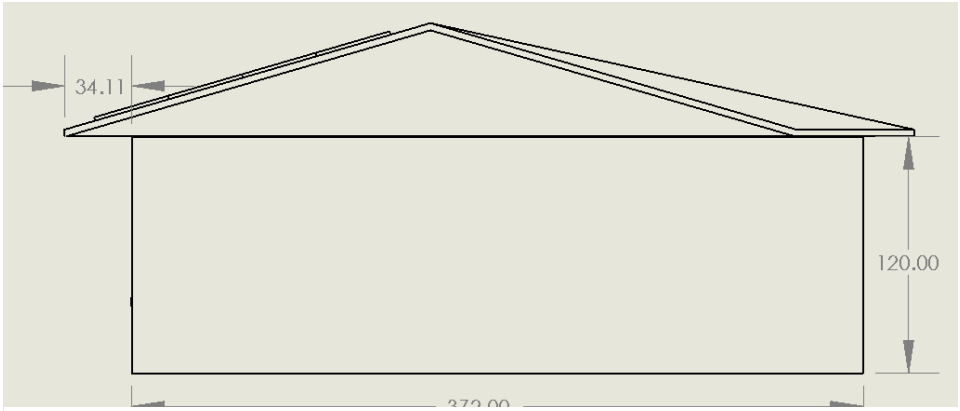


Figure 4 East Side Dimensioned

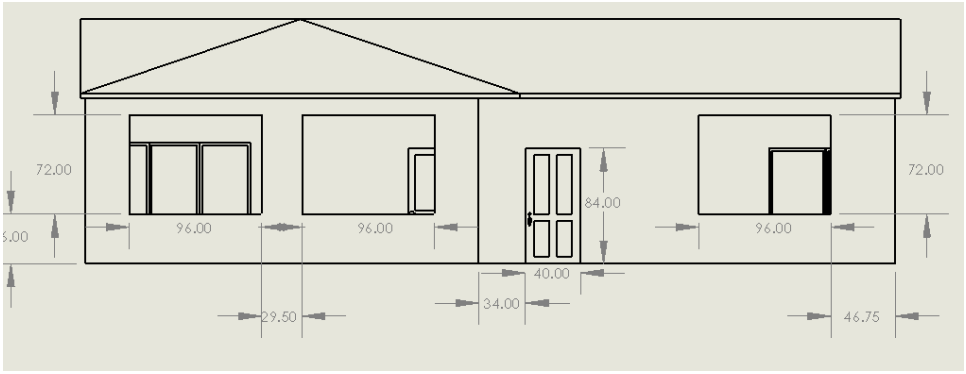


Figure 5 Front View Dimensioned

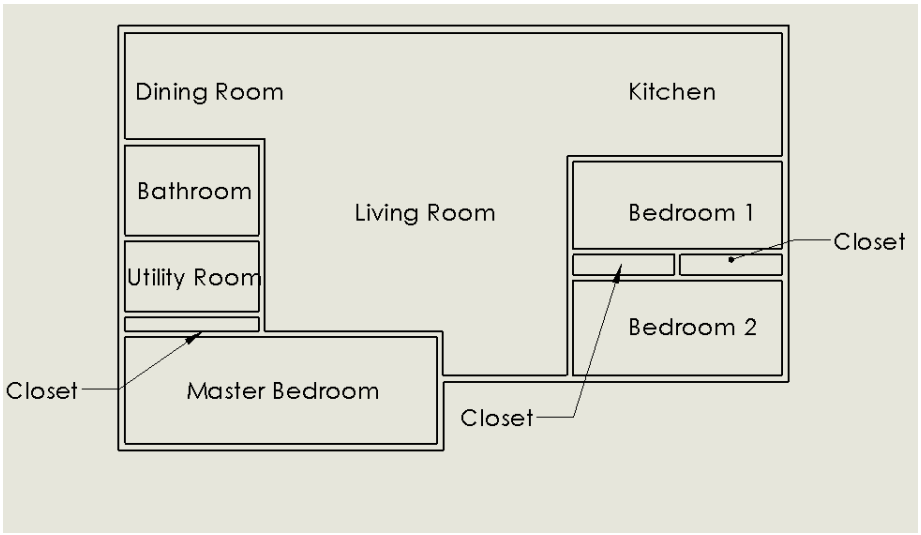


Figure 6 Labeled Floor Plan

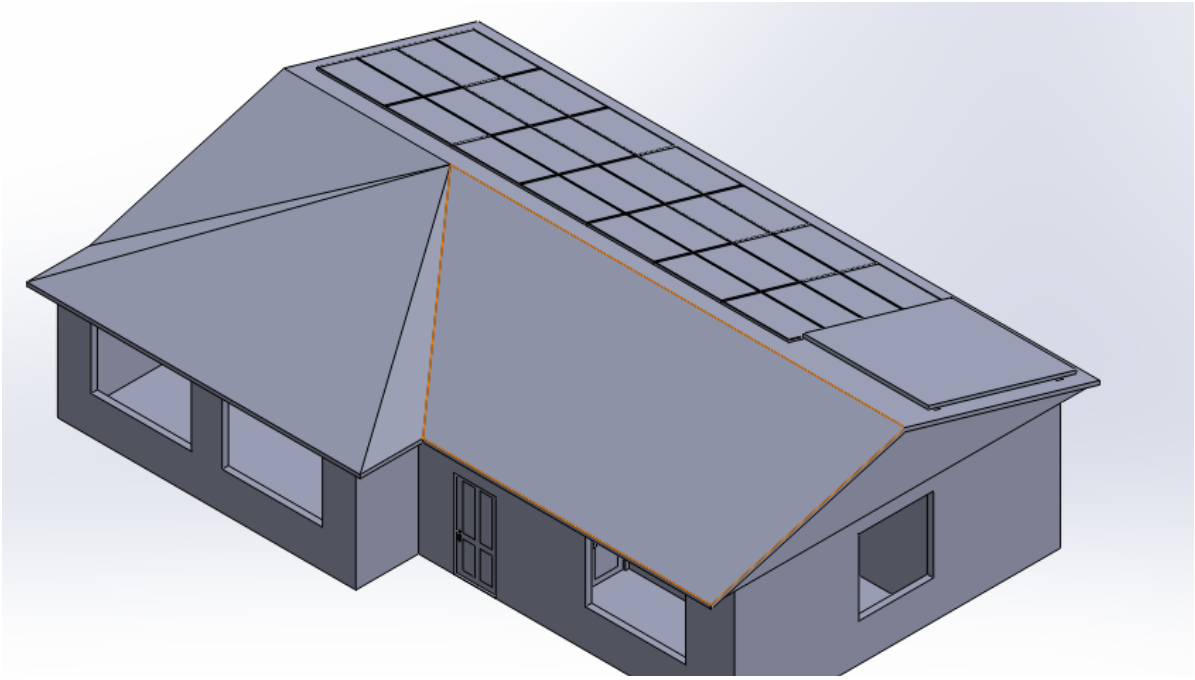


Figure 8 Front Isometric

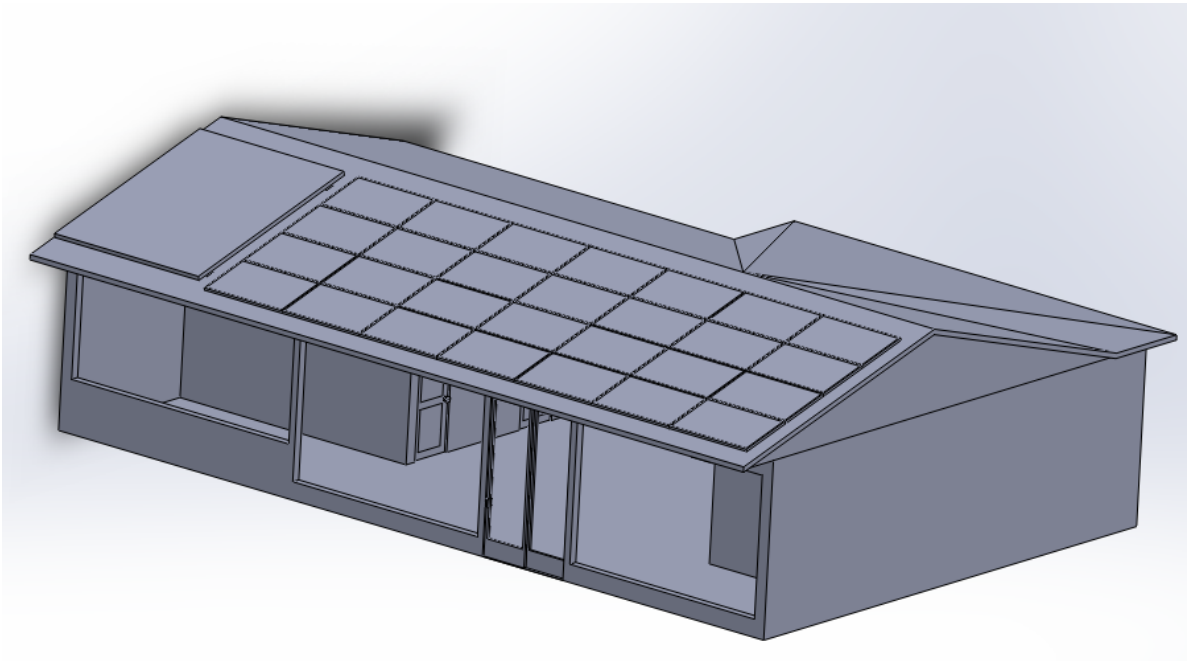


Figure 7 Rear Isometric

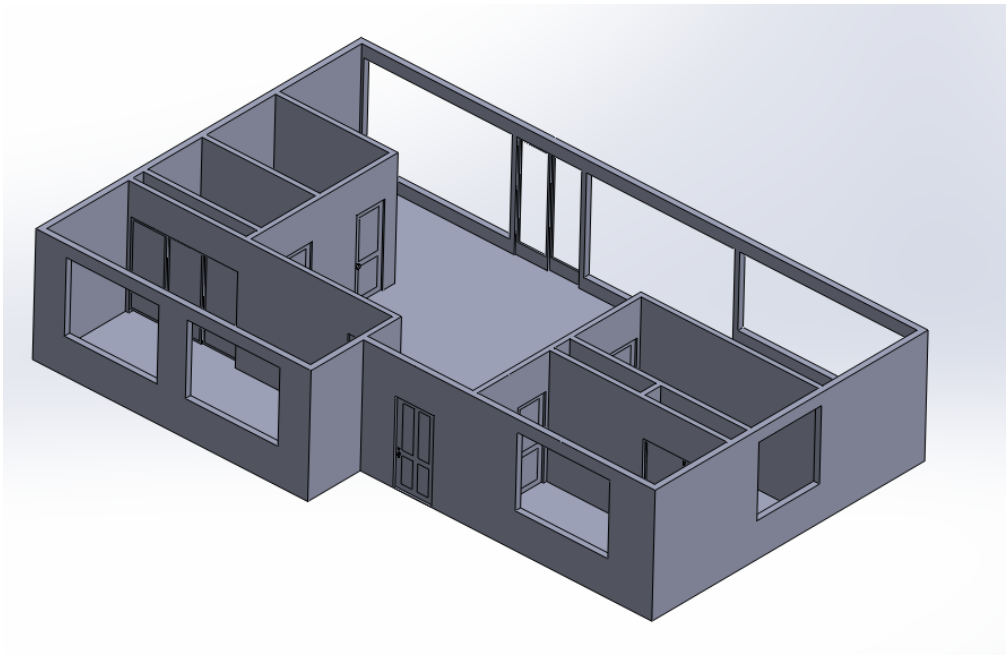


Figure 9 No Roof Isometric

Notes from the Final Design

The first step in this design was establishing an open, spacious floor plan that included enough rooms for a typical family. We specifically included a utility room to house the water tank, heat pump, laundry machines and usage meters so that these could be hidden from view and not compromise the interior aesthetics.

The slope of the roof (16°) was specifically designed to coincide with the optimum summer angle of the sun, for maximum photovoltaic generation. The length of the roof overhang was also specifically calculated using this summer solar angle; so that the sunlight would be virtually blocked from the windows and the home could be kept cool during summer months.

Since windows can be a source of heat loss as well as heat gain, they were kept to a minimum other than the south-facing wall.

The PV system and solar water heater collector are included on the image of the roof. These dimensions coincide with the actual models we chose, which will be seen later in the report.

Establishing Target Specifications

Assigning values to needs in using a Needs-Metrics Matrix.

Needs	Metrics	Photovoltaic System creates surplus energy	Ceilings insulated at R-values of 60	Walls insulated with R-value of 22 and 1" foam	Light gained from ambient sunlight	Solar water heating unit	Triple low-e glazed windows		Energy Star Appliances	Water conserving utilities installed	1300+ sq. ft. with minimal walls	Electric heat pump
		1	2	3	4	5	6	7	8	9	10	11
The home not only produces all of the energy it needs over a year, but also puts some excess into the grid	1	o	o	o			o			o		
The home demonstrates that solar-powered Zero Energy Homes can be made to work well in the Commonwealth.	2	o					o					
Meets the needs of a typical family of four.	3	o			o	o			o	o	o	o
The use of alternative energy sources does not hinder the common family lifestyle.	4				o	o			o	o	o	o
Residents have access to hot water.	5					o						
Residents have access to common electrical appliances.	6								o			
The use of alternative energy sources does not compromise safety, health, or comfort.	7					o			o	o		o
The home can produce energy year-round in the Pennsylvania climate.	8	o										
Little to no extra maintenance is required for the operation of energy sources.	9						o					
The home complies with local building codes and regulations.	10		o				o		o	o	o	
The design of the home will be aesthetically pleasing.	11			o			o		o		o	

Final Concept Selections

Heat Pump

As shown on page 7, the two main types of heat pumps are air-source and geothermal. With marketability and maintenance in mind, we researched the drawbacks of each type and ultimately decided that geothermal heat pumps can place constraints on geographic location, as well as run several risks if not properly maintained. Air-to-Air HRVs also improve indoor air quality and can be used in cooling.

Our chosen model is the **Infinity Series Heat Pump** by Carrier, which has high heating and cooling rating as well as a silencer.

Water Heater

Using the same selection criteria as before, we wanted a solar water heater that didn't burden the homeowners. Passive solar heaters require no input of electricity but significantly limit the design of the home. Direct solar heaters carry higher maintenance risks than indirect systems, so we chose an indirect active solar system.

Based on this criteria and efficiency ratings, we chose the **EnerWorks EWRA4-E120-1T**. The collector plate fits within our available roof area (after PV installation) and the efficiency ratings our very high. The tank volume can accommodate a family of four.

Photovoltaic System

We used the solar energy calculator shown in the next section to estimate how many kilowatts our design would need annually to sustain itself. This came out to be 5.2 kW to reach a net energy of zero. Using a comprehensive spreadsheet of commercially available PV models, and comparing their efficiencies, costs, areas, and number of panels needed, we pinpointed the **Sharp ND-235QCJ** as the ideal solar cell.

Cost per Panel	$325.95
Efficiency	24%
# of panels needed for 5 kW	23
Area of one panel	17.5 sq. ft
# of panels desired	28
Total area	491.1 sq. ft

Utilizing all roof space, we were able to fit enough panels for 6.4 kW to be generated.

For the inverter, which converts DC to AC current, we contacted an associate of PV Depot who recommended the **Sunnyboy SB7000 7kW** US inverter. This is well within our range of voltage.

Solar Energy Calculator

Zero Energy Home Calculator

Penn State Center for Sustainability

General Info

Location	Philadelphia
Electricity cost ($/kwh)	0.1
Conditioned floor area (sq.ft.)	1315
Number of bedrooms	3

Envelope Details

Wall construction	2x6 with R22 batt & 1" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1315
North wall area (gross) (sq.ft.)	336
East wall area (sq.ft.)	310
South wall area (sq.ft.)	133.9166667
West wall area (sq.ft.)	274.25
North window area (sq.ft.)	144
East window area (sq.ft.)	0
South window area (sq.ft.)	346.0833333
West window area (sq.ft.)	35.75
Air tightness	Tight with heat recovery

Appliances

Refrigerator	Energy Star
Clothes Washer	Energy Star
Dishwasher	Energy Star
Amount of other appliances	A lot less

Heating & Cooling

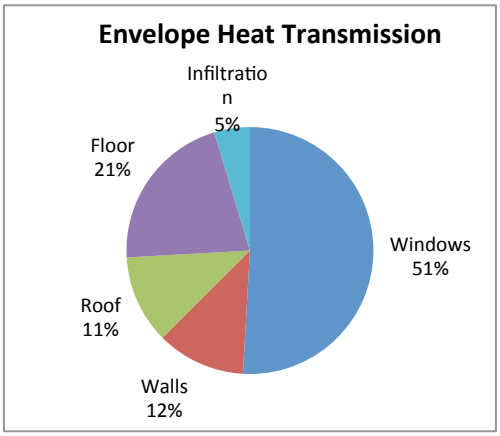
Type of heating & cooling system	Electric resistance

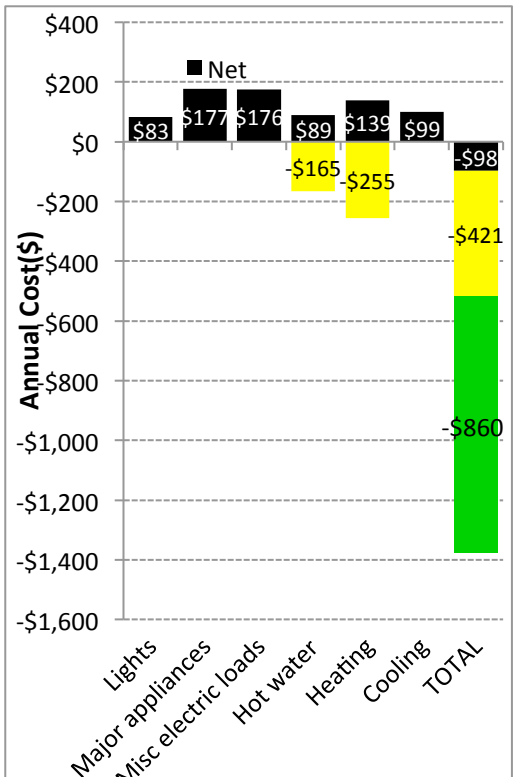
Solar Technologies

Size of PV system (kw)	6.4
Solar water heater	Yes

Behavior

Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	70
Cool thermostat setting (F)	76





We input all of the areas of our walls and windows, and based on given equations we were able to see the necessary photovoltaic output to create a net zero energy home. As shown, our larger cell area output leads us to becoming a plus energy home.

Conclusion

We effectively applied the design process to this project and generated concepts that met each and every need. What really set this project apart, though, was the push to find actual models of all of our concepts. Our design process transitioned from an idea to a reality as we calculated the actual values and needs of our energy consumption, and sought out commercially available models for each of our concepts. We effectively covered every aspect of a functional Zero-Energy Home with great detail. Collectively, we feel very satisfied with our design selection and are confident that his could be a functional home if it were to be constructed.

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