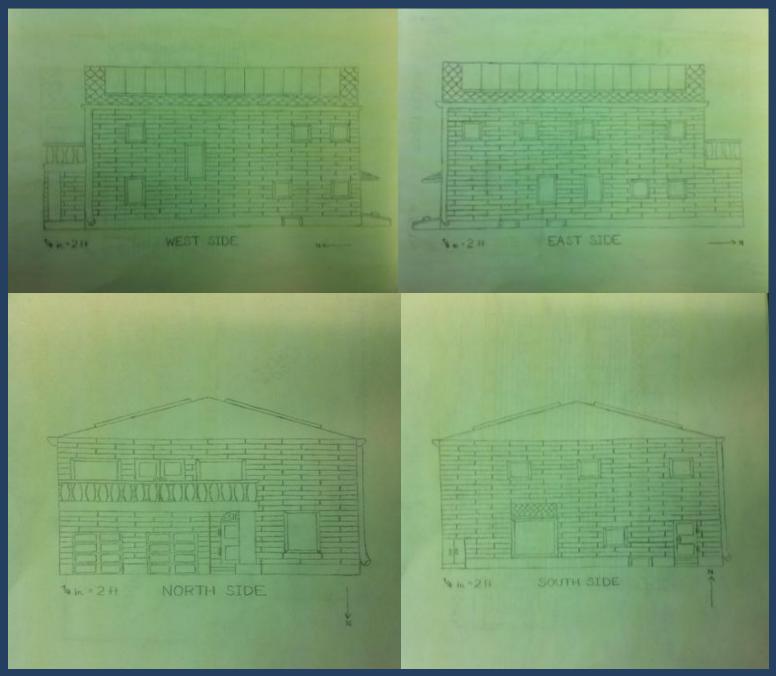
ZERO ENERGY HOME: Camden, Maine

Engineering Design 100: Section 10

February 24th, 2012

Team 3: The Bosses

Submitted to: Professor Catanach



Team Members:

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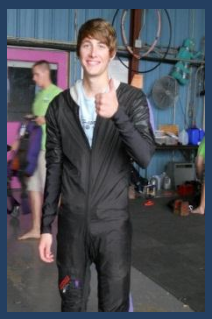


Abstract

As efforts are being made to reduce the ecological impact of humans on the earth, the Zero-Energy Home Project gives hope for a promising future. It efficiently reduces the Carbon Footprint of the human civilization. These goals are accomplished by incorporating present green technology and resources. Our goal is to design and develop a Zero Energy Home which drastically reduces energy requirements and at the same time provides a comfortable and sustainable living environment for the residents.

Introduction

For the Zero Energy Home Project, our design team kept our goals simple and straightforward. Our aim was design a home which would yield net zero energy all over the year and also provide an aesthetically pleasing and affordable living environment. Our team kept in mind that the costumer should be provided with all the essential luxuries. We started by identifying the problem and understood all customer requirements. Thereafter we researched the current Zero Energy Homes and available green technologies and resources. After several brainstorming sessions we decided on a design and started working on the development of a prototype of the home.

Mission Statement

The objective of team 'The Bosses' was to design a home which would meet all customer needs and provide them with a pleasant living environment and at the same time be sustainable, keeping future generations in mind.

Customer Need Analysis

The team used surveys to determine the demands and needs of the customer for their Zero Energy Homes.

Customer Needs

1. The house should be occupied by a typical medium sized family and has a backyard. (3)
2. The house should be two stories. (3)
3. The house should be easy to maintain. (4)
4. The house should be in a friendly, safe and convenient environment. (5)
5. The house should have a low energy bill. (5)
6. The house should have an affordable price. (3)
7. The house should have all the basic luxuries of a normal house. (4)

Interpreted Needs

1. The house comfortably accommodates a medium sized family.
2. The interior design makes efficient use of space, allowing a suitable living environment.
3. The house draws its energy from multiple green natural renewable sources.
4. The house is affordable by the average middle class family.
5. The house incorporates highly efficient technology.
6. The house premises are easily maintainable by the occupants.

Metrics / Need	Three Bedrooms	R-value of walls	R-value of ceiling	Solar heating	Wind turbine	Solar panels	Heat recovery	Windows	Balcony	Location	Backyard	Two stories	1.5 Bathrooms	Cost of Production
Accommodate medium sized family	■											■	■	
Interior design uses space efficiently	■											■	■	■
Draws energy from multiple natural resources				■	■	■		■						
Zero net energy		■	■	■	■	■	■	■						
Affordable for average middle class family	■							■	■	■	■	■	■	■
highly efficient technology and appliances				■	■	■	■	■						
Aesthetic and economically stable	■				■			■	■	■	■	■	■	■
Luxuries	■							■	■	■	■	■	■	
Conserves water				■									■	■

Figure: Selection Matrix

External Research

Benchmarking (Existing Zero Energy Solutions)

Each team member provided information and fact sheets of two different Zero Energy Homes from different geographic locations across different continents. On understanding the design of these homes we realized that each home did consist of a much needed solar module system. Most of the homes stated electricity as their prime source of energy. Moreover, many homes had a solar water heater installed. We also concluded that a higher R-value for the provided higher energy savings during winter.

Figure: Existing Zero Energy Projects

ZEH	Adam1	Adam2	Matt3	Matt4	Geo5	Geo6	Anant7	Anant8
Location	**Turner Falls, MA**	**Boulder, CO**	**Denver, CO**	**Lebanon, NJ**	**New Paltz, NY**	**Gloucsester, MA**	**Turner Falls, MA**	**Bellevue, Washington**
House size	1,248 sqft	5,860 sqft	1,280 sqft	4,200 sqft	3,237 sqft	N/A	1,152 sqft	1630 sqft
# of Floors	2	3	1	2	3	2	1	2
# of occupants	4	4	4	5	3		2-4	2
# of bedrooms	3	5	3	4	N/A		3	2
Heating System	Heat Pump	Radiant Floor	Heat Pump	Forced Air+Radiant Floor	Heat Pump	Heat Pump	Electric Heating, Solar Heating	Heat Pump, Radiant Floor
Main Heating Fuel	Electricity	Solar Energy (Electricity)	Electricity	Electricity	Electricity	Electricity, Wood	Electricity	Electricity, Gas
Size of Photovoltaic System (kW)	4.94kW	6.84kW	4kW	9.8kW	10kW	4.3kW	4.892kW	5.4kW
Solar Water Heater	Y	Y	Y	Y	N/A	Y	Y	Y
R-Value of Wall Insulation	R-42	R-34	R-40	R-35	R-21	R-30	R-42	R-24
R-Value of Ceiling insulation	R-100	R-45	R-60	R-35	R-50	R-76	R-100	R-40
Ventilation Air Heat Recovery	Y	Y	Y	N		Y	Y	Y
Predicted or Measured Annual Energy Use	1,949kWh	8,000kWh	3,585kWh	6,500kWh	8,180kWh	2.7kWh	1.949kWh	4.821kWh

Figure: Existing Zero Energy Projects Fact Sheet.

Product Dissection

Before designing and developing the home we had to decide on the technology and appliances that our design team will be installing at the home. We reviewed green technologies such as solar panels, solar water heaters, wind turbines, geo-thermal sources and insulation techniques. We also understood that more than 80% of the appliances being used were energy star and therefore we searched for energy star appliances for out project.

Types of Technologies

- **Solar water heater:**

1. **Close coupled:** In this technology the storage tank is place directly above the solar collectors. With the help of passive heat exchange method the water rises to the storage tank without use of a pump.
2. **Pump circulated:** In the technology the storage tank can either be ground mounted or on the floor. A pump is used to circulate the water in between the collectors and the tank.

Comparison of Water Heaters					
High Efficiency Water Heater Type	**Energy Savings vs. Minimum Standards**	**Best Climates**	**Expected Energy Savings Over Equipment Lifetime**	**Expected Lifetime**	**Major Advantages**
High Efficiency Storage (Tank) (Oil, Gas, Elec.)	10%–20%	Any	Up to $500	8–10 Years	Lowest first cost
Demand (Tankless) Using Gas or Elec.	45%–60%	Any	Up to $1,800	20 Years	Unlimited supply of hot water
Heat Pump	65% (Compared to electric resistance)	Mild-Hot	Up to $900	10 Years	Most efficient electric fuel option
Solar with Electric Back-Up	70%–90%	Mild-Hot	Up to $2,200	20 Years	Largest energy savings using a renewable energy source

Figure: Water Heater Fact Sheet.

- **Insulation:**

1. Fiberglass Insulation is the most commonly used insulation by far, but it is very basic. It is usually stuffed inside the walls. Typically, it is important to ensure air tight seals in the walls prior to installing this type of insulation.

2. Cellulose Insulation is more expensive than conventional fiberglass insulation, and requires professional knowledge to install. It can be done two ways, dry as loose fill in wall, or sprayed on.

3. Cotton Batts are made completely from recycled materials, making them eco-friendly. It is efficient and effective if installed perfectly by a professional, but this always proves difficult because it is very tough to cut properly.

4. Spray Polyurethane Foam Insulation comes in two forms: open-cell, and closed-cell. This type of insulation is perfect for zero energy homes. Closed cell foam is very expensive, but outperforms all other types of insulation. It has an R-value of 6 per inch, where open cell foam has an R-value of 3.5 per inch (the same as fiberglass). However, open cell is considerably cheaper, and still provides good protection from the wind, like closed cell foam.

Type of Insulation	R-Value
Fiberglass	3.5 per inch
Cotton Batts	3.5 per inch
Cellulose	3.5 per inch
Closed-cell Foam	6 per inch
Open-cell Foam	3.5 per inch

**These R-values may vary between installations

Figure: Insulation Fact Sheet.

- **Geo-Thermal System:**

This technology extracts the heat from the earth using a heat pump. It is highly efficient but can only be used during winters. If the water comes out of a well as steam, it can be used directly, as in the design. If it is hot water of a high enough temperature, a flash system can be used; otherwise it must go through a heat exchanger. Since there

are more hot water resources than pure steam or high-temperature water sources, there is more growth potential in the heat exchanger design.

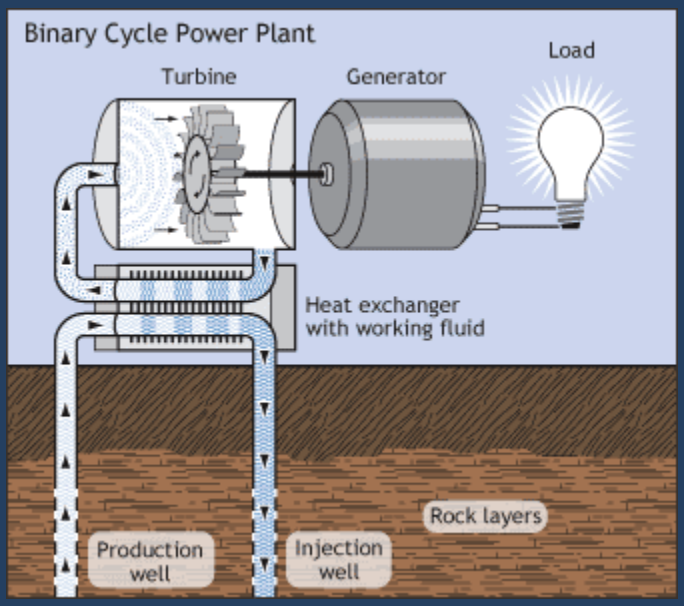


Figure: Geo-Thermal Flow Diagram.

- **Wind Turbine Technology:**

1. The technology generates electricity and feeds it directly to the grid.

2. The turbine usually has two or three rotor blades, positioned in front of the tower in the direction the wind are blowing.

3. Several different technologies are involved with a wind turbine: Aerodynamics, lightweight construction, electrical engineering, electronics, computer science and so on.

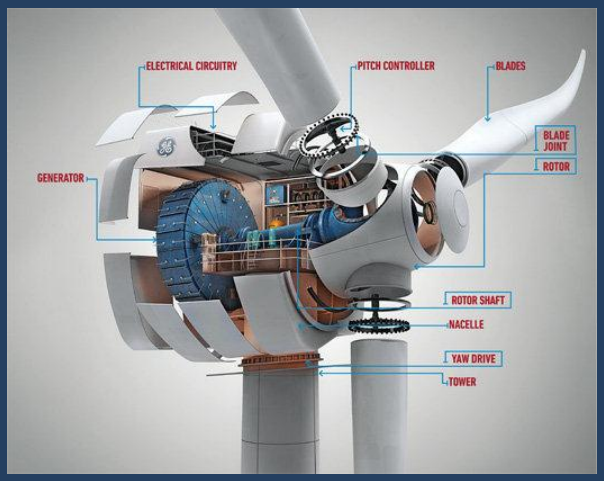


Figure: Wind Turbine Components.

- **LED Lighting:**

LED stands for Light Emitting Diode. It is a semiconductor light source that is most commonly used as an indicator light in electronic devices. They are starting to show up in a lot of other applications lately, including home lighting. Initially, the cost is more than that of compact fluorescent bulbs (CFL), but the savings over time is greater.

Advantages:

1. Extremely energy efficient, more so than CFL bulbs
2. Durable; they have no fragile filament inside

3. Long-lasting at about 50,000 hours: up to ten times as long as CFL bulbs

4. All LEDs are dimmable, and provide a high quality of light compared to other sources

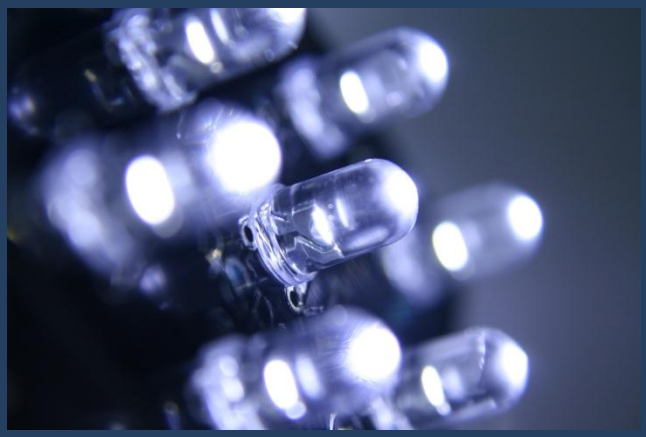


Figure: LED Lighting.

- **Solar-Window Technology:**

1. Ordinary glass windows can become solar windows by spraying the windows with a special electricity-generating substance.

2. The spray coating is thinner than a human hair and does not hinder visibility at all.

3. The coating produces electricity by absorbing both natural and artificial light.

4. The coating produces ten times more electrical energy than the leading solar window technology.

5. The coating can be applied at room temperature.

6. The coating is much cheaper than other solar window technologies.

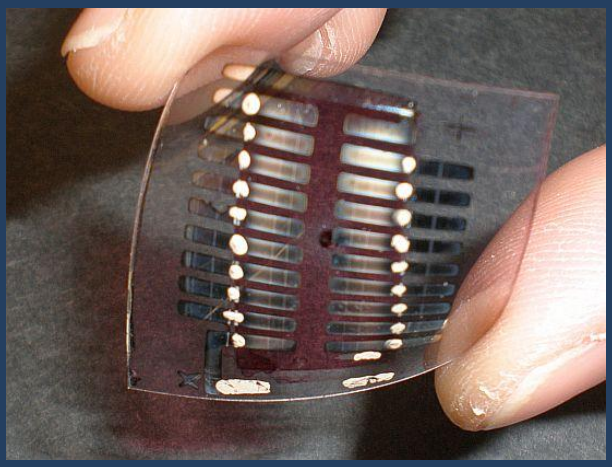


Figure: Solar Window Technology.

- **Solar Tubes:**

During the daytime, or whenever the sun happens to be out, solar tube lighting eliminates the need for artificial lights in any room in contact with the roof of the building. Essentially, solar tubes reflect sunlight into the house through the roof. The light is collected in a small dome, and sent through a metal tube to a diffuser lens, where it can flood through the room.

Figure: Solar Tube Prototype.

- **Tidal Energy:**

Tidal power, a form of hydro energy converts energy of tides to electricity. Even though its use is limited, it is a promising technology for future energy generations and is more predictable than wind or solar energy.

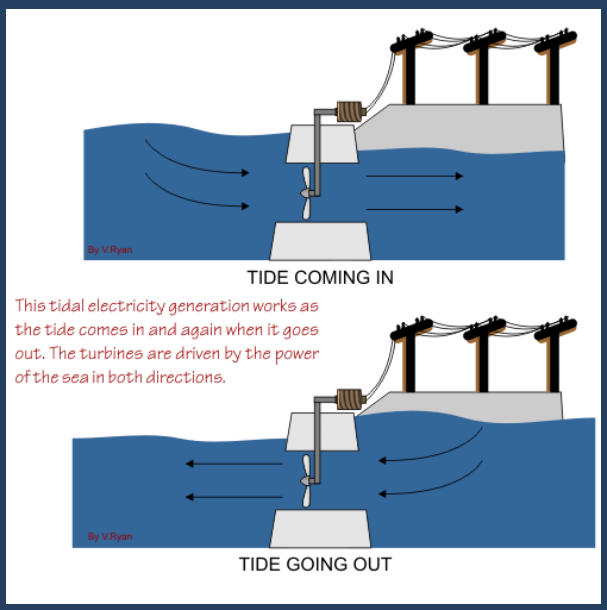


Figure: Tidal Plant Functional Diagram.

Energy Star Appliances

1. **Microwave Oven and Stove.**

Frigidaire Gallery 30” Slide-In Dual-Fuel Range

MRSP - $2249

Voltage Rating: 240V / 208V, 60Hz

Connected Load (kW Rating) @ 240V: 5.6 / 4.2

Amps @ 240 Volts: 23.3 / 20.2

Minimum Circuit Required (Amps): 20A

2. **Dish Washer.**

Frigidaire Professional 24” Built-In Dishwasher

MSRP - $749

Voltage Rating: 120V, 60Hz

Amps @ 120 Volts: 10.0

3. **Refrigerator.**

Frigidaire Gallery 22.6 Cu. Ft. French door Counter-Depth Refrigerator

MSRP $2,899

Voltage Rating: 120V, 60Hz

Amps @ 120 Volts: 8.5

Minimum Circuit Required (Amps): 15A

Connected Load (kW Rating) @ 120V: 1.02

4. **Washer.**

Frigidaire Affinity 3.81 Cu.Ft Front Load Washer featuring Ready Steam.

MRSP $1199

Power Supply Connection Location: Rear

Voltage Rating: 120V, 60Hz

Connected Load (kW Rating) @ 120V: 1.10

Amps @ 120 Volts: 10.0

5. **Dryer.**

Whirlpool Duet High Efficiency Front Loading Electric Dryer

MRSP $667

Voltage240 V

6. **HVAC.**

Frigidaire 15 SEER R6GF Gas/Electric Packaged Unit

Frigidaire 14/15 SEER FT4BE Heat Pump

World Marketplace

There is growing concern over the ecological impacts caused due to human exploitation of resources and therefore green energy and highly efficient technology is always on the charts. A Zero Energy Home which has zero net energy requirements, definitely interests the costumers. Since these homes can meet standards of a normal home and still meet all energy requirements, the demand for them is always rising.

Concept Generation

After understanding the problem, developing the need statements and doing extensive research on the present technologies we started brainstorming different ideas and discussed the benefits of these technologies.

First, we had to decide on the location. The team agreed on two promising cities, Bridgeport, Connecticut and Camden, Maine. Thereafter we reviewed all possible green technologies which included geo-thermal, tidal, wind, solar energies. We reviewed many technologies for the insulation and windows on the bases on cost and efficiency. The team paid close attention to the appliances that would draw energy and therefore reviewed energy star appliances from various companies. Various types of lighting technologies were also discussed keeping in mind the weather and the energy requirements of light bulbs. Natural sun lighting was also on the charts. At the end of the brainstorming session, with all the concepts laid down we started decided on the floor and screened the concepts as per requirements of our house.

Concept Selection

The after screening and scoring various concepts the team decided that the beach city Camden in Main a promising option for our Zero Energy Home as it received optimum sun light, was a pleasant city to live in and the changing weather would also test the capabilities of the house. Thereafter we started discussing the possible technologies that should be installed. A solar panel module which is a must and also the main energy generating source as seen in most of the successful homes was agreed upon. We also easily agreed that the home should have a solar water heater so that the sun's energy was directly harnessed to heat water instead of

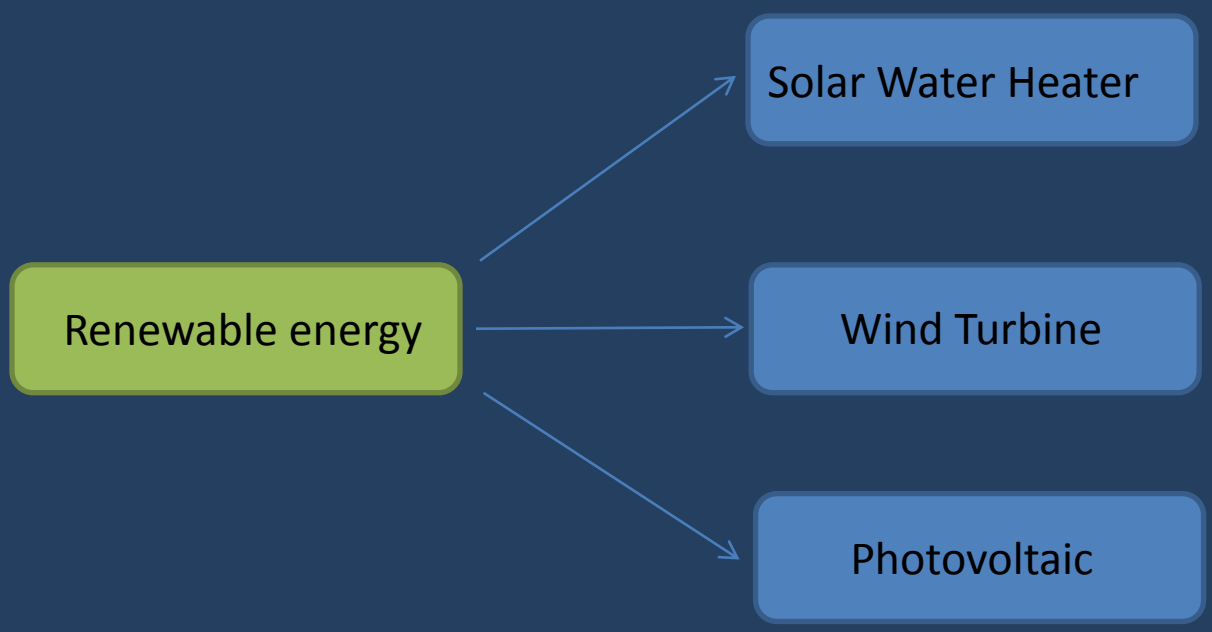
using electricity to perform the same task. The solar panels will be connected to the grid directly so that there is easy energy transfer during excess production and when electricity is required.

The team had a comprehensive discussion on whether to install a geo-thermal system or a wind turbine. Being restricted by the budget the team agreed that the wind turbine would be a better source for energy considering the proximity of the house to the ocean. The tidal energy system would be a complicated process to install and therefore was also dropped. We also agreed that use of the solar glass technology would be a better option rather than installing high-performance windows for the home. The roof insulation consists of a spray of Closed-Cell Polyurethane Foam which has an R-Value of 6 per inch. For the ceilings we decided on an Open-Cell Polyurethane Foam which has an R-Value of 3.5 inch. A HAVC unit which consists both the heating and conditioning unit will provide the required ventilation for the house.

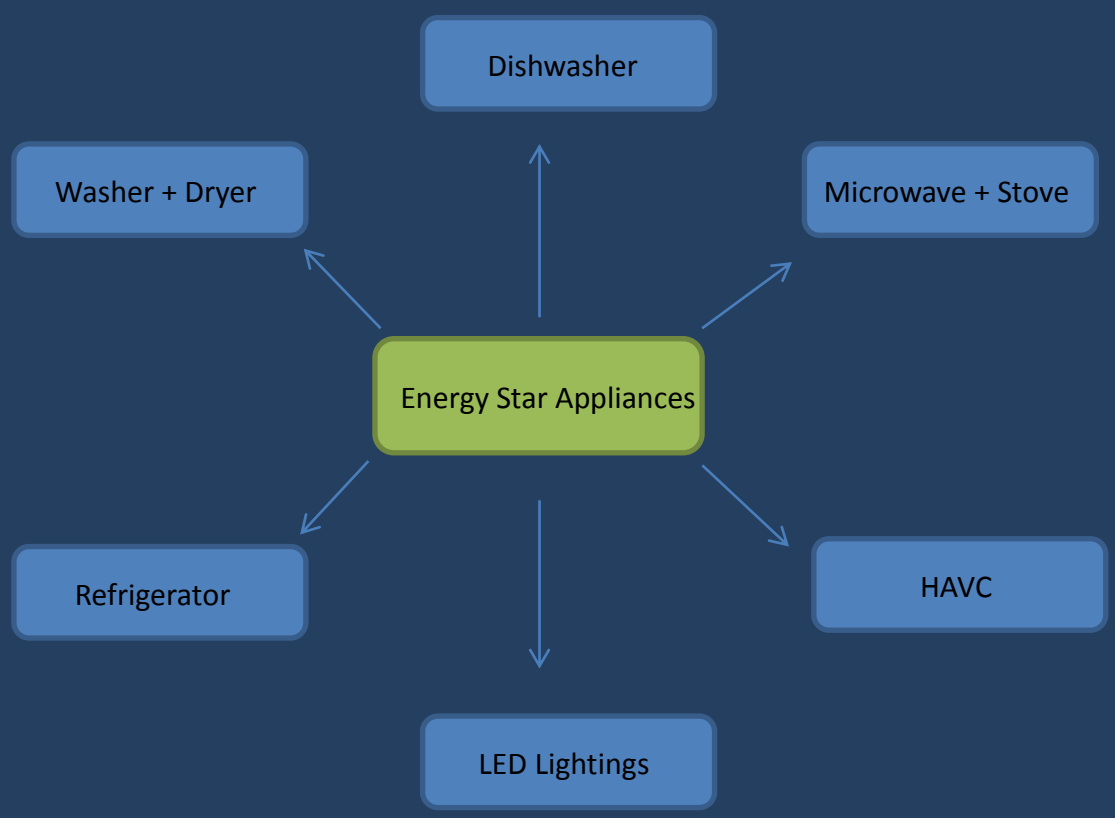
	Spray-On Solar Coating	Solar Film	Argon-Sealed Solar Glass	Fiberglass	Cotton Batts	Cellulose	Closed-Cell Foam	Open-Cell Foam	Solar Panels	Geo-Thermal	Tidal Energy	Solar Water Heater	Wind Turbine
Criteria													
Accomodates a medium sized family	+	+	0	0	0	0	0	0	0	0	0	+	0
Efficient use of space	0	0	0	-	0	+	+	0	+	0	-	+	+
Efficient use of energy	+	0	0	-	+	0	+	0	+	+	0	+	+
Contributes to energy production	+	+	+	0	0	0	0	0	+	+	+	0	+
Efficiently heats/cools house	0	-	+	0	0	+	+	+	0	0	0	+	0
Affordable	+	+	-	+	0	-	-	0	+	0	-	+	0
Prevents air flow	0	0	-	-	0	0	+	+	0	0	0	0	0
Sum (+)	4	3	2	1	1	2	4	2	4	2	1	5	3
Sum (0)	3	3	3	3	6	4	2	5	3	5	4	2	4
Sum (-)	0	1	2	3	0	1	1	0	0	0	2	0	0
Net Score	4	2	0	-2	1	1	3	2	4	2	-1	5	3
Continue	Yes						Yes	Yes	Yes			Yes	Yes

Figure: Concept Scoring

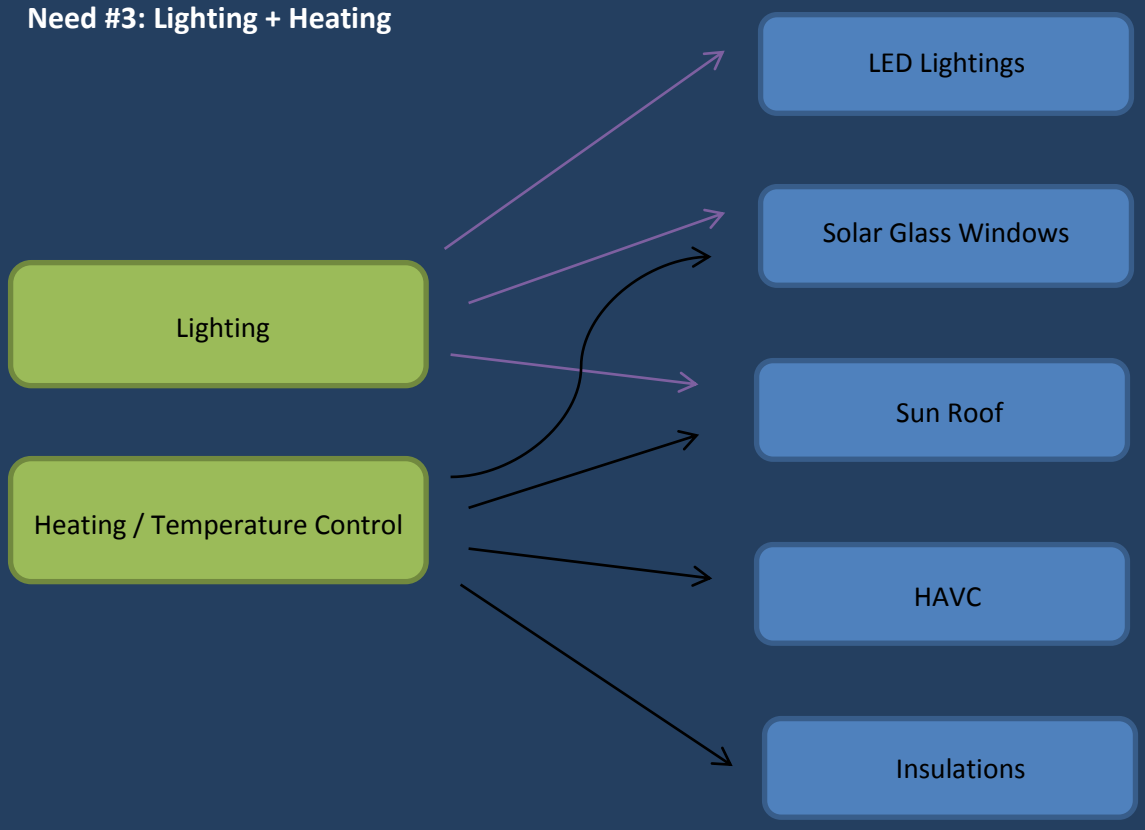
Need #1: Renewable Energy



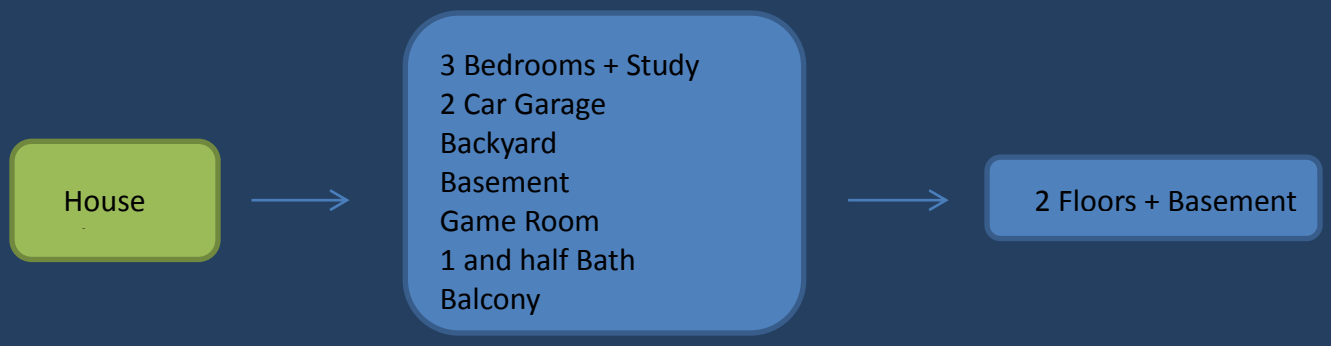
Need #2: Energy Star Appliances



Need #3: Lighting + Heating

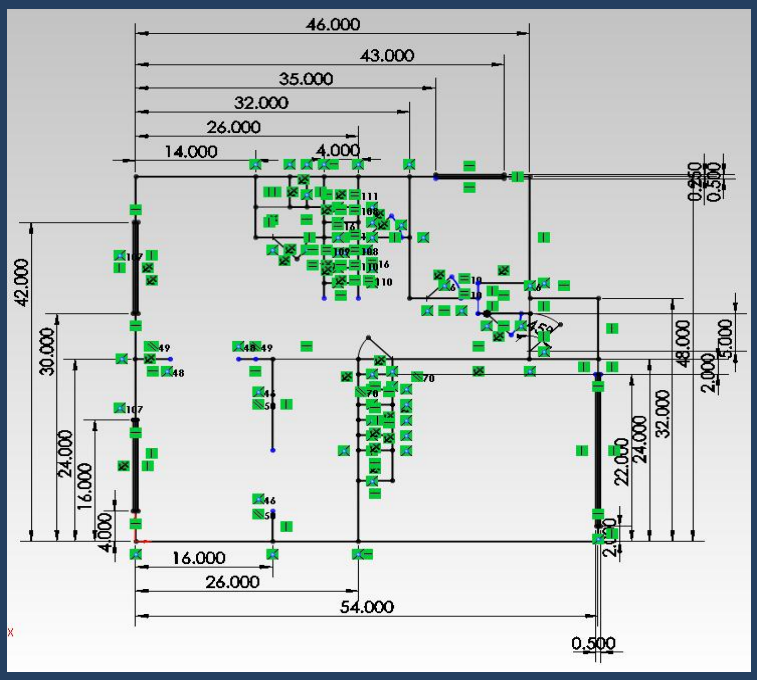


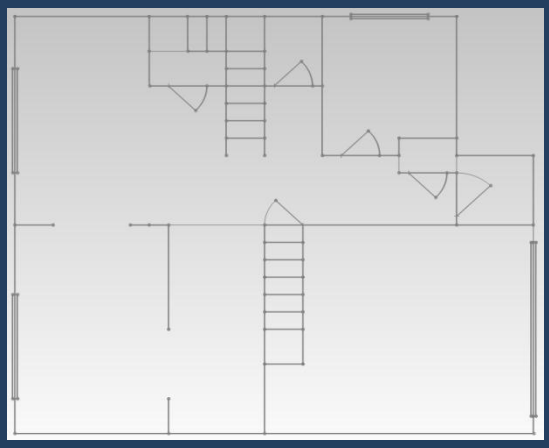
Need #4: House Plan



Final Design

Ground Floor





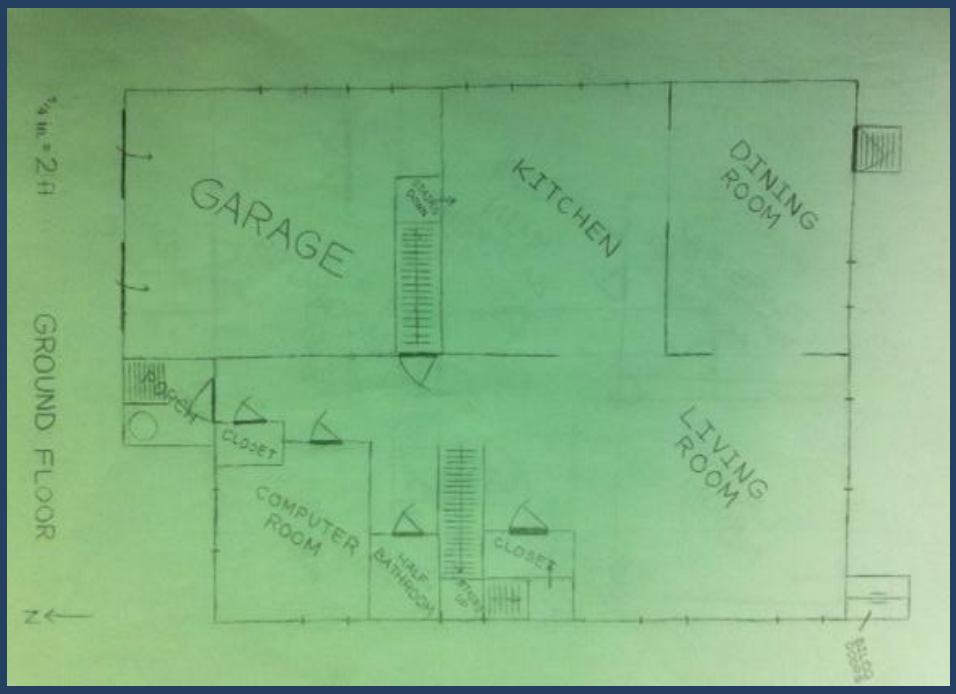
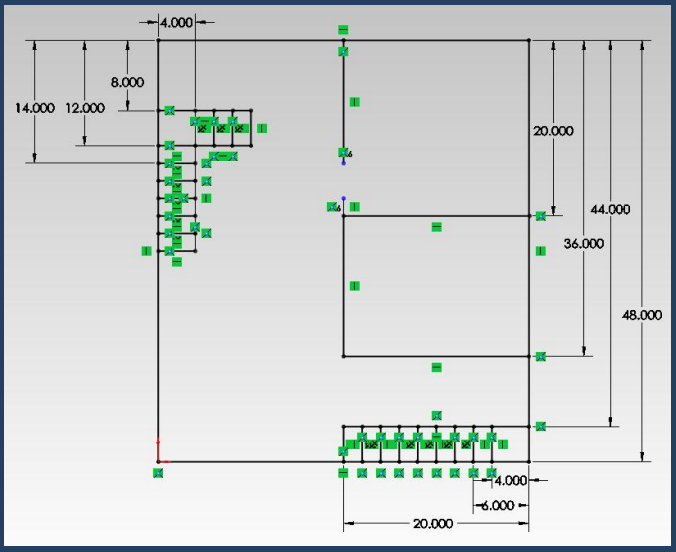
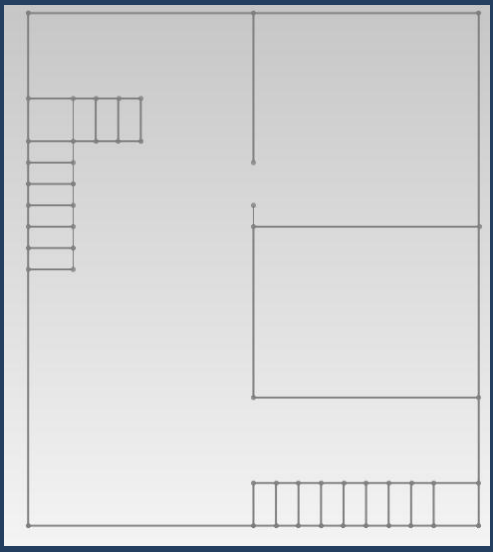


Figure: Ground Floor Sketch.

First Floor





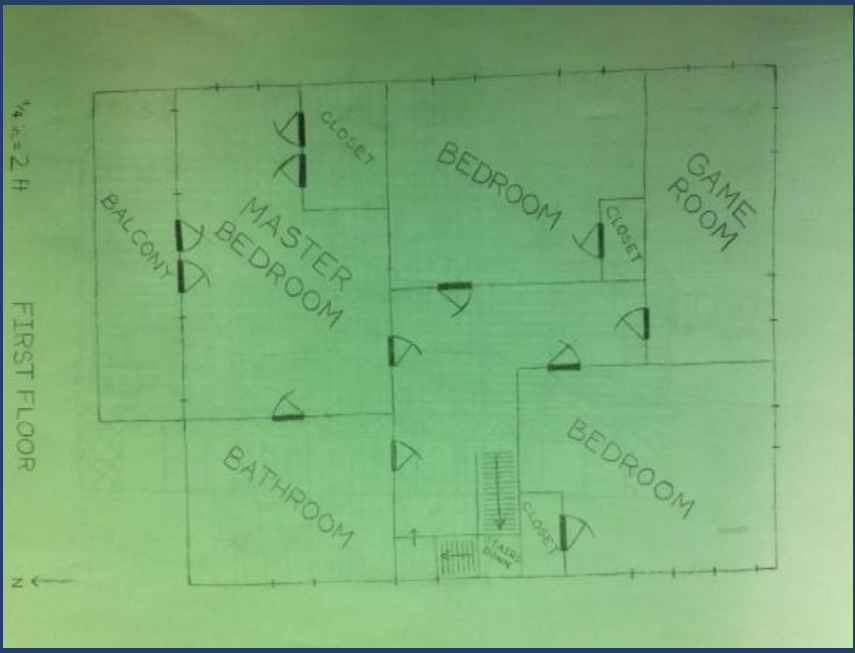
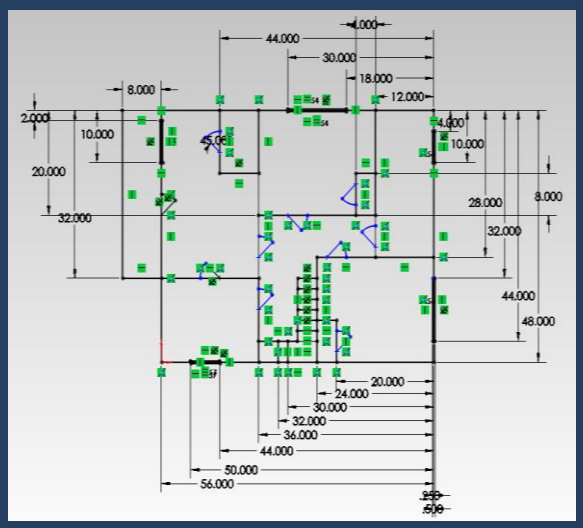
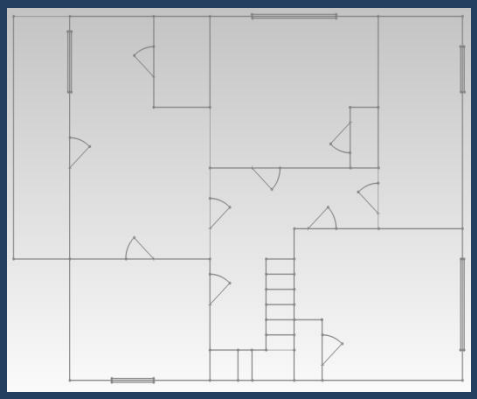


Figure: First Floor Sketch.

Basement





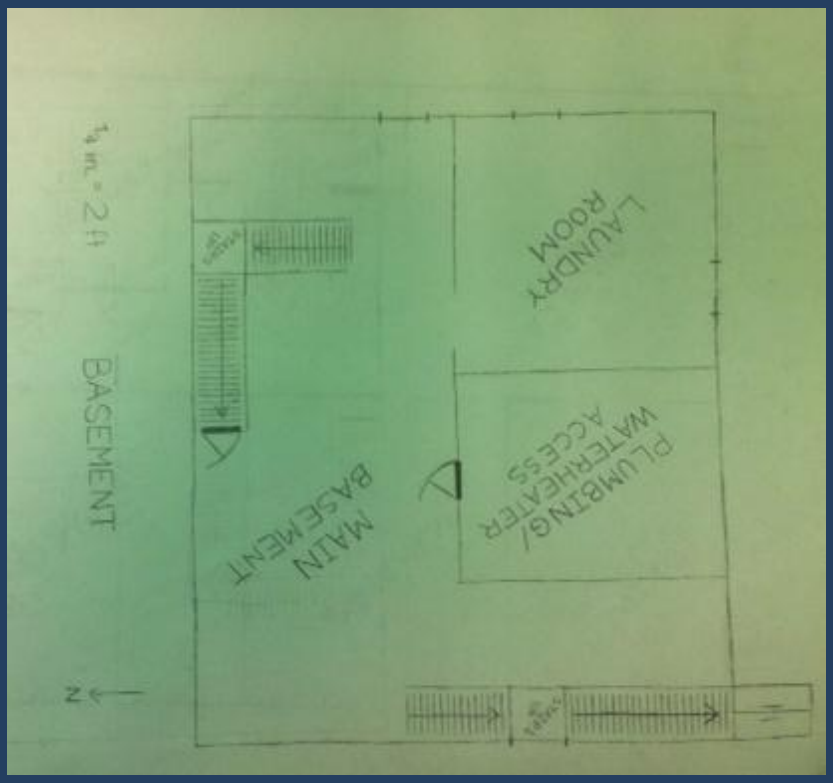
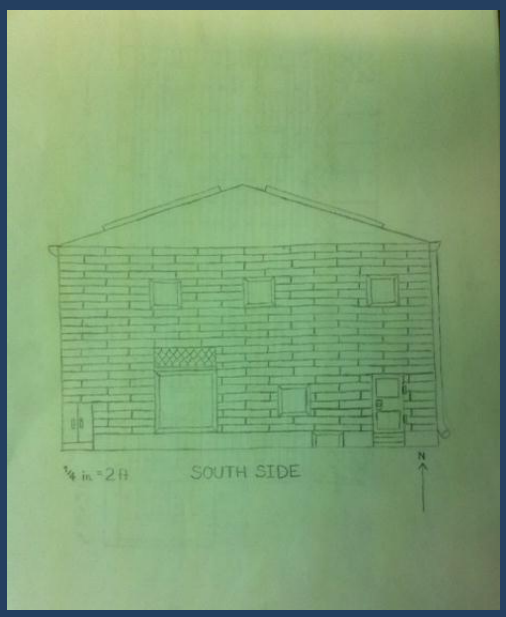
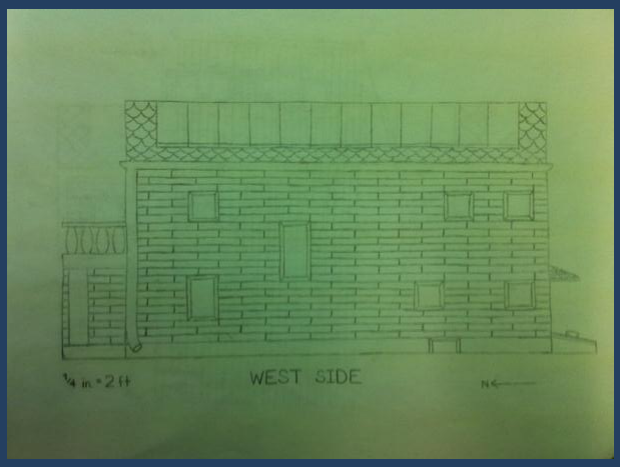
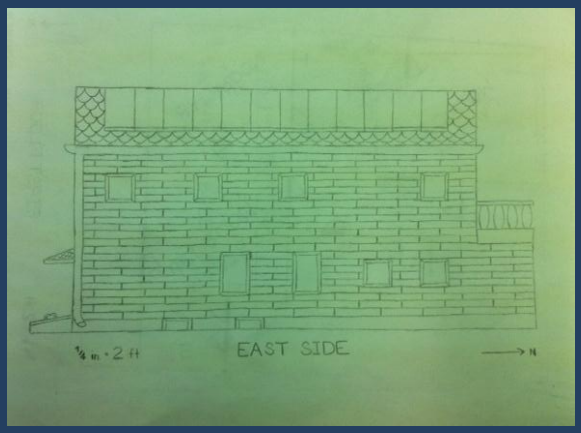


Figure: Basement Sketch

Elevation Views







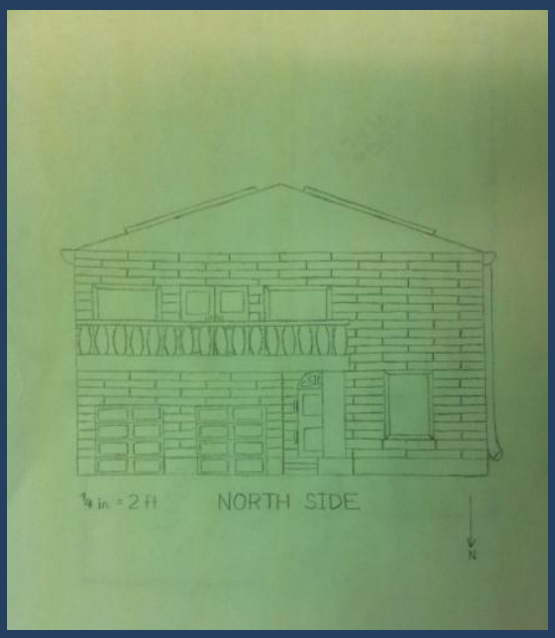


Figure: South, North, East , West Elevation Views.

Note: There was a change in design and location of windows and is shown in the Solidworks drawing.

Conclusion

Our team is now working on the prototype of the Zero Energy Home Project. We believe that our home can comfortably accommodate a medium size family and provide them with all the luxuries of a normal home. The house is installed with highly efficient energy star appliances which are guaranteed to satisfy customer needs. Our Zero Energy House utilizes efficient energy generating systems so that the house has at least a net-zero energy over the year. Our design ensures that the house utilizes most of the natural resources. This project helped us understand the engineering process which we incorporated in the design and development. Our team strongly believes that Zero Energy Homes should be built all across the world as they present promising statistics which make our Earth more sustainable and reduces the impact of humans on it.

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