Zero Energy Home Project

Team No Name
Chris Chesko Rachel Perini, Elaina Ripepi, Kayleigh Tinjar

Pennsylvania State University
College of Engineering
EDSGN 100: Fall 2012
Wallace Catanach

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Introduction

A zero energy home is more specifically referred to as a net zero energy home. The term "net zero" refers to the idea that the total energy consumed and produced by the home totals to zero. A zero energy home utilizes green technology, renewable resources, and innovative design features to effectively save energy. A zero energy home strives to create enough energy to make up for the amount lost. Many aspects must be taken into consideration when creating an effective design. Details such as location, cost, and availability are important concerns when completing such a project. Although creating a zero energy home requires a sufficient amount of research and work, many benefits reside. Benefits not only include saving energy but extend to creating a healthier, more cost-efficient, toxin-free environment. With an increased interest in "going green" in our society, net zero energy homes prove to be a huge step towards helping the environment.

Mission

As students in the College of Engineering at Pennsylvania State University, it is our mission to challenge ourselves through projects such as creating a net zero energy home. Our goal is to design an environmentally friendly, energy-saving home with a desirable visual appeal. After completing a respectable amount of research, our team's objective is to use an effective design process to construct a net zero energy home that meets our customer's needs.

Abstract

Our team, Team No Name, was given the task of building a net zero energy home as a challenge. We were introduced to important topics in class regarding the requirements, possible resources, and construction techniques for our home. We also learned about the design processes. The design process helped us effectively tackle the challenge given to us. First, our team had to consider the customer needs. Taking the customers wants into consideration; we developed a list of components that we needed to include in our home. We then selected and researched a specific location for the home based off of the customer's requirements. We also did additional external research regarding other's opinions on energy efficiency and on other previously built zero energy homes. Our research helped us to develop our own set requirements. Next, more in depth research was conducted in order to compare the requirements we had created with existing components of well-designed zero energy homes. We were then able to clarify the problem at hand and produce diagrams to aide us in understanding these obstacles in detail. We found that we needed more research. The new research helped us to rank and decide on our final specifications of our home. We included energy saving features such as solar panels, energy star appliances, an open floor plan, correct R-values for the walls and ceilings, and an air-tight structure. Finally, after designing a floor plan, we created both a 3D Solid Works model and physical model to display our final product. With the knowledge gained in class and applying hard work, our team was able to complete the challenge given to us, designing an effective zero energy home.

Customer Requirements

- Design a net zero energy home in Pennsylvania
- Design the home so it accommodates a family of four
- Build the house using green principles and design features
- Make the house aesthetically appealing
- Create a design that benefits the community's welfare
- Practice sustainability, preparing for future generations
- Use solar energy and other valuable renewable resources
- Produce enough energy to power an electric car

Customer Needs Statements

Needs Statements	
Customer Statements	**Needs Statements**
The home meets the needs of a typical family of four.	The home is built for a family of four with 3 bedrooms and 2 bathrooms
The home demonstrates that solar-powered Zero Energy Homes can be made to work well in the Commonwealth.	The ZEH is built in Pennsylvania.
	The ZEH withstands the elements of Pennsylvania weather and uses the local resources.
	The ZEH uses solar panels.
The home not only produces all of the energy it needs over a year, but also enough to charge an electric car, and still put some excess into the grid.	The ZEH produces more energy than it will use in a year.
	The ZEH accommodates an electric car.
The home is made as sustainable as possible using green building principles.	The ZEH will use green building principles for maximum sustainability and efficiancy.
	The ZEH will utilize energy efficient appliances.
The home is aesthetically pleasing.	The home will be attractive in terms of appearance and location
The home improves the health and welfare of the community	The ZEH will be environmentally friendly

Project Timelime

				9/03/2012					10-Sep					17-Sep					24-Sep					1-Oct					8-Oct				
				M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F
ID	**Tasks**	Owner(s)	% compl																														
1	**Analysis of Customer Needs**	All																															
2	Customer Requirements	Chris		X		R																											
3	Selecting City/Location	Elaina				K																											
4	Background Information on City/Area	Kayleigh				K																											
5	Renewable Energy Source Survey	Rachel				E																											
6	Other Surveys					E																											
7	Research of ZEH					C																											
8	Needs Statements					R																											
9	Review					A												X															
10	**Establish Target Specifications**																																
11	Product Spec Metrics & Matrix										R																						
12	Set target specifications										A																						
13	**Benchmarking**																																
14	a. Existing structures										K																						
15	b. Existing renewable energy sources										C																						
16	Develop a cost model										A																						
17	Review										A							X															
18	**Concept Generation**																																
19	Clarify the problem															E																	
20	Develop a functional diagram															K																	
21	**External search**																																
22	a. Literature Review															K																	
23	b. Patent Search															K																	
24	Brainstorming															A																	
25	Review															A							X										
26	**Concept Selection (Iterate as required)**																																
27	**Concept screening**																																
28	Prepare the selection matrix																				R												
29	Rate the concepts																				A												
30	Rank the concepts																				A												
31	Combine and improve the concepts																				A												
32	Select one or more concepts																				A												
33	Review																				A						X						
34	**Concept scoring**																																
35	Prepare the selection matrix																									R							
36	Rate the concepts																									A							
37	Rank the concepts																									A							
38	Combine and improve the concepts																									A							
39	Select one or more concepts																									A							
40	Review																									A		X					
41	**Establish Final Specifications**																																
42	Maintenance Reqiurements																														A		
43	Examination of Manufacturing Processes																														A		
44	Update final specifications																														A		
45	Review																														A		X
46	**Design and build**																																
47	Detail Design																														A		
48	Prototype Construction (CAD/ physical)																														A		
49	Review																														A		
50	**Report Reparation**																																
51	Abstract																														C		
52	Introduction																														E		
53	Mission Statement																														E		
54	Customer Needs Analysis																														R		
55	External Research																														K		
56	Concept Generation																														A		
57	Concept Selection																														A		
58	Design																														E		
59	Conclusions																														E		
60	References																														C		
61	**Presentation**																																
62	Prepare the presentation																																A
63	Present																																A
64	**Milestones**																						X					X					X

Selected Location Details

Location: State College, Pennsylvania, Centre County (ZIP: 16802)

A Brief History:

- ➔ "Farmer's High School" was to be built upon farmland nearby Bellefonte (12 miles by primitive roadways)… Began construction of school in 1855… After passing of Morrill Act of 1862, the "farmer's high school" was renamed the Agricultural College of Pennsylvania… In 1875 it received a new name, the Pennsylvania State University
    - The growing college attracted more students and workers as time passed… Growing from nearly 25 residents and 110 students in 1860 to 300 residents and 337 students in 1896… As of the 2010 population survey, there are 42,034 residents and 44,817 students in State College

Demographics:

- ➔ Population (as of 2010 survey): 42,034 people (22,681 of which are male as 19, 353 are female…. 54% male to 46% female)
- ➔ Median household income: $47,401
- ➔ Estimated median house/condo value: $158,300
- ➔ Median Resident Age: 21.5 years old
- ➔ 83.2% white, 9.8% Asian, 3.8% black/African American, 3.9% Hispanic/Latino, 3% other, .2% Native American
- ➔ Unemployment: 5.5%
- ➔ Job Growth (as of 2011): 1.3%
- ➔ % of those who walk or bike to work: 42.4%
- ➔ Average cost of:
    - Living: 4.7% below nat'l average

Climate:

- ➔ Latitude: 40°47'46" N & Longitude of 77°51'46" W
- ➔ Elevation of 1137 ft
- ➔ Temperate forest & ridge and valley system… Within valley… Rich agricultural lands
- ➔ Average amount of sun:
    - High: 4.44 $kW*hr/m^2*day$
    - Low: 2.79 $kW*hr/m^2*day$

- Average: 3.91 kW*hr/m^2*day

➔ Wind speed:
- High: 24 mph
- Average: 10.3 mph

➔ Average annual snowfall: 45.9 in

➔ Annual rainfall: 39.76 inches

➔ % clear days: 18%

➔ High temperature in July, average high: 80.7 F

➔ Low temperature in Jan, average low: 18.3 F

➔ The National Oceanic and Atmospheric Administration (NOAA) Station at the latitude 40° 48’ N and longitude 77°52’ W reports the following annual statistics:

NOAA Code	Statistic	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
0101	Temperature Mean Value	F	24.6	26.8	36.5	47.7	58.6	67.3	71.2	69.6	62.2	51.1	40.8	29.8	48.9
0201	High Temperature Mean Value	F	32.5	35.4	46.2	58.3	69.6	78.1	82	80.4	72.9	61.5	49.3	37	58.6
0301	Low Temperature Mean Value	F	16.7	18	27	37	47.7	56.3	60.6	58.8	51.6	40.6	32.5	22.8	39.1
0615	Precipitation Mean Monthly Value	Inches	2.5	2.7	3.3	3	3.8	4.2	3.8	3.3	3.4	2.9	3.4	2.8	3.3

0101	Temperature Mean Value	C	-4.1	-2.9	2.5	8.7	14.8	19.6	21.8	20.9	16.8	10.6	4.9	-1.2	9.37
0201	High Temperature Mean Value	C	.3	1.9	7.9	14.6	20.9	25.6	27.8	26.9	22.7	16.4	9.6	2.8	14.78
0301	Low Temperature Mean Value	C	-8.5	-7.8	-2.8	2.8	8.7	13.5	15.9	14.9	10.9	4.8	.3	-5.1	3.97
0615	Precipitation Mean Monthly Value	mm	62.0	65.0	80.0	73.9	92.2	102.4	92.2	80.5	81.8	71.6	82.3	68.1	79.33

ZEH Surveys and Graphs

CREDIT FOR SURVEYS IS GIVEN TO:

Jetson Green (2011). *Survery: Saving Energy is a Top Priority*. Retrieved 23 September 2012 from Jetson Green: **http://www.jetsongreen.com/2010/03/green-building-survey-leed-energy-savings.html**

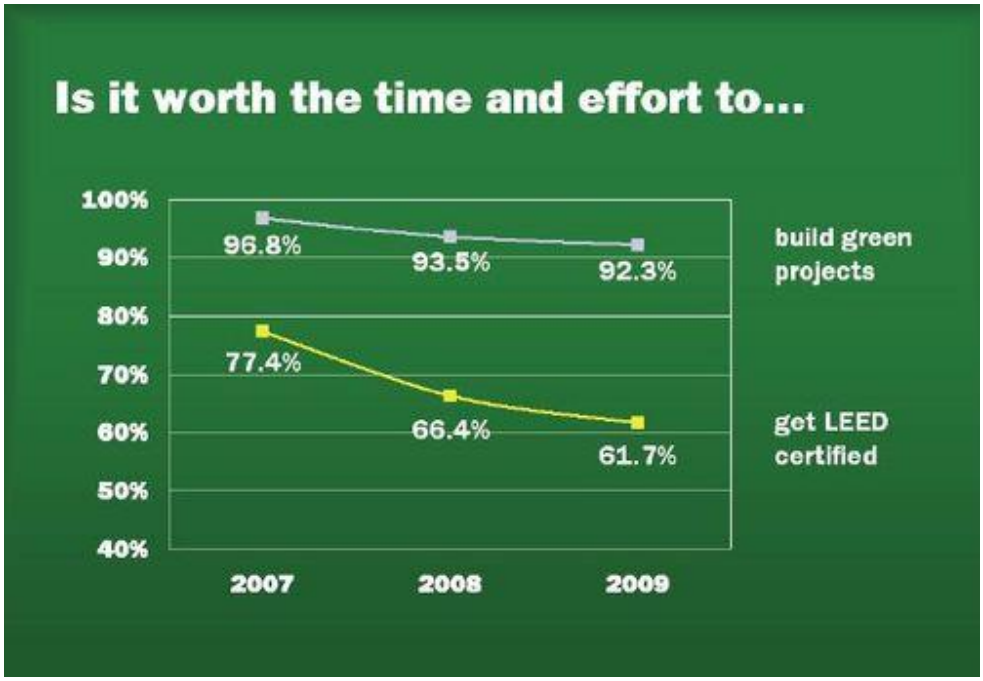
And Specifically to:

The Fourth Annual **Green Building Survey**

Published by: Allen Matkins, CTG, and Green Building Insider

Question Asked:

Is it worth the time to build projects green? Or, to obtain LEED certification?

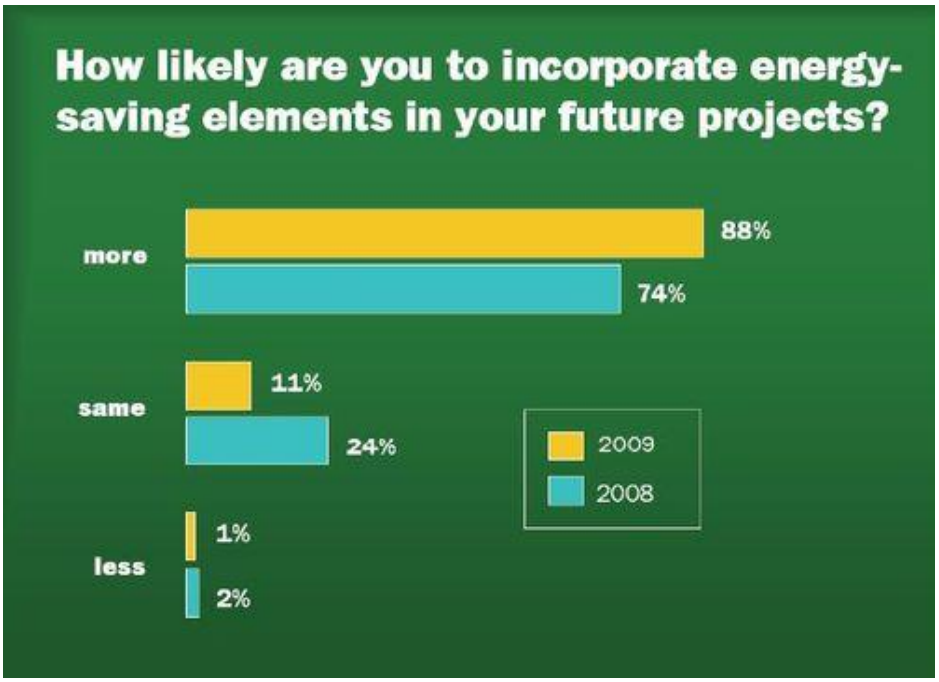


Question Asked:

How important are these factors to your building green or sustainable projects?

Question Asked:

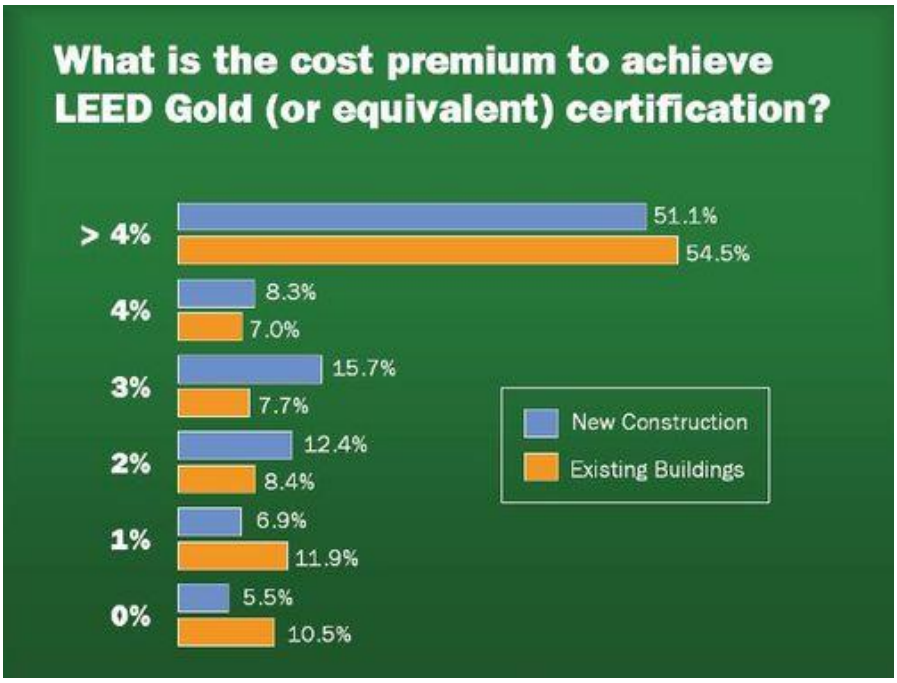
How likely are you to incorporate energy-saving elements in your future projects?



Question Asked:

(directly to respondents that had actually helped to build and certify a LEED-NC project to the Gold level)

What is the cost premium to achieve LEED Gold (or equivalent) certification?



Zero Energy Home Research

Existing Homes with ZEH features:

EX #1:

Location (city, state)	Norwalk, CT
House size (floor area in square feet)	2,562 sq ft
Number of floors	2
URL of web site where info is found	http://www.ctzeroenergychallenge.com/participant_specs.php?ID=bpc
Number of occupants	Single family
Number of bedrooms	5
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Geothermal heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Gas and wood
Size of photovoltaic system (kilowatts)	10 kW
Solar water heater (yes or no)	no
R-value of wall insulation	R-31.5
R-value of ceiling insulation	R-59
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	13.9 MMMBTU/yr ($119)
Any other pertinent info	HERS rating: 8

EX #2

Location (city, state)	Harwinton, CT
House size (floor area in square feet)	3,561
Number of floors	2
URL of web site where info is found	http://www.ctzeroenergychallenge.com/participant_overview.php?ID=Paul_Honig_
Number of occupants	Single family
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Air source heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	electricity
Size of photovoltaic system (kilowatts)	10 kW
Solar water heater (yes or no)	Yes, Solar thermal/electric
R-value of wall insulation	R-49
R-value of ceiling insulation	R-83
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	65.3 MMMBTU/yr ($2781)
Any other pertinent info	HERS rating: 100 Can charge electric car, too

EX#3

Location (city, state)	Holderness, NH
House size (floor area in square feet)	3400 ft^2
Number of floors	
URL of web site where info is found	http://www.greenbuildingadvisor.com/homes/true-net-zero-gut-rehab-new-england-style
Number of occupants	
Number of bedrooms	3
Type of heating system (forced air, hydronic,	Water furnace ground-source heat pump with three

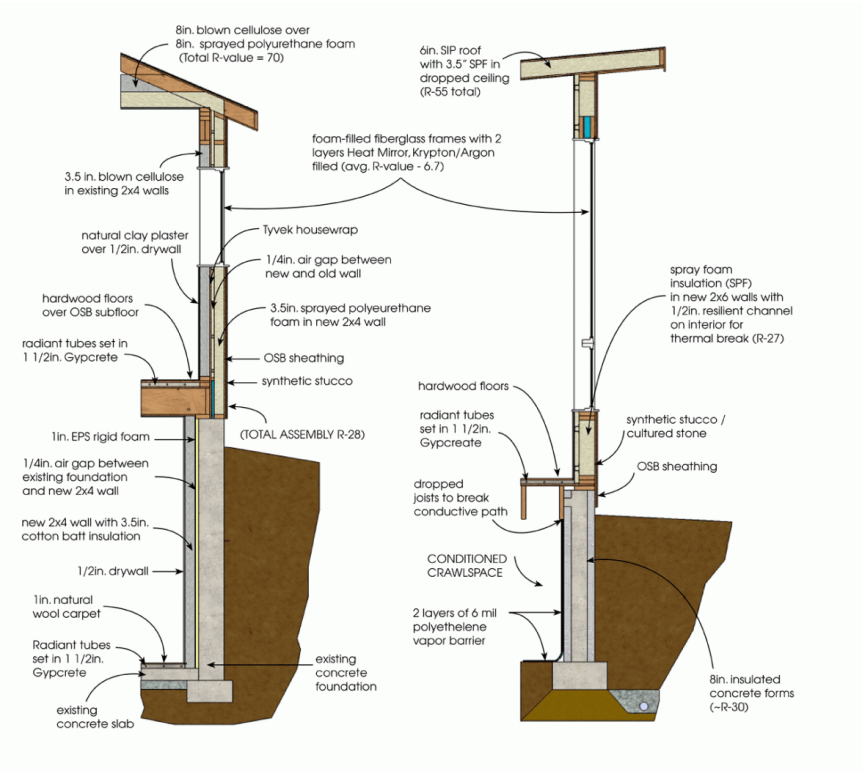
radiant floor, heat pump, etc.	220-ft. deep vertical closed ground loops; heat distributed through in-floor hydronic tubing
Main heating fuel (electricity, natural gas, wood, oil, etc.)	electricity
Size of photovoltaic system (kilowatts)	7.5 kW
Solar water heater (yes or no)	Yes, 2 solar thermal collectors connected to 200 gallons
R-value of wall insulation	- Basement wall R-value: R-40 - Wall R-value: R-52
R-value of ceiling insulation	Roof R-value: R-73
Ventilation air heat recovery (yes or no)	Yes, Mechanical ventilation: **Renewaire** ERV
Predicted or measured annual energy use	Annual heat load: 8,500 kWh Annual domestic hot water budget: 2,660 kWh Annual PV production: 6,800 kWh
Any other pertinent info	Windows: Triple-glazed double low-e Thermotech windows with fiberglass frames Window area: 568 square feet

Additional Pictures of EX#3

EX#4

Location (city, state)	Boulder, CO
House size (floor area in square feet)	2700 ft^2
Number of floors	
URL of web site where info is found	http://www.greenbuildingadvisor.com/homes/1970s-home-goes-net-zero
Number of occupants	
Number of bedrooms	4
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Wood burning fireplace with backup electric boiler
Size of photovoltaic system (kilowatts)	6 kW
Solar water heater (yes or no)	Yes, 180 evacuated tubes, two 168-gal. insulated storage tanks (R-80)
R-value of wall insulation	2x4 framing filled with blown cellulose; 2x4 framing added to exterior, filled with Icynene spray foam (R-28 total)
R-value of ceiling insulation	8 in. open-cell foam and 12 in. blown cellulose (R-70)
Ventilation air heat recovery (yes or no)	Yes, Operable windows and motorized skylight for ventilation and cooling
Predicted or measured annual energy use	
Any other pertinent info	Windows- foam-filled fiberglass frames with two layers of Heat Mirror, krypton/argon filled (Duxton, R-7.1)

Pictures of EX#4



Product Specs and Target Specifications

Needs Metric Matrix

Needs Metric Matrix																							
		Metric																					
	Need	Located in State college, PA	Three bedrooms	Two Bathrooms	Large Windows	Windows placed for cross breeze and maximum sunlight	Solar Window Shades	High R-value insulation	Solar water heater	Fire place	Roof Overhangs	Sunroof	Energy Star Appliances	Timer lights	Water saving appliances	Thermal slab	Electric car accomidations	Open design	Ceiling fans	Stone exterior	Solar panels	Radiators	Geothermal heat pump
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Designed for famaily of 4		x	x													x						
2	Located in PA	x																					
3	Withstands elements					x		x		x						x				x		x	x
4	Ues local resources				x	x	x			x		x								x	x		x
5	Uses solar panels																				x		
6	Produces more energy than uses								x				x	x	x		x				x		x
7	Accommodates electric car																x						
8	Uses green building principals				x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
9	Includes energy efficient applinces												x									x	x
10	Aesthetically pleasing	x			x					x		x						x		x			
11	Environmentally friendly					x			x	x		x	x	x	x	x	x				x		x

Benchmarking

Details of features offered by energy efficient builders in 2 areas:
Areas Include:
1. State College, PA
2. Newburgh, NY

State College, PA

S&A Homes

Mission of Builder:
S&A Homes takes a different approach than most builders. S&A Homes builds the home around the mechanical system rather than building the structure first. The company's main goal is energy efficiency. The company works with Building America to learn more about reducing energy consumption. S&A is now working to create a "lab home" in which they can test different energy saving features.

General House Details:
Size: 3 bedrooms, 3 baths
Square Footage: 3,108 ft2, includes
1,004 ft2 basement
Price Range: $216,000 to $305,000

Energy Saving Details:

- HERS 51-55-center advanced framing
- **Wall insulation**: R-24 blown-in fiberglass
- **Attic insulation**: R-49 blown-in fiberglass insulation
- Foundation insulation: Superior Wall xi™ includes2½-inch Dow® extruded polystyrene insulation (R-12.5)
- Windows: Double-pane, U = 0.33 and SHGC = 0.30
- Air sealing tightness: blower door testing of 3.0 ACH at 50 Pa
- 96%-AFUE natural gas-fi red furnace with a multi-speed blower
- 14-SEER cooling system
- 0.82 EF (energy factor) tank-less gas-fired hot water heater
- Ducts in conditioned space
- 100% CFL lighting
- ENERGY STAR appliances

More Details Can Be Found At:
http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_bp_sahomes_cold.pdf

Newburgh, NY

Habitat for Humanity

Mission of Builder:

Habitat for Humanity works with the U.S. Department of Energy program to build affordable homes for the less fortunate. They renovate old homes, refraining from destroying any structural demolition when possible. When renovating, Habitat for Humanity takes into consideration health and safety hazards and energy consumption. By reducing energy consumption, the energy bills for the houses decrease. This achieves the builders' main goal of making houses more affordable for the needy.

General House Details:

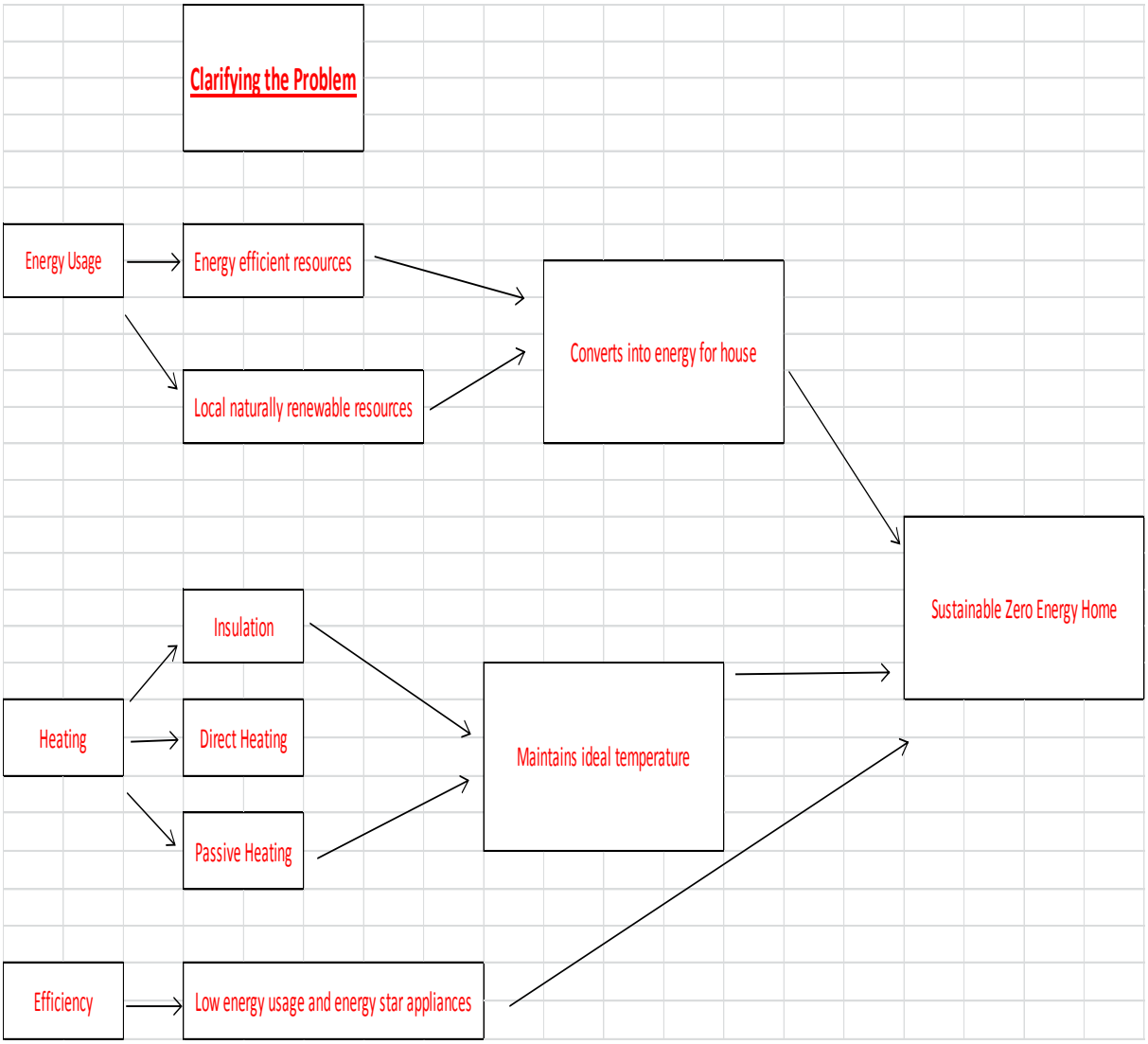
Size/ Square footage: Most houses are larger than 1,400 sq. ft.
Price Range: below $60,000 (these are renovated houses)

Energy Saving Details:

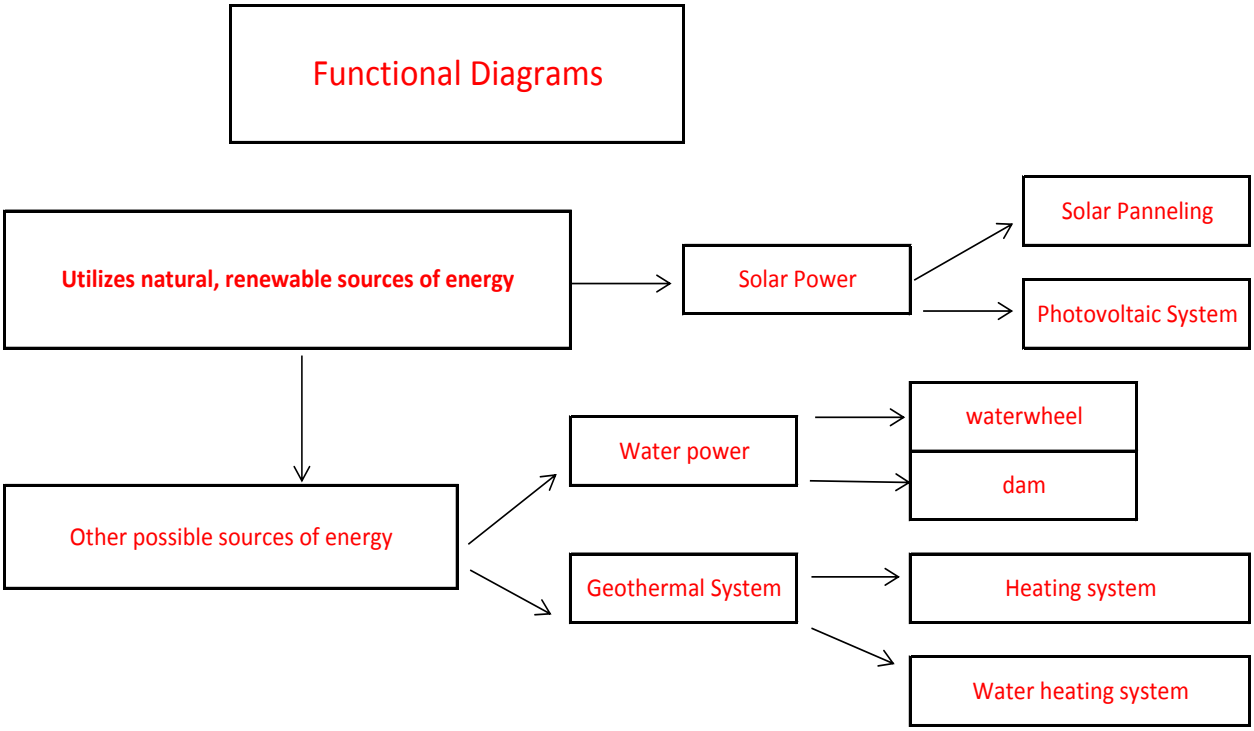
- Teledyne Laars direct-vented, sealed-combustion, 85% AFUE combination boiler and water heater for hydronic space heating and domestic hot water
- 8 inches, R-40 rigid XPS foam insulation in attic
- 3 inches, R-15 rigid XPS foam insulation on walls between double-layer brick outer wall and steel-stud inner wall
- Insulated, weather-stripped attic hatch
- R-19 fiberglass batt insulation between floor joists above basement, held in place with mesh
- Basement rim joists insulated with rigid foam board, caulked and foam sealed
- Waterproofing applied to inside of foundation walls
- Rigid insulation caulked and sealed to ceiling to improve envelope air sealing
- Double-pane low-emissivity windows
- ENERGY STAR certified with pre-2007 HERS score of 89.7
- Blower door testing
- ENERGY STAR refrigerator
- 70% CFL lights
- Panasonic Whisper Lite 0.6 sone fan in bathroom on timer for continuous 20-minute cycle ventilation
- Kitchen fan vented to outside

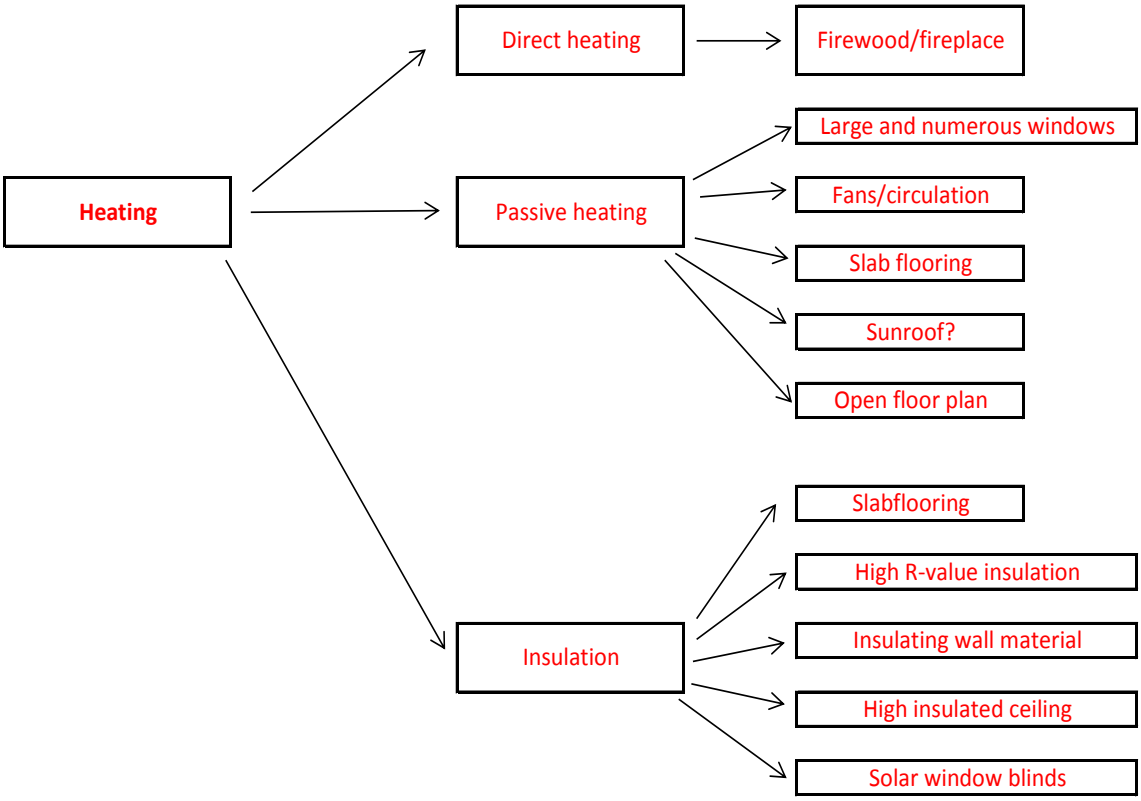
More Details Can Be Found At:
http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_cs_retrofit_newburgh_habitat.pdf

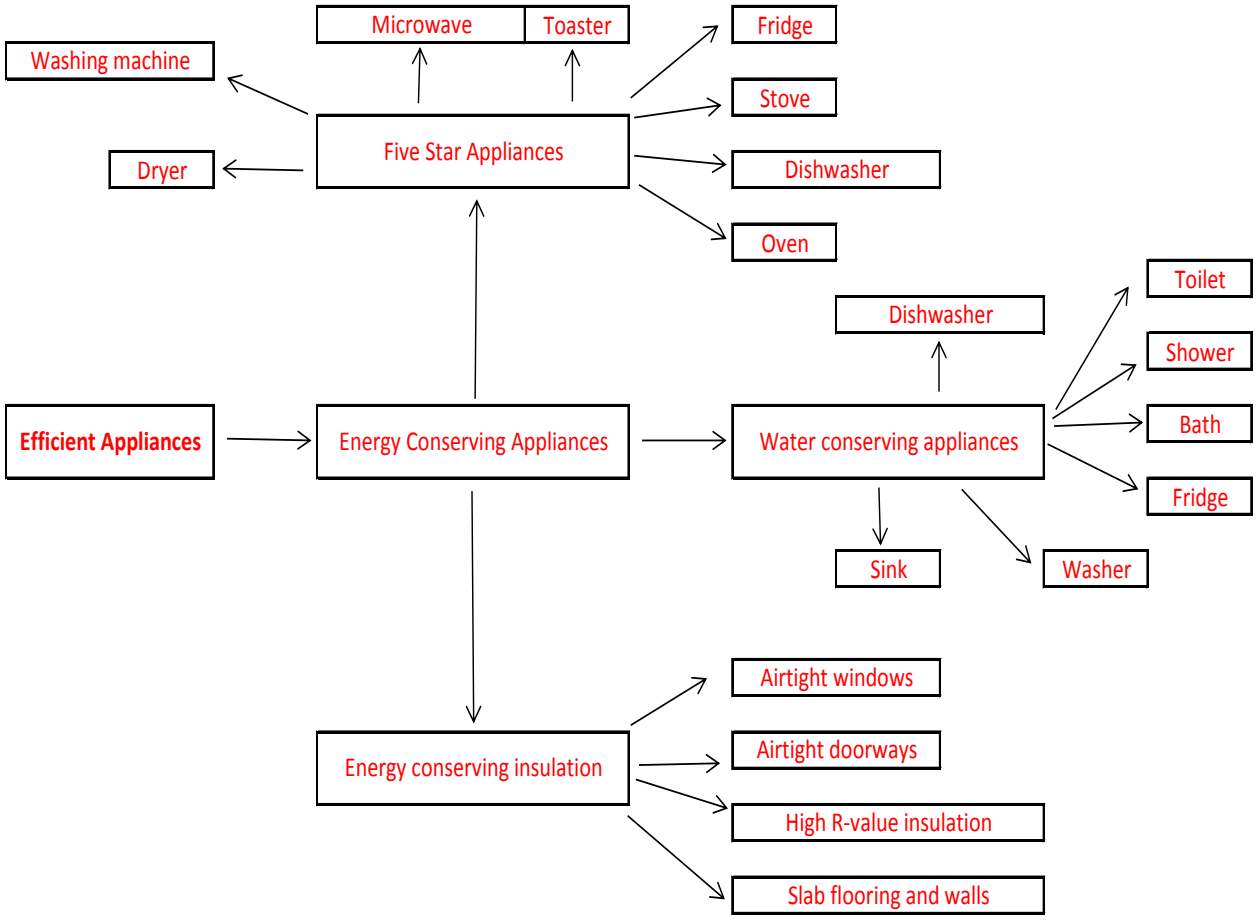
Clarifying The Problem



Functional Diagrams






Microwave
Toaster
Washing machine
Fridge
Stove
Five Star Appliances
Dryer
Dishwasher
Oven
Toilet
Dishwasher
Shower
Efficient Appliances
Energy Conserving Appliances
Water conserving appliances
Bath
Fridge
Sink
Washer
Airtight windows
Energy conserving insulation
Airtight doorways
High R-value insulation
Slab flooring and walls

Additional External Research

Literature Review

Link: http://www.renewablegreenenergypower.com/zero-energy-home-zero-energy-building/

Renewable Green Energy Power

Zero Energy Home – Zero Energy Building

By Dino Green

This source gave a detailed description of zero energy buildings and houses. The website guides the reader through the steps of the building's construction, from its initial designs until its completion thus permitting a deeper understanding to the term of zero energy building. This source also provided a great amount of general information regarding zero energy buildings as well as guidelines by which one can follow when constructing a zero energy building.

Link: http://www.wbdg.org/resources/netzeroenergybuildings.php

Whole Building Design Guide (a program of the National Institute of Building Sciences)

Net Zero Energy Buildings

By Steven Winter Associates, Inc.

This source gave a multitude of guidelines and definitions as to aid in the process of constructing a zero energy building. It includes a comprehensive definition of what constitutes as a zero energy building, a large list of processes that when addressed will increase the energy efficiency of the building, and renewable resources that can be utilized as to reach the net zero goal. This website provided a great amount information in regards to the federal net zero energy building goals and guidelines as well as connecting the reader to a large database of zero energy buildings and many other sources to aid in the process of constructing a zero energy home.

Patent Research

Zero Energy Home

This patent is for the description of a Zero Energy home and it lists the many components and requirements for a home that falls underneath the title of a Zero Energy Home.

Link: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=%22zero+energy+home%22&OS=

Affordable, sustainable buildings comprised of recyclable material and methods thereof

Inventors: Erla Dogg Ingjaldsdottir (Santa Monica, CA) and Tryggvi Thorsteinsson (Santa Monica, CA)

United States Patent Number: 7,941,975

Filed: April 11, 2008…. May 17,2011

Description: An affordable, sustainable building, comprising substantially entirely mass-produced, prefabricated constituent parts manufactured off-site, the prefabricated constituent parts comprising a foundation, a frame module comprising a plurality of frames, wherein the frame module is secured to the foundation, a reversible connector to connect the plurality of frames to form the frame module, a wall panel configured to be mounted onto the frame module, a floor panel configured to be mounted onto the frame module, and a ceiling panel configured to be mounted on to the frame module. Each constituent part forms part of a library of parts from which the constituent parts are selected. The constituent parts are preferably made in standardized sizes to facilitate efficient mass production. The constituent parts are predominantly made of recyclable material so as to be environmentally friendly. Computer software may be developed to facilitate design and construction of the affordable, sustainable building and to calculate proper attachment points for lifting and moving frame modules.

Electric Car

Electric Hybrid Car

Part of our requirement was to create a house that could produce enough energy to power an electric car. Below are links to two different company's electric cars. The Chevrolet Volt is a hybrid car, meaning that it utilizes the power of both electricity and natural gas. The charging capacity of the Volt's battery works perfectly in our zero energy house, thus fulfilling the capacity for the house to charge an electric-powered car.

Links: http://www.chevrolet.com/volt-electric-car.html

http://gm-volt.com/full-specifications/

http://gm-volt.com/chevy-volt-reasons-for-use-and-cost-of-operation/

Chevrolet Volt

Battery Capacity: 16 kWh

Mileage possible with electric battery only: 40 miles

Time for complete charge: w/ 120 V charger: 10-12 hrs

w/ 240 V charger: 4 hours

Average price for complete charge of battery in PA: $9.55/kWh

Concept Screening

Concept Screening		
Category	Component	Votes
Floor plan:	2 floors including basement	1
	4+ bedrooms	
	closets	
	1/2 bath for guests with detailed stone	
	open floor plan	4
	2nd floor loft/balcony	2
	high ceilings	2
Kitchen	Open, roomy kitchen	3
	half wall between kitchen and dining space	
	cherry wood cabinets	
	granite countertops	
	stainless steel appliances	
	energy star appliances	4
	open kitchen with center island	3
Flooring	Burbur	
	wooden furninshings and floor	1
	hardwood floors	
Heating/Cooling	radiators	2
	fireplace	3
	forced air	
	cross ventilation	3
	ceiling fans	3
	well insulated	4
Energy Source	Geothermal	1
	Wind	
	Solar	3
	Natural Gas	1
	Bio Gas	
	Bio Mass	1
	Nuclear	
	Oil	
Landscaping	stone pathways in yard	
	flat front yard and hill in backyard	
	pond in front yard	
	large yard space	
	three huge evrgreens and one cherry blossom	2
	nice patio…	
	waterfall +2 fish	
	garden	2
	patio	3
Exterior	basketball hoop in driveway	
of house	beautiful landscaping	
	deck area with table, furniture, and hottub	2
	stone exterior	
	pillars in front of house	
	2 story house with many windows in front	3
	huge window in foyer	3
	brick exterior	3
Extras	garage	
	BIG windows	4
	planty of sunshine	4
	dog greeting at door	
	plant life in house	1
	warm, earthy, homey tones	
	visually appealling architectural structures	2
	paintings on walls	
	skylight	2

Concept Scoring

Concept Scoring

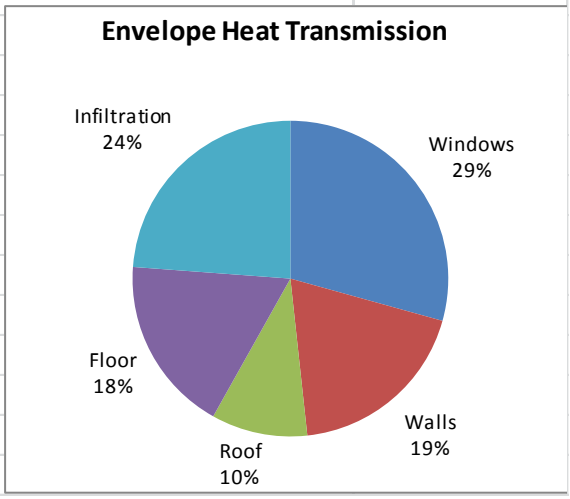
Selection Criteria	Weighting (points per +/-)	Concepts										
		Energy Providers						Energy Distrubuters				
		Solar Panels	Passive Solar	Geothermal heat pump	Biomass	Biogas	Wind Turbine	Wood Stove/ Fireplace	Radiators	Insulation	Ceiling Fans	Forced Air
Efficiency	5	+	0	+	-	-	0	+	+	+	0	-
Price	4	0	+	-	+	-	-	+	0	-	0	-
Environmentally Friendly	3	+	+	+	0	+	0	+	+	+	0	0
Resource Availability	3	0	+	+	+	+	-	+	0	+	+	+
Aesthetics	1	-	+	0	0	-	-	+	-	0	+	-
Durability/ survives elements	2	+	+	+	-	0	0	+	+	+	0	+
Ease of use	1	+	+	0	-	-	0	-	+	-	0	+
Upkeep effort required	2	+	+	0	-	-	0	-	0	+	+	-
Net score		12	12	9	-3	-7	-8	15	10	10	6	-6
Rank		1	1	3	4	5	6	1	2	2	4	5
Continue?		yes	yes	no	no	no	no	yes	yes	yes	yes	no
		combine						combine		combine		

Final Specifications

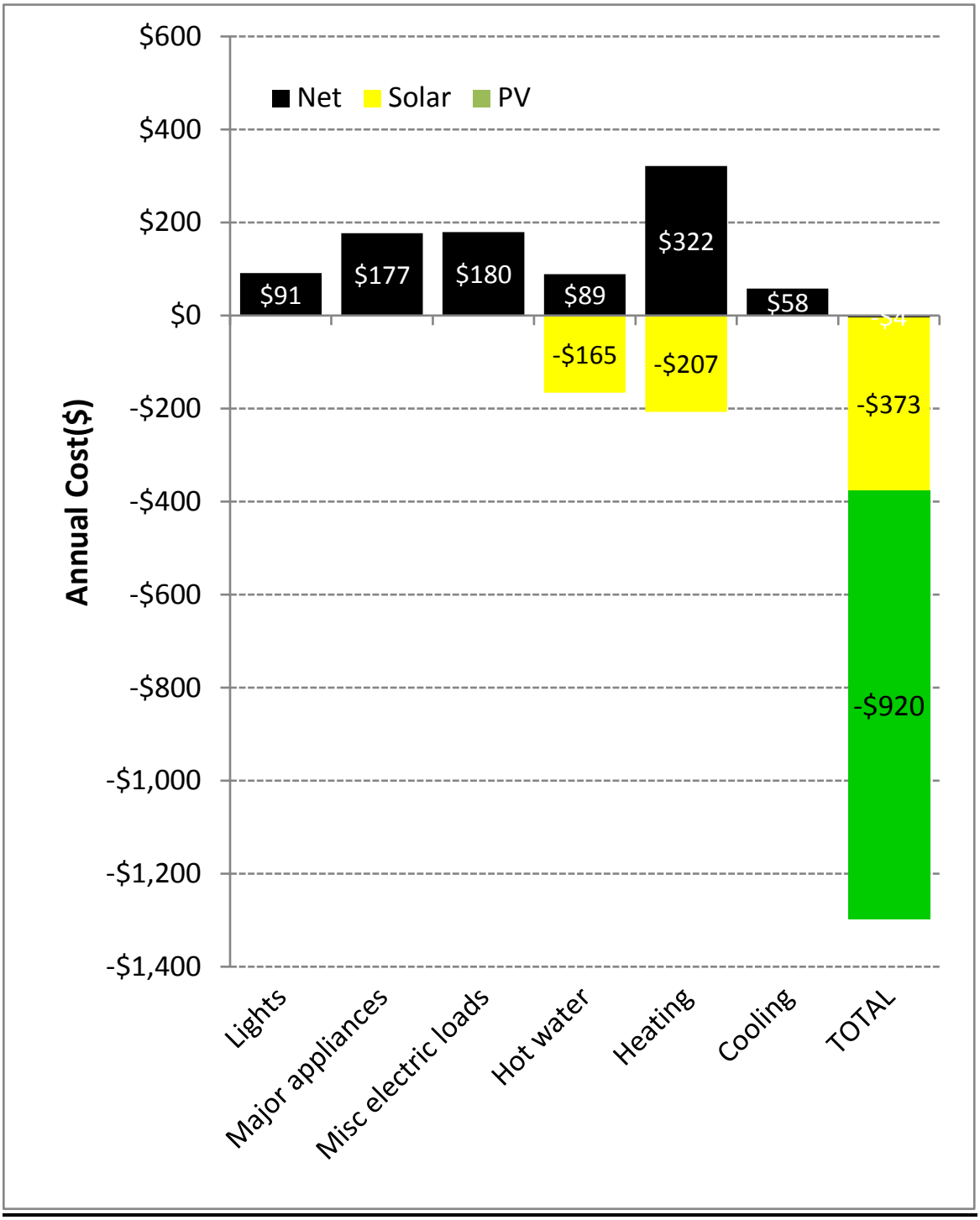
After completing a significant amount of research, keeping our customer's needs in mind, our team was able to create our final specifications for our home. Our teacher, Wallace Catanach, provided us with an effective tool called the "Zero Energy Calculator." After imputing our desired dimensions and home components, we were able to determine the size needed for our PV system. The results from this calculator also helped us see the other important energy saving features we needed to include in our home.
Here are the results we obtained:

General Info	
Location	Harrisburg
Electricity cost ($/kwh)	0.1
Conditioned floor area (sq.ft.)	1536
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.)	1536
North wall area (gross) (sq.ft.)	480
East wall area (sq.ft.)	320
South wall area (sq.ft.)	480
West wall area (sq.ft.)	320
North window area (sq.ft.)	79.83
East window area (sq.ft.)	87.83
South window area (sq.ft.)	160.3
West window area (sq.ft.)	87.83
Air tightness	Tight
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)	7.0
Solar water heater	Yes
Behavior	
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	66
Cool thermostat setting (F)	82



Graph Showing Results:



Specifications Regarding R-Values

In order to determine the R-Values needed for our home, additional research was conducted.

Surface	Thickness	Materials	Insulation
Exterior Walls	6 in	2x6 with R22 batt & 1" foam	R-30
Interior Walls	4 in	2x4 frame with drywall	R-30
Ceiling	18 in		R-60

The information on the following two pages helped us set specifications regarding the insulation on our home.

Insulating Our Zero Energy Home

↑ Standard Insulation System

VERSUS

↓ Energy Complete Insulation System

While researching how to best seal and insulate our ZEH to ensure the least possible amount of heat leakage to the environment, we discovered Owens Corning's EnergyComplete insulation system. This system addresses the most common sources of heat leakage in typical homes, as seen in the pictures to the left. EnergyComplete features both high R-value insulations and Flex Technology insulation sealants (to avoid possible cracks and gaps) strategically placed throughout the home.

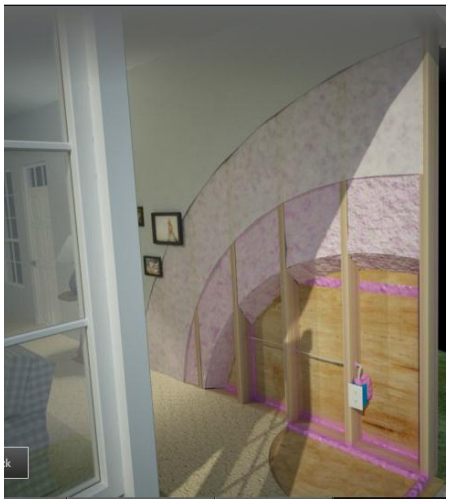
We will incorporate many of EnergyComplete's ideas, explained on the next page, into the insulation of our ZEH to ensure minimal heat loss.

ATTIC/ROOF

Over 40% of a house's energy can escape from the house's attic and roof. Heat rises, so it is important to insulate the attic and roof especially well in order to keep the heat in the house. For this reason we decided to make the roof 18 inches thick, use a R-60 insulation, and fill the crawlspace attic, where applicable, with insulation.

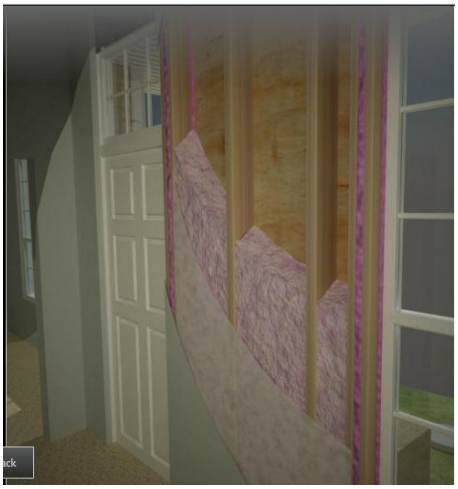
BASEMENT

WALLS



Air can also escape or enter the house through joints in walls and exterior housing materials. To solve this problem we will use EnegryComplete's Flex Technology/spray insulation and R-30 insulation in walls.

DOORS/WINDOWS



Over 10% of a home's heat can escape through tiny cracks around doors and windows. For this reason we will seal all house openings extremely tightly, use high R-value insulations, and solar efficient windows from Andersen.

Specifications Regarding Windows

Size, location, and model type of the windows is an important aspect of our zero energy home. We first had to take into consideration which side of the house would receive the most light. Then we had to utlize that information to maximize the amount of sunlight entering our home.

	Basement	1st Floor	
Square Footage (Ft^2)	1536	1536	
Window Square Footage (Ft^2)	0	415.79	
	# Of Windows	**Dimensions of Windows**	
South Facing Windows	6	32"x36"	
	2	93.875"x73.375"	
East Facing Windows	5	32"x36"	
	1	93.875"x73.375"	
North Facing Windows	4	32"x36"	
	1	93.875"x73.375"	
West Facing Windows	5	32"x36"	
	1	93.875"x73.375"	
Windows on Front Door	1	30"x40"	

Windows	**Brand**	**Efficiency features**	**Size**
400 Series 30° Casement Angle Bay Window	Andersen	HP Low-E4 SmartSun glass U-factor: .28 Solar Heat Gain Coefficient: .18 Visible light transmitted: .41	# sq.ft.
A-Series Double-Hung Windows	Andersen	Same as above	32"x36" # sq.ft.

Specifications Regarding Solar Energy

The zero energy calculator also helped us determine which solar panels would be the best choice for our home. Our goal was to maximize the amount of sunlight captured while keeping the cost relatively affordable. We also found an effective solar water heater to accommodate the needs of our house.

Selected Solar Panels

Mfg				Sharp
Model		**Units**		ND-240QC
Area		m2	1.63	1.63
Rating		W	240	240
Average Daily Solar radiation	It	kwh/m2-day	3.91	3.91
PV required output	Prated	kW	7	7
Days	t	days/yr	365	365
Efficiency	n		24%	24%
Numbe of panels			30	30
Area of panels	A	m2	48.9	48.9
Area of panels	A	ft2	526.4	526.2
Esol=It * A * n * t	Esol	kWh/yr	16749	16745

Selected Solar Water Heater

Energy Star Solar Water Heater	
Brand	EnerWorks Appliances
Model	EWRA4-E120-1T
Collector Panel Area	123 sq. ft
Collector Type	Flat plate
System Type	Indirect forced circulation
Solar Fraction	1
Solar Energy Fraction	47
Auxilary Fuel	electric

Selected Appliances

To maximize the amount of energy saved by our home, we have chosen to use energy star appliances. Below is a chart of several models of each appliance. The highlighted model is the one we have chosen to include within our zero energy home.

Appliance Selection Chart

For Energy Star Capable Appliances

Appliance	Brand	Model	Size (in)	kWh/year	Price ($)	Energy Star	Lights	Airflow
Ceiling Fan	MinkaAire	Gyro	42	-	549.95	yes	compatible	5077
	Fanimation	FP4640OB	54	-	319	yes	yes	6300
	MinkaAire	Concept II 52	52	-	279.95	yes	yes	5050
	Emerson	CF765BS	60	-	249	yes	no	7530

Appliance	Brand	Model	Size (in)	kWh/year	Price ($)	Energy Star	Lights
Dishwasher	Samsung	DMT400RHS/XAA	24	279	699.99	yes	$30 - electric, $23 - gas
	Bosch	SHE3AR56UC	24	279	494.99	yes	$30 - electric, $23 - gas
	Whirlpool	WDF530PAYW	24	258	449.99	yes	$27 - electric, $20 - gas
	LG	LDF7551ST	24	245	809.99	yes	$27 - electric, $19 - gas

Estimated Yearly Operating Costs (EYOC)

Appliance	Brand	Model	Size (ft^3)	kWh/year	Price ($)	Energy Star	Amps (A)	Volts (V)	EYOC ($)
Washer	LG	WM3470HWA	4	116	989.1	yes	10	120	12
	Frigidaire	FAFW3801LW	3.26	99	679.1	yes	9	115	11
	Maytag	MHW6000XG	4.3	168	1078.2	yes	15	120	18

Appliance	Brand	Model	Size (in)	kWh/year	Price ($)	Energy Star	Energy Efficiency Rating
Refrigerator/Freezer	Frigidaire	LFTR1814LW	18.2	489	579	no	none
	Samsung	RF4287HARS	28	590	3199	yes	Tier 1
	Whirlpool	ED2GVEXVD	21.7	418	1149	yes	Tier 1

Projected Cost

Below is a compiled list of the cost of the appliances and other features of our home. After taking all of these costs into consideration we were able to come up with a total estimated cost for our net zero energy home.

Predicted Cost Model

Based on average family of four

General	
Land in State College	$145/sq ft.
Average 1500 ft^2, two bedroom house	$220,362
Energy used by electric car (Chevy Volt)	$9.55 per charge
Solar Panels/Solar Kit	$25,000
Water Heater	$2,500 - $3,500
Floor Slab	$5 - $7/sq ft.
Sewage	$6/kgal
Water Usage	$4/kgal

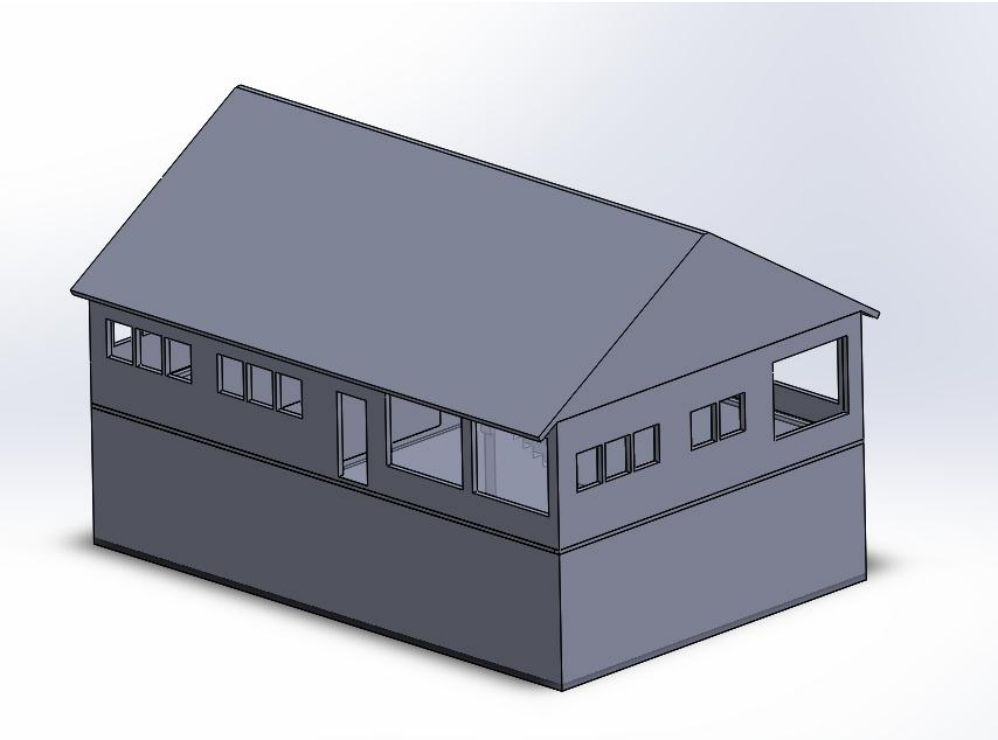
Appliances	
Ceiling Fan	$319
Dishwasher	$258
Washer	$989.10
Dryer	$449
Refrigerator/Freezer	$1,149
Microwave	$150
Oven	$4,000
Toilet (2)	$150 each
Sink (3)	$40 each
Shower (2)	$300 each

Total Estimated Cost: < $500,000

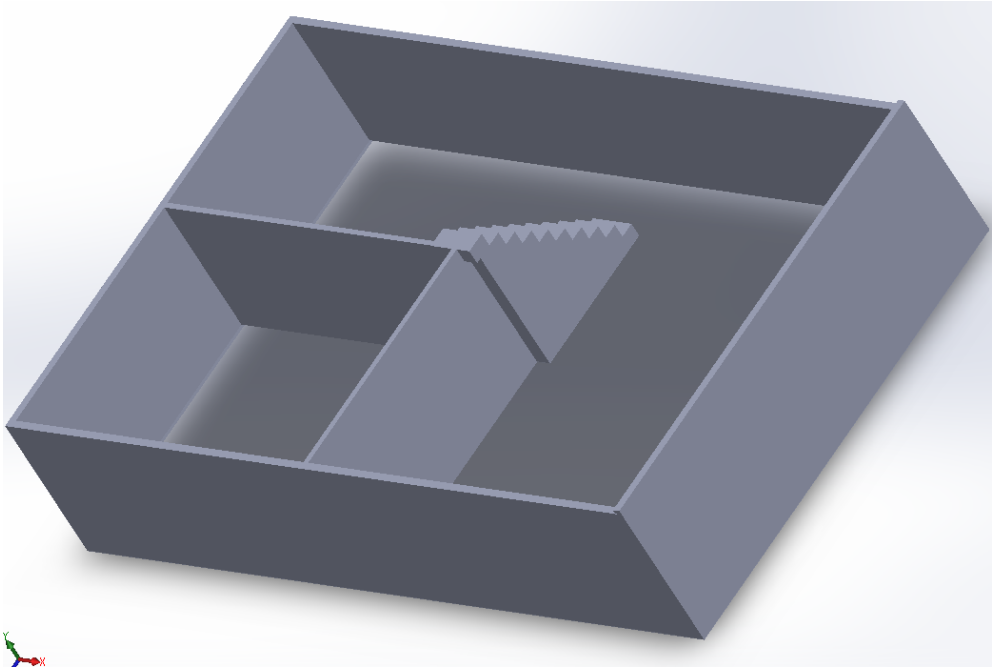
Final Design

Solid Works Model

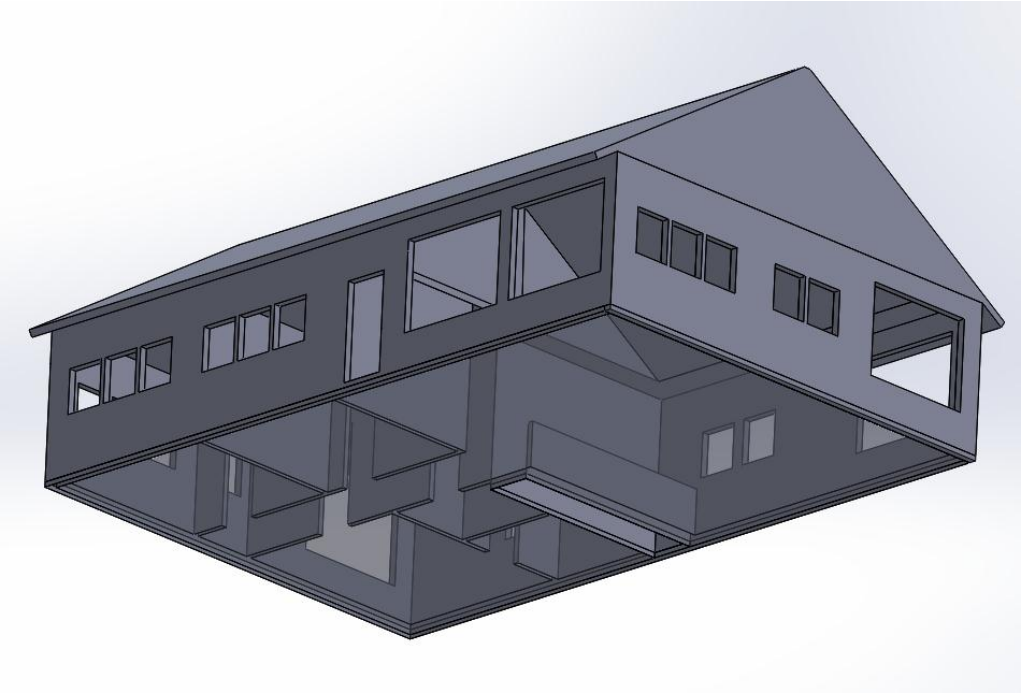
Entire House



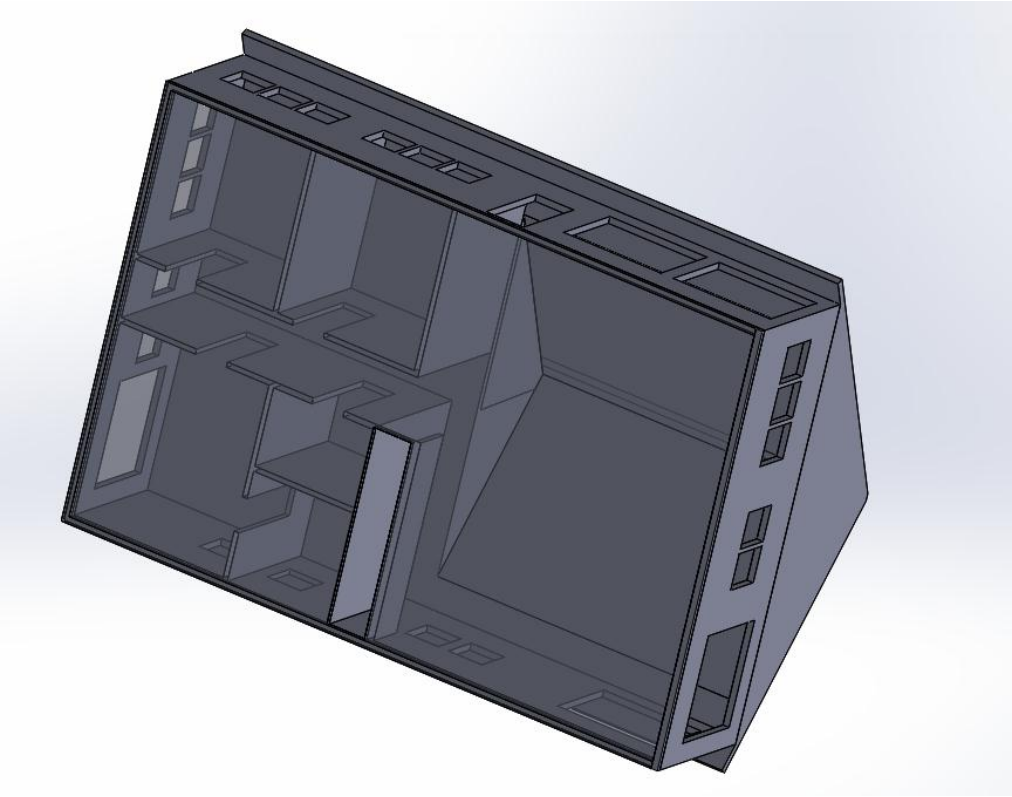
Basement



Upstairs

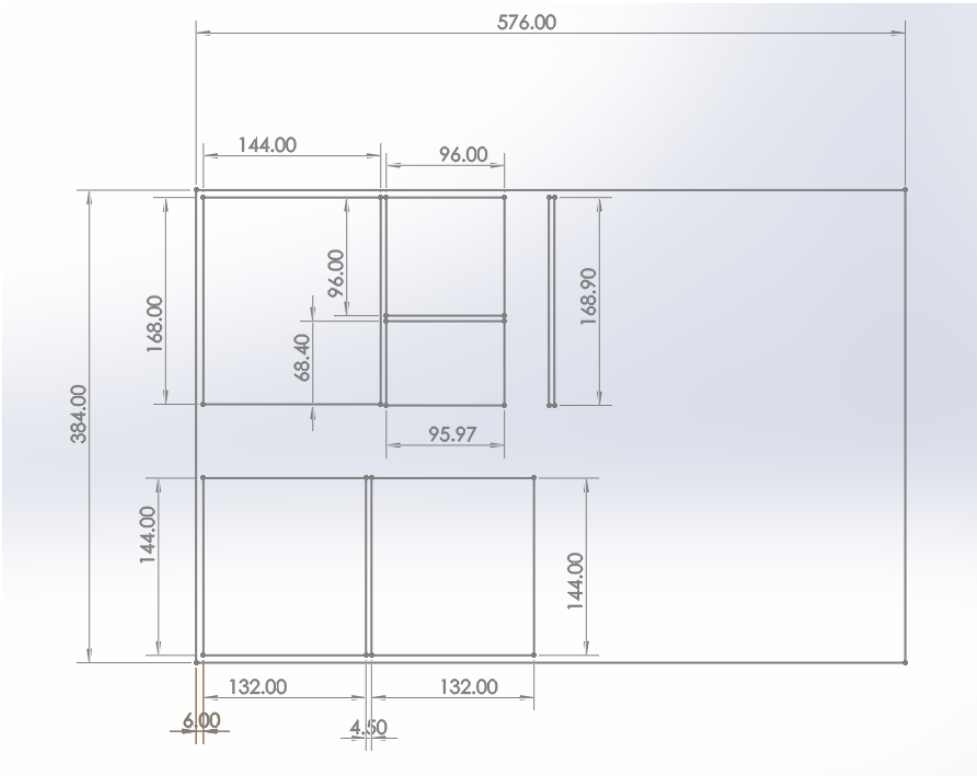


Additional View of the Upstairs

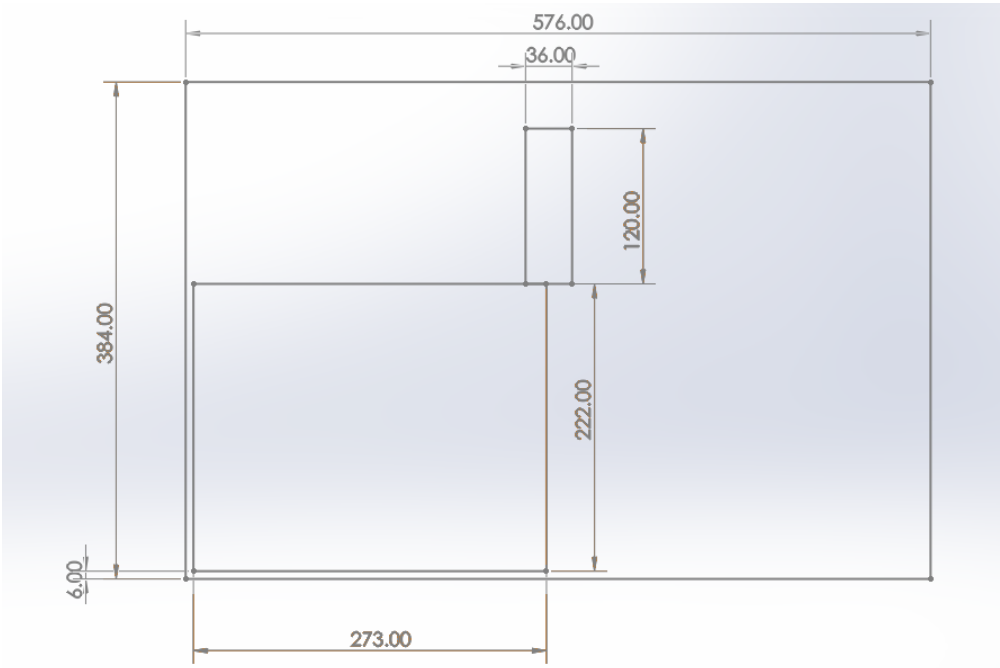


Dimensions

Upstairs



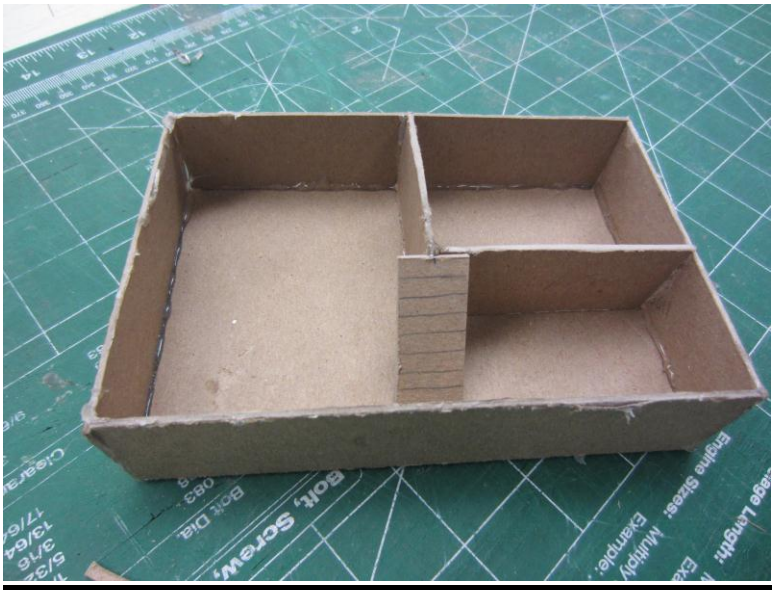
Basement



Physical Model

First Floor

Basement



Conclusion

After many long weeks of hard work, our net zero energy home finally came together. When building our house, we took into consideration many different aspects. We took features we learned about in class and did additional research. We then incorporated these key energy saving features in our own home. Throughout the entire project we have learned the importance of using the engineering design process, staying organized, and communication within a group. Our use of the engineering design process can easily be seen on the project timeline. By planning ahead and staying on task, we were able to create an effective net zero energy home within the short period of time allotted. We had to maximum progress in class by using our time wisely. Additionally, by staying organized, we avoided overlapping work. Another essential component that resulted in a successful project was working well with one another. We split up the required work based on group members' strengths, weaknesses, and interests. Also, we worked on a majority of the project together by collaborating ideas. In conclusion, creating a net zero energy home not only taught us about energy saving techniques, but our group also obtained important life-long skills such as organization and communication.

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