Zero Energy Home Project

EDSGN 100

Team 8 (aka Team N-Finite)

Submitted to Wallace Catanach

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Abstract

This design project focuses on the objective of creating a zero-energy home. Our home will be located in Pittsburgh, Pennsylvania. Research into this area yielded many positives aspects that could be beneficial to achieving our goal of a net zero-energy home. Based on this research as well as other external research into similar homes we decided on a single-story home utilizing the sun as our primary renewable source of energy. This home is aesthetically as well as innovative in its design.

Introduction

A Zero Energy Home is by definition a building with zero net energy consumption and zero carbon emissions. A zero energy home makes as much energy as it consumes. Building a ZEH can be more expensive, but long-term the amount of money saved will be much more. This will significantly decrease the net monthly cost of living.

To achieve the zero energy consumption, the house is built in an orientation in which it will get as much energy from the Sun as it can. The floor, walls, and ceiling are built with materials that will conserve as much energy inside the house as possible. The water used by the house is heated by a solar system or a geothermal system rather than gas.

These types of homes will increase its popularity in the future when other energy sources such as fossil fuels become more scarce, and therefore more expensive.

Mission Statement

The need for Zero Energy homes is rising due to the fact that non-renewable energy are becoming more scarce.

Our goal is to design a house that is self-sustainable, and require little or no non-renewable energy.

Our vision is that as houses like the one we design are built, the world will become more green, people will become more self-dependent, and we will greatly reduce are carbon footprint.

Analysis of Customer Needs

Needs Statements

-House needs to be located in north/east of US, specifically Pennsylvania.

-House needs to be sef-sustainable and enviornment-friendly

-House should produce enough energy for customer's uses through "green" technology

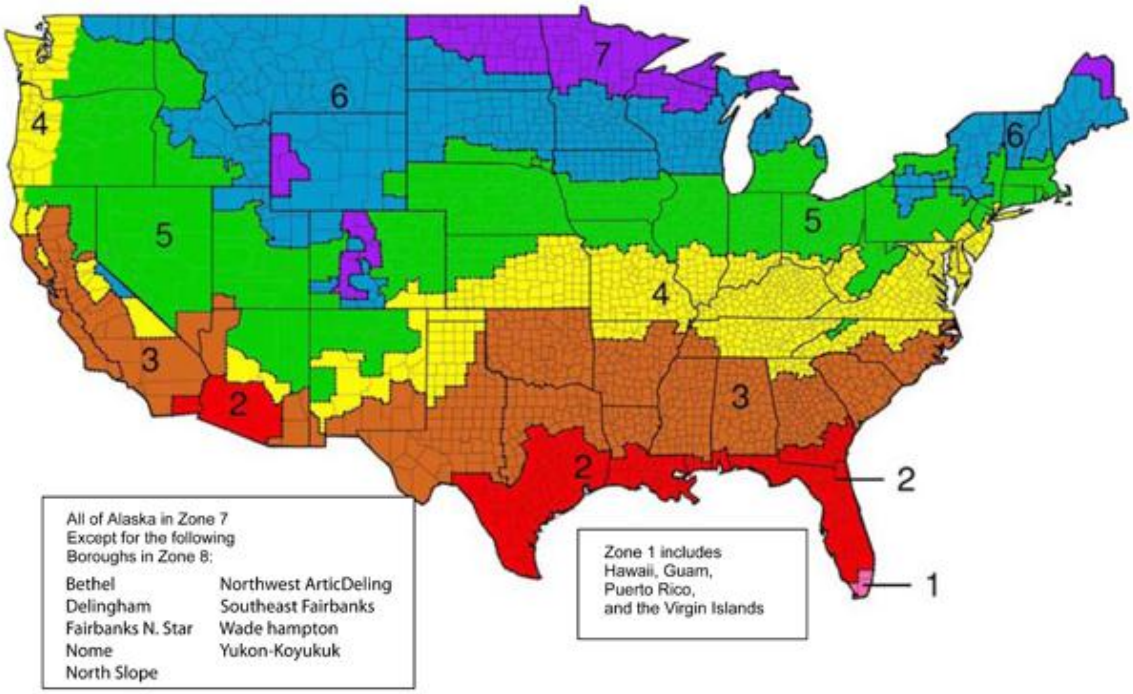
-House needs to be fitting for family of four

-House should be physically attractive

-Roof overhang of the house needs to block sunlight during summer, and allow sunlight in to house during winter

Selecting a Location:

If you look on the next page, you will see a map of the united states and the corresponding R values for each zone in the country. We are looking to build a house with relatively high insulation values and so we decided to choose the ***Pittsburgh*** area. The values for Pittsburg include: R13 - R 15 for the wall cavity, R2.5-R5 for the insulation sheathing. R25-R30 for the floors. Our design will not have an attic.



Insulation Recommendations for New Wood-Framed Houses

Zone	Heating System	Attic	Cathedral Ceiling	Wall		Floor
				Cavity	Insulation Sheathing	
1	All	R30 to R49	R22 to R38	R13 to R15	None	R13
2	Gas, oil, heat pump	R30 to R60	R22 to R38	R13 to R15	None	R13
	Electric Furnace					R19-R25
3	Gas, oil, heat pump	R30 to R60	R22 to R38	R13 to R15	None	R25
	Electric Furnace				R2.5 to R5	
4	Gas, oil, heat pump	R38 to R60	R30 to R38	R13 to R15	R2.5 to R5	R25-R30
	Electric Furnace				R5 to R6	
5	Gas, oil, heat pump	R38 to R60	R30 to R38	R13 to R15	R2.5 to R5	R25-R30
	Electric Furnace		R30 to R60	R13 to R21	R5 to R6	
6	All	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30
7	All	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30
8	All	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30

Insulation Recommendations for Existing Wood-Framed Houses

Zone	Add Insulation to Attic		Floor
	Uninsulated Attic	Existing 3-4 Inches of Insulation	
1	R30 to R49	R25 to R30	R13
2	R30 to R60	R25 to R38	R13 to R19
3	R30 to R60	R25 to R38	R19 to R25
4	R38 to R60	R38	R25 to R30
5 to 8	R49 to R60	R38 to R49	R25 to R30

Wall Insulation: ***Whenever exterior siding is removed*** on an
Uninsulated wood-frame wall:

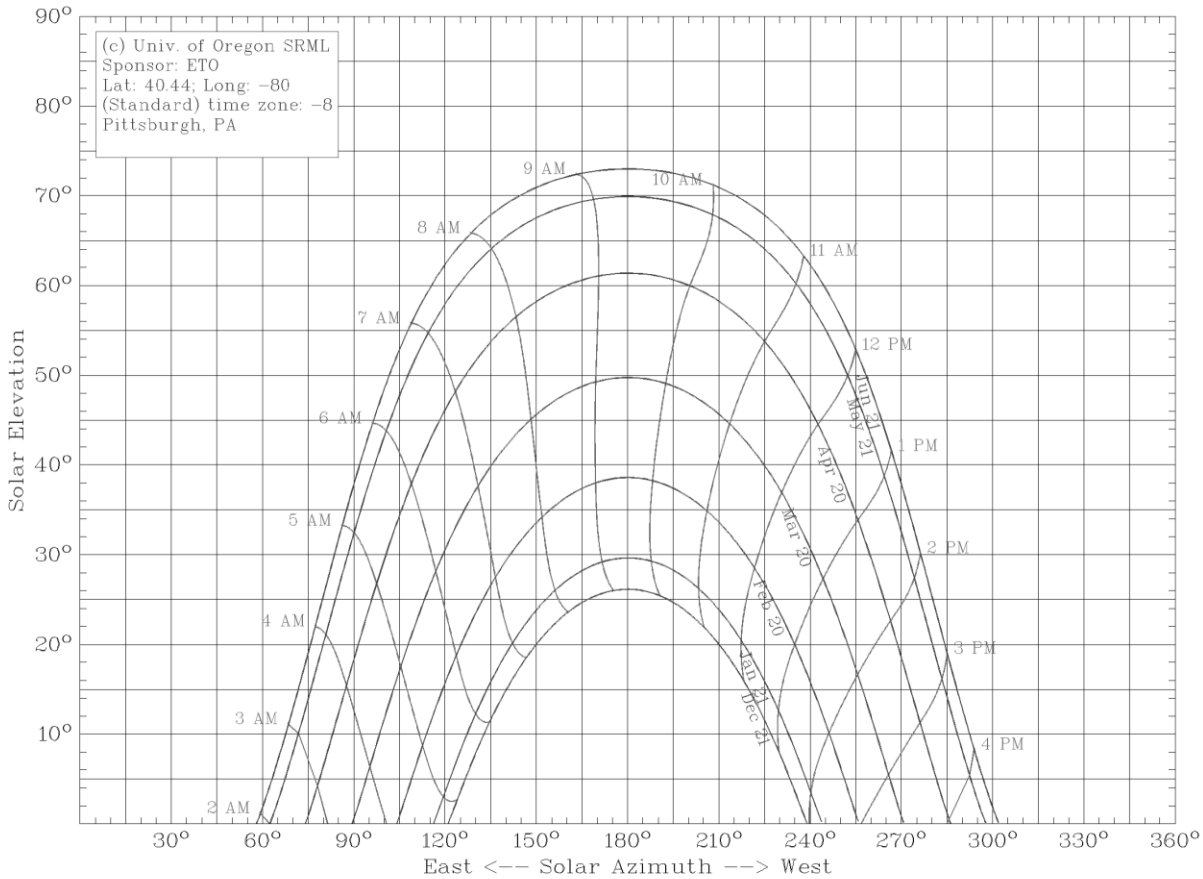
- Drill holes in the sheathing and blow insulation into the empty wall cavity before installing the new siding, and
- Zones 3-4: Add R5 insulative wall sheathing beneath the new siding
- Zones 5-8: Add R5 to R6 insulative wall sheathing beneath the new siding.

Insulated wood-frame wall:

- For Zones 4 to 8: Add R5 insulative sheathing before installing the new siding.

Background Information on City/Area

-Pittsburgh's temperature oscillates between 20 and 53 degrees in the winter and 41 to 85 in the summer
- Average electricity cost of 16 cents per kilowatt hour
- Water Cost: minimum rate: Residential $8.48 per 1,000 gallons of water



-Average Precipitation 37.85 inches per year

- Shortest Day 9 hours 17minutes

- Longest Day 15 hours 14 minutes

Establish Target Specifications

Product Specifications and Matrix

From the research of other ZEH from the Pennsylvania area, it can be concluded that spray foam is a good material for insulation for the walls and the ceiling of the house. The average cost of the material is around $1 sqf.

The light bulbs should be LED due to its durability and efficiency. The average life span of LED light bulbs is of 50,000 hours and requires 6-8 watts.

External Research

-Standard houses consume 40% of fossil fuel energy in the US and EU, and are one of the major contributors of greenhouse gases.

-One of the designs to overcome this problem is Zero-energy house.

-Zero-energy house is a house designed for zero net energy consumption and zero carbon emissions.

-With ability to reduce carbon emissions and independent from non-renewable energy source zero energy houses are beginning to be recognized as design that can create sustainable world in near future Zero energy house can be free from non-renewable energy source with green technologies: solar panel, wind turbine, and geothermal heater. While these technologies depend on location of the house, zero energy house still can be designed with other technologies, such as wall-insulation or advanced window, which doesn't depend on location.

-Zero energy houses are also beneficial economically. With the right location and technology, consumer benefits from tax reduction, near-zero electricity and gas bill. With long-term benefits in mind, consumer can gain economically while making world stable.

Benchmarking

As the research showed, when building a Zero Energy Home, efficiency is key.

The house showed below is located in Ann Arbor, Michigan. This example is relevant, because the weather of Ann Arbor is very similar to the weather in Pittsburgh. The house is 1,300 sqf. It consists of 3 bedrooms and 2 bathrooms. This project focused on insulating the house as much as possible to avoid heat loss. Besides all of the light bulbs in the house are LED's.

Number of floors	2
Number of occupants	4
Number of bedrooms	3
Type of Heating system	3-ton Water Furnace envision
Size of photovoltaic system (kW)	House oriented south at a 45 ° angle to increase PV efficiency
Solar Water Heater (yes or no)	yes
R-value of wall insulation	R-13 dense packed insulation
R-value of ceiling insulation	R-30
Ventilation heat recovery	yes
Other info	Awarded USA Today's Best Green Homes of 2010

Location (city, state)	Seattle WA
House size (floor area in square feet)	1915 sqft
Number of floors	2
URL of web site where info is found	http://www.greenbuildingadvisor.com/homes/net-zero-energy-house-125-square-foot
Number of occupants	4
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Hydronic radiant floor, space heat distribution
Main heating fuel (electricity, natural gas, wood, oil, etc.)	electricity
Size of photovoltaic system (kilowatts)	28 Solar World PV modules. 230 kW each. 6440 kW total
Solar water heater (yes or no)	no
R-value of wall insulation	R-26 including siding and drywall
R-value of ceiling insulation	R-42
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	6,064 kWh
Any other pertinent info	Energy produced a year 7,903 kWh South window orientation Finished January 7, 2013

Location (city, state)	Toronto, Canada
House size (floor area in square feet)	3,000 sq-ft
Number of floors	3
URL of web site where info is found	http://www.housingzone.com/business-management/zero-energy-home
Number of occupants	2
Number of bedrooms	2
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	"Both a solar photovoltaic system and a solar thermal system in the design of the house"
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	7.2 kw
Solar water heater (yes or no)	Yes
R-value of wall insulation	R-33
R-value of ceiling insulation	-
Ventilation air heat recovery (yes or no)	Yes

Predicted or measured annual energy use	"Even though this is a year of tweaking—the initial inefficiencies created a greater draw from the grid and required much more energy than would otherwise be required—we still expect the house to achieve NZE this year"
Any other pertinent info	"HRV was not properly balanced, which went unnoticed for almost two months" "The PV system's panels are known for their high efficiency. On two cold, very sunny days—when they reached their maximum efficiency—they blew a fuse"
Location (city, state)	Perkiomenville, PA
House size (floor area in square feet)	2016 Sq. Ft
Number of floors	3
URL of web site where info is found	http://ebookbrowse.com/jackie-oneil-pdf-assetguid-bff6a671-f992-4667-b1d14c0a36e28e18-pdf-d85981066
Number of occupants	3-5
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Geothermal heating system
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	5.25 kw
Solar water heater (yes or no)	Yes
R-value of wall insulation	-
R-value of ceiling insulation	-
Ventilation air heat recovery (yes or no)	Yes
Predicted or measured annual energy use	2,911 kWh generated to 2,845 kWh consumed
Any other pertinent info	gas for a cook top & fireplace

Location (city, state)	Pittsburg, PA
House size (floor area in square feet)	1850
Number of floors	3
URL of web site where info is found	See below
Number of occupants	4
Number of bedrooms	2
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricty
Size of photovoltaic system (kilowatts)	8,000
Solar water heater (yes or no)	No
R-value of wall insulation	R-40
R-value of ceiling insulation	R-40
Ventilation air heat recovery (yes or no)	No
Predicted or measured annual energy use	
Any other pertinent info	Through the EnergyStar HERS rating system, a score of 100 means a home meets energy requirements ... An 85 gets a home EnergyStar status." The net-zero house weighs in at minus 4.

Location (city, state)	Boston, Massachusetts
House size (floor area in square feet)	1,000
Number of floors	1
URL of web site where info is found	http://4dhome.us/
Number of occupants	4
Number of bedrooms	2
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	Peak Power (+5/-3%) Pmax 238 W
Solar water heater (yes or no)	Yes
R-value of wall insulation	R-56
R-value of ceiling insulation	R-64
Ventilation air heat recovery (yes or no)	Yes
Predicted or measured annual energy use	
Any other pertinent info	Innovative moveable and adaptable features throughout. Also uses passive house design.

Product Dissection

Solar Panels

Durability:

-Lasts more than 30 yrs

-Tempered glass :designed to withstand impact of hail up to 1inch in diameter (travelling at 50 mph)

Maintenance

-Requires very little since there are no moving parts

-Inspection is needed for dirt/debris few times a year

-To clean, using garden hose is fine, however spraying water on how panel may crack them

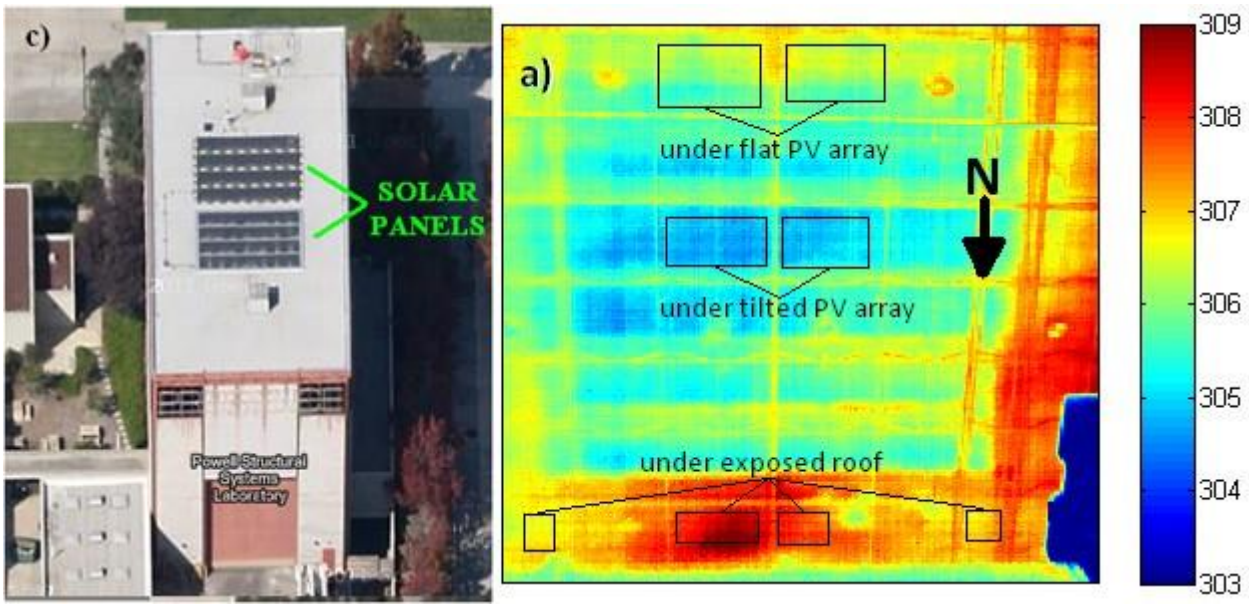
-There are automatic cleaners available as well, suitable for desert area etc.

Installation

-Expert's installation highly recommended

Insulation

-Blocks sunlight



Cost per year

-Close to $0 electricity bill for sunny areas

-Normally cost $25,000 but can be saved up to $14,000

30% Federal Tax Credit (there may also be state/local incentive which can save about $5,000)

Ease of use

-Controller is provided to regulate the flow of electricity

Small Scale wind turbine (15-50 meter)

Durability

-Up to 20-30 years

Maintanence

-Maintanence once/twice a year

Installation

-Expert's installation required

Insulation

-None

Cost/Saving

-Roof-mounted 1kW microwind system costs around $3,000

-2.5kW pole-mounted system costs around $23,000

-6kW pole-mounted system costs around $35,000

-Well sited 6kW turbine can generate 10,000kWh

Ease of Use

-Built-in control and inverter

Geothermal heating

Durability

-Last up to 25-50 years

Maintanence

-Mechnical components are underground, therefore sheltered from enviornment

anti-freeze is required

Installation

-Expert's installation required

Insulation

-Great for both summer and winter:

During summer, heat is taken from house to earth

During winter, vice versa

Cost/Saving

-Varies because of how much drilling depends on location

-In Pennsylvania, avg cost is $7,000

Cost Model:

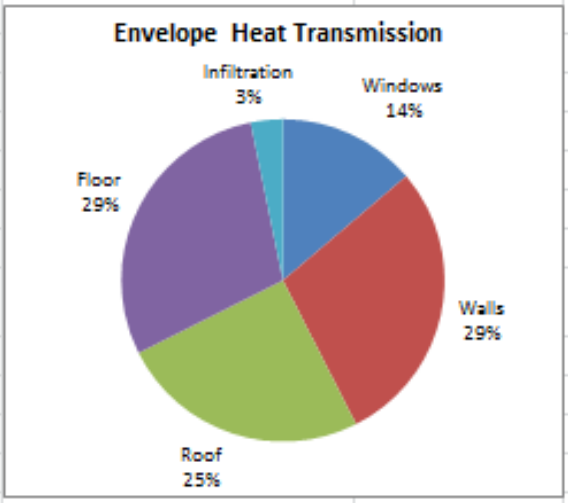
State Center for Sustainability

General Info	
Location	Pittsburgh
Electricity cost ($/kwh)	0.1
House type	1 story
Conditioned floor area (sq.ft.)	600
Number of bedrooms	2
Envelope Details	
Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R40
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1199.74
North wall area (gross) (sq.ft.)	480
East wall area (sq.ft.)	240
South wall area (sq.ft.)	480
West wall area (sq.ft.)	320
North window area (sq.ft.)	0
East window area (sq.ft.)	20
South window area (sq.ft.)	65
West window area (sq.ft.)	20
Air tightness	Tight with heat recovery
Appliances	
Refrigerator	Energy Star
Clothes Washer	Energy Star
Dishwasher	Best
Small Appliance Input	
Extras	
Garage	a. None
Hot Tub	a. None
Pool	a. None

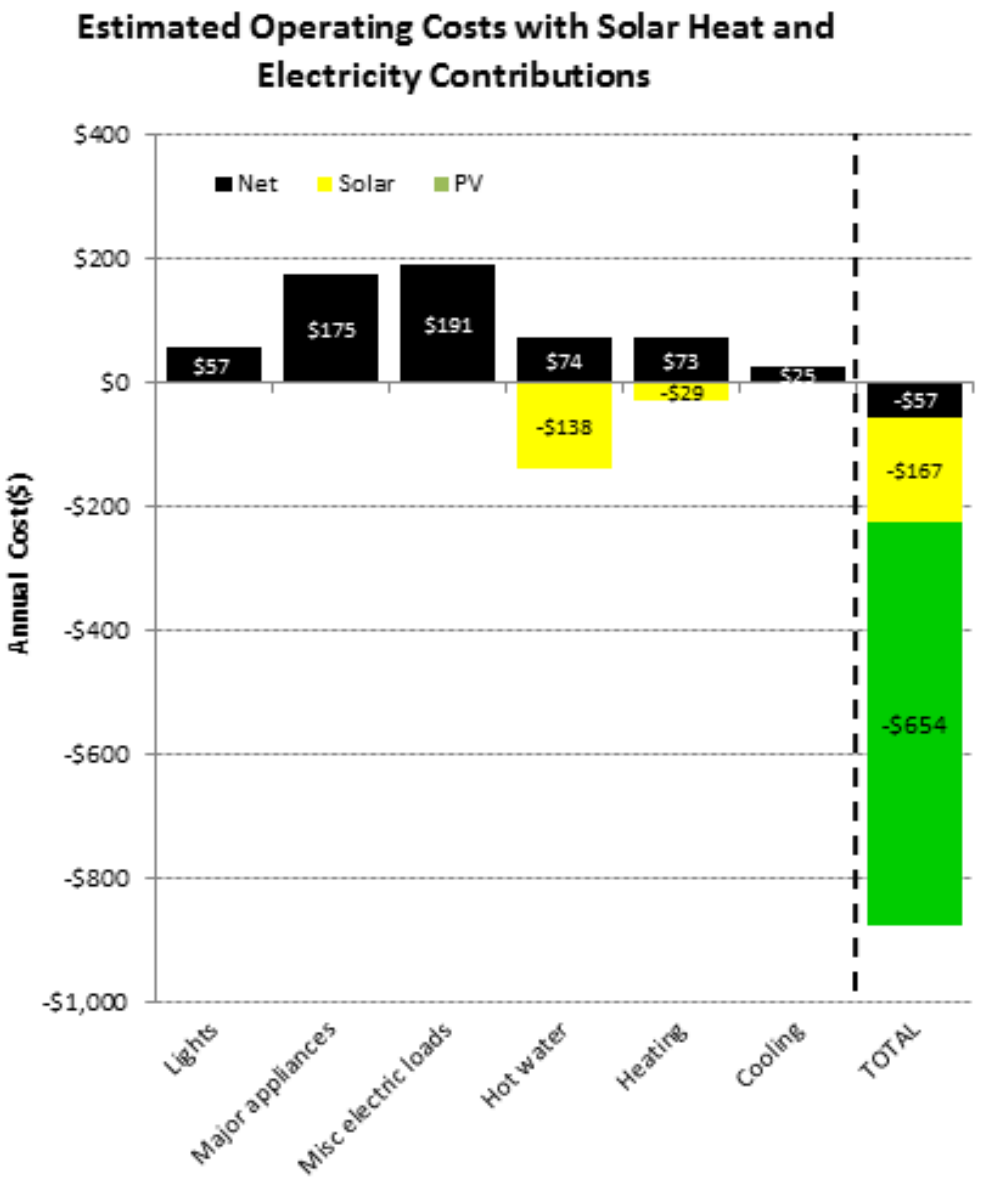
Zero Energy Home Calculator

Heating & Cooling	
Type of heating & cooling system	Electric geothermal heat pump
Solar Technologies	
Size of PV system (kw)	5.33
Solar water heater	Yes
Behavior	
Water conservation	A lot
Uses clothesline	Some
Thermostat setback	Some
Heat thermostat setting (F)	73
Cool thermostat setting (F)	70

Results



Base House Cost	$	93,129
PV Cost	$	26,650
Upgrade Costs	$	17,463
Total House Cost	$	137,241



Global Marketplace

Number of zero energy house is increasing throughout the world. With Europe in the lead, many countries, which ranges from Malaysia to China, are becoming more progressive on building zero energy houses. Recently, it is announced that European Union will require near-zero energy public buildings by 2019 and in all new construction by 2021. U.S. and Japan are said to process similar requirement. Worldwidee revenue from the zero energy market is projected to reach $690 billion by 2020 and $1.3 trillion by 2035. With compound annual growth rate predicted to be 43%, zero-energy houses are beginning to be recognized as a way to obtain sustainable world.

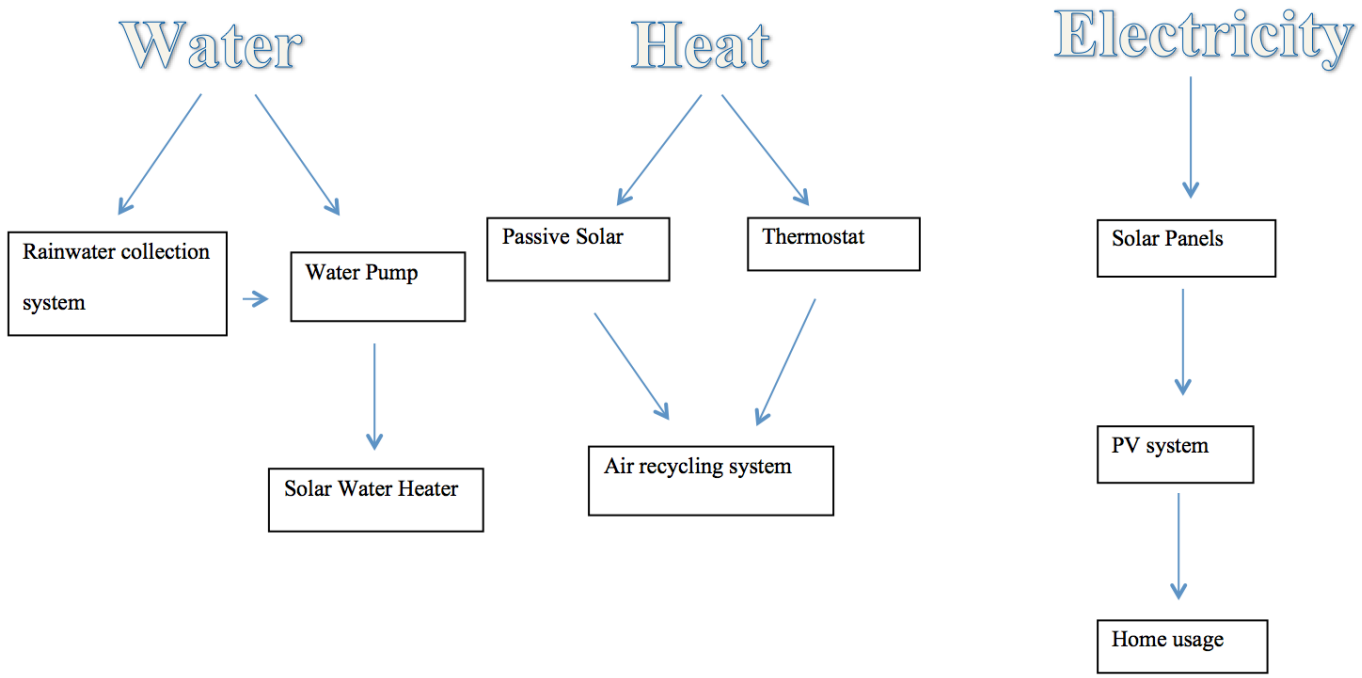
Concept Generation

Clarifying the Problem

The problems that need to be solved are:

- Insulate the floor, walls, windows and ceilings in a manner that the amount of heat/coolness is as least as possible.
- Find the best insulators possible which match the budget.
- Use technologies that consume the least amount of energy possible. (From refrigerators to lightbulbs)
- Provide energy to the house using autosufficient energy sources.
- Solar panels are not very efficient and have a high cost.
- Finding the most efficient angles for the solar panels, so they become as effective as possible all year round.
- Heat water without using a traditional gas boiler.
- Make the house aesthetically pleasing.
- Create as much energy as it is consumed.

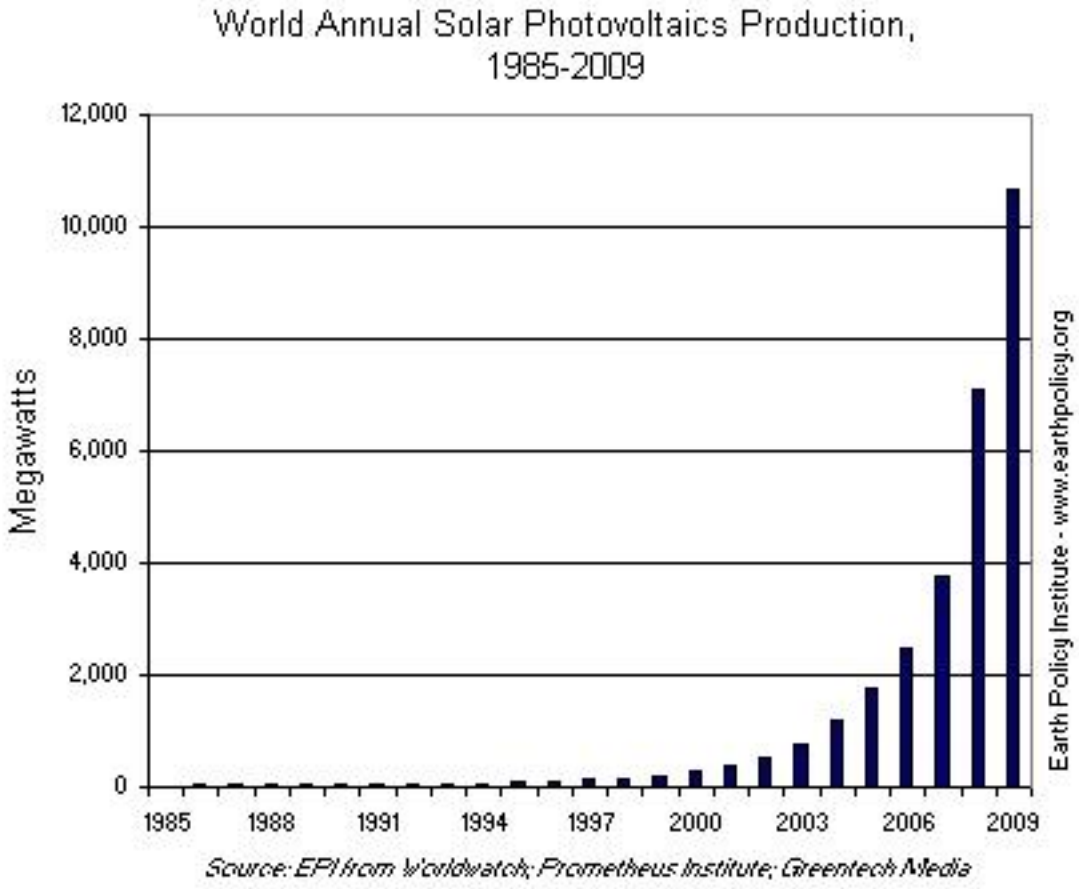
Functional Diagram



Concept Selection

Prepare the Selection Matrix

Currently the most efficient solar panels are the Photovoltaic Monocrystaline Cells. Sanyo Electric produces the most efficient system created so far with a 17.24% efficiency per area.

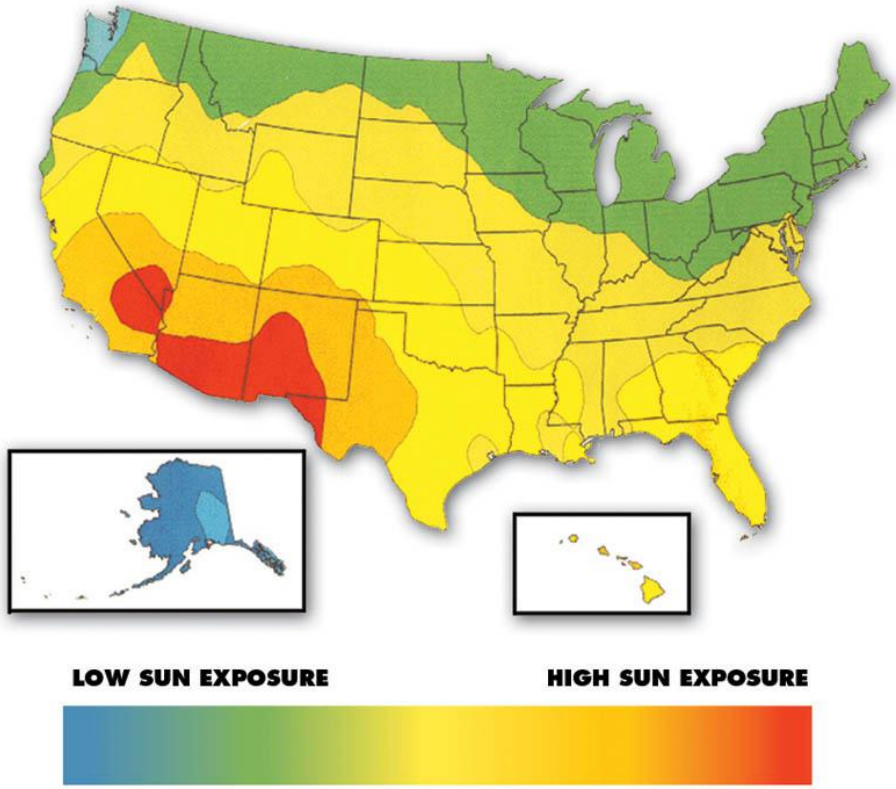


Manufacturer	ID	STC	Density	Eff.	Tier
Sanyo Electric	HIP-200BA19	200	**14.89**	17.24%	**1**
SunPower	SPR-200-WHT-U	200	**13.55**	16.08%	**1**
Canadian Solar	CS5A-200M	200	**13.29**	15.66%	**2**
Suntech Power	PLUTO200-Ada	200	**13.28**	15.66%	**2**
Trina Solar	TSM-200DA01A	200	**13.12**	15.64%	**2**
Kyocera Solar	KC200GT	200	**12.03**	14.74%	**3**
Schuco USA	SPV 200 SMAU-1	200	**11.82**	14.21%	**3**
BP Solar	SX3200B	200	**11.52**	14.17%	**3**
Yingli Green Energy	YL200P-26b	200	**11.26**	13.65%	**4**
ET Solar Industry	ET-P654200	200	**11.18**	13.61%	**4**
Evergreen Solar	ES-200-RL	200	**10.69**	13.40%	**4**
Sharp	ND-200U1	200	**9.86**	12.27%	**5**

Product Decision

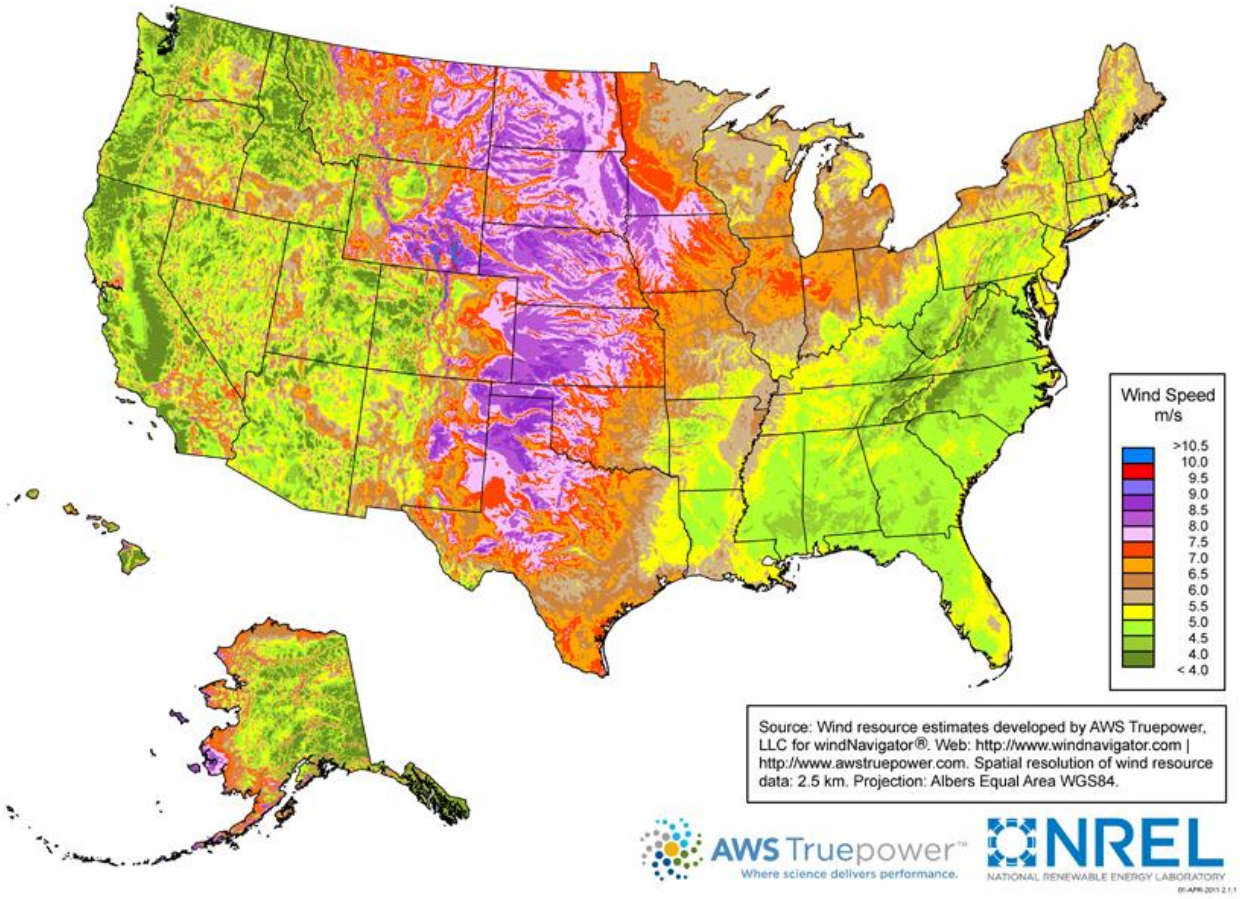
<u>Solar Panels</u>

Solar panels are a very useful way to produce energy. Although there is not a great amount of sun exposure, as seen in the diagram below, we will still be implementing the solar panels into our design. Pittsburg may not receive too much sun, but according to city research, there is enough sunlight to be offset the darker days when we lose energy.



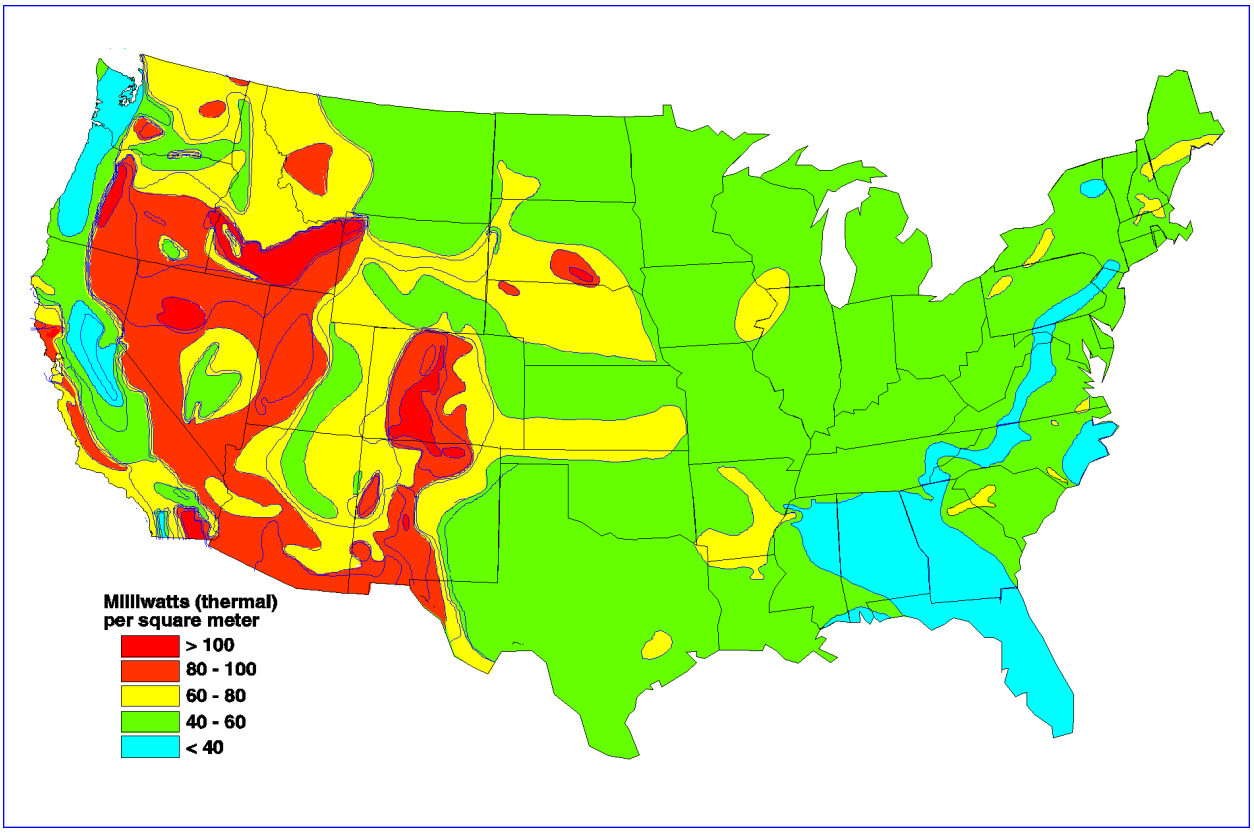
Small Scale wind turbine (15-50 meter)

Although an interesting concept for a zero-energy home, small scale wind turbines will not help in our area (see below). The wind speed is simply not high enough to produce the needed results.



Geothermal heating

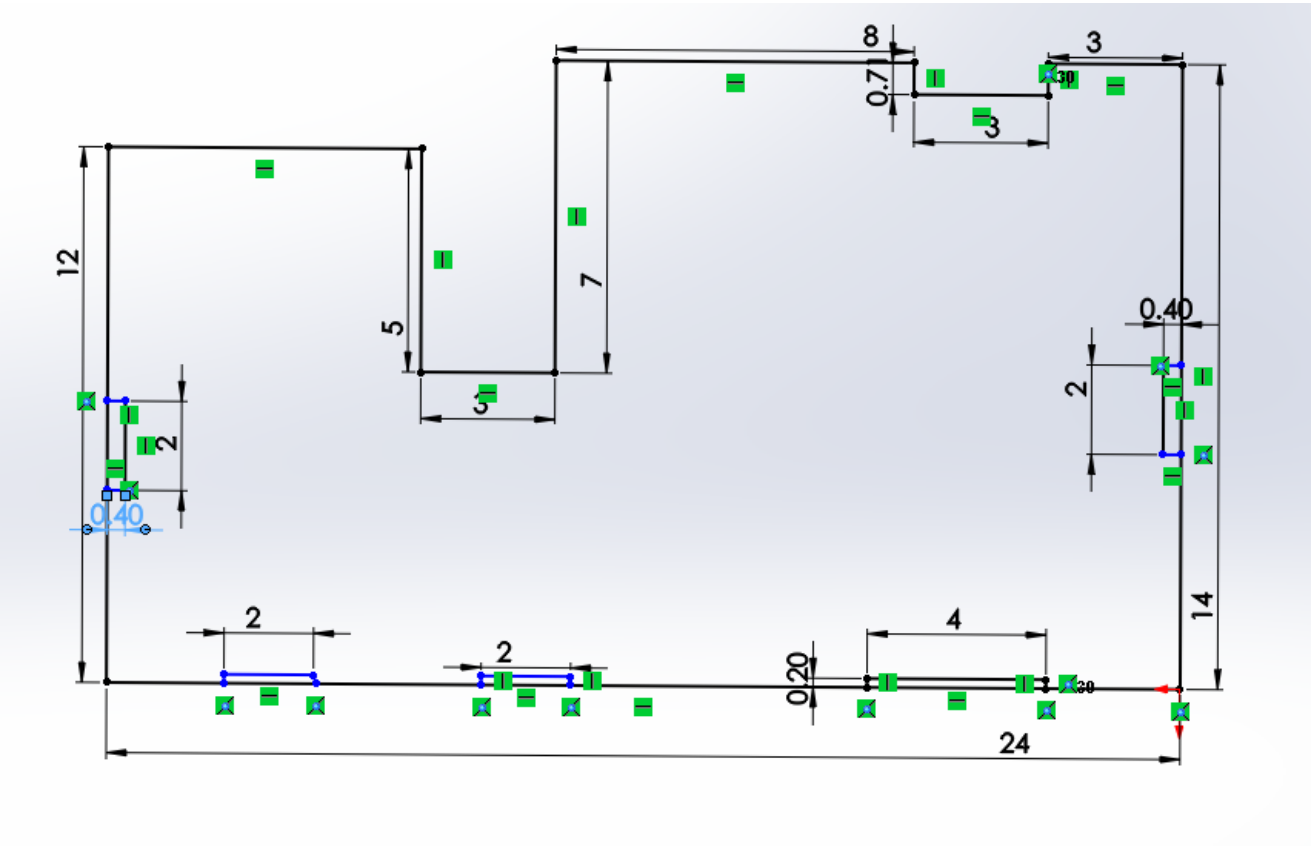
As you can see, geothermal heating is not efficient in our PA area, however the need results are still produced and we will incorporate it into our design.



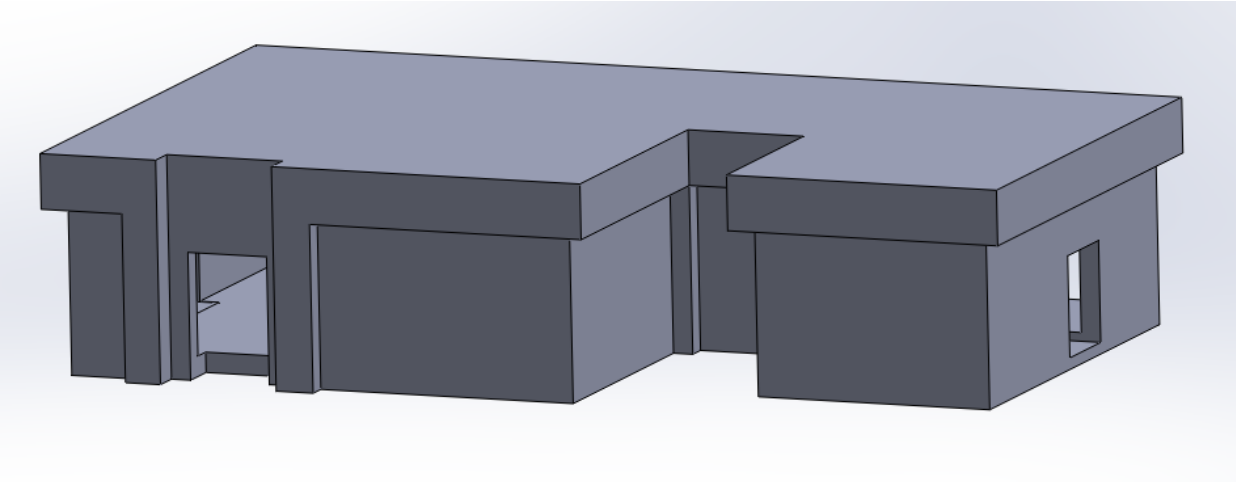
Select one or more Concepts

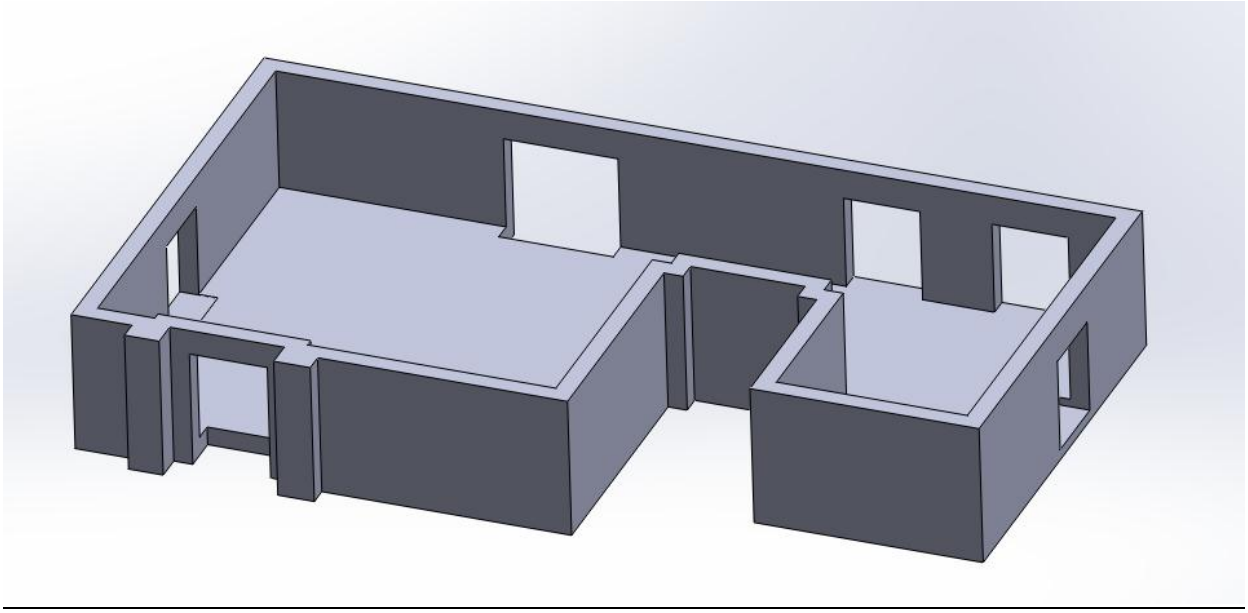
The areas of the house are crucial. The size of the roof is important because it determines the number of solar panels the house can have. On the other hand the size of the windows determine the amount of sunlight that comes into the house. The problem is that just as energy comes easier through windows it can leave just as easliy. Besides if the area of windows is too big the house would be too hot in the summertime, making it an unpleasant place to be in. Also the orientation of the windows is of great importance. If the windows don't recieve direct sunlight, the amount of energy that leaves the house will be bigger than the amount that gets in. Our house will feature the following concepts:

Design:



Units in Diagram: CM Scale: 1 cm= 2ft





Not included in CAD drawing:

-Solar panels on roof

-Stairs outside in front of house that lead up to the roof for a garden/solar panels.

-Wooden overhang on top sides of house (see image below)

We based the roof on our house on the following design because of the potential solar energy it allows for use in the house. The shape of the roof allows plants to be grown in the harsh spring and summer of Pittsburgh to block out the majority of sun. In the colder fall and winter the plants will die and allow direct sun to enter through the roof and add heat and light throughout the winter months.

Conclusion:

We achieved a zero-energy home through innovative design and use of renewable sources. Our design of utilizing skylights as both a heat and light source drastically reduces our energy intake and allows the house to net-zero in energy use. They also make the house more aesthetically pleasing. Solar energy is a reliable, renewable source for heat and electricity that also helps to create a net-zero house. We also used efficient appliances, and energy conservation tactics to achieve our goal.

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