Design Project 1

Zero-Energy Home

EDSGN 100-Section 016

Team Number 6: The Peacocks

Submitted to: Wallace M. Catanach

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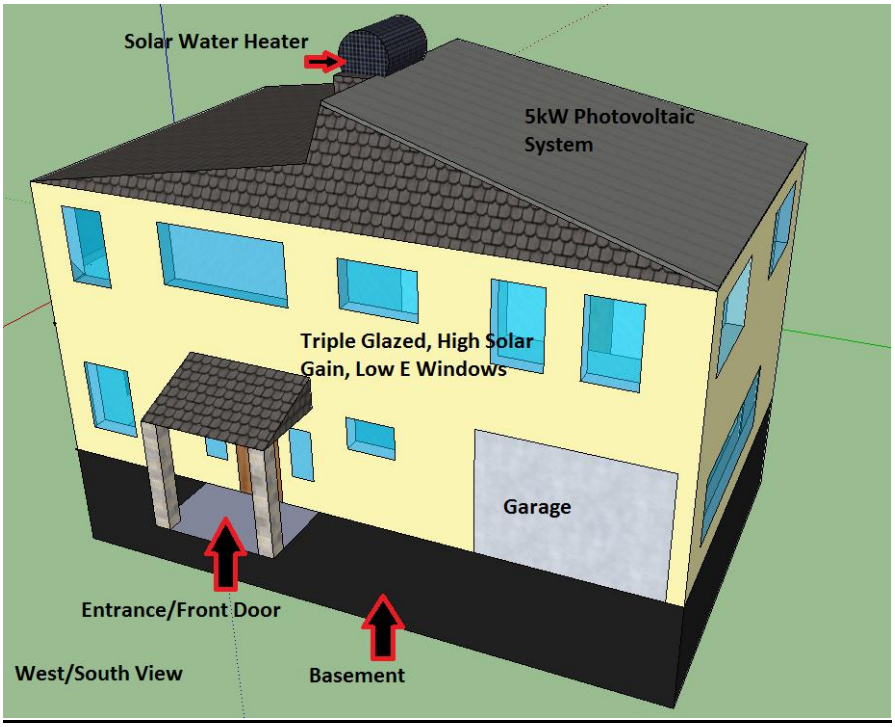
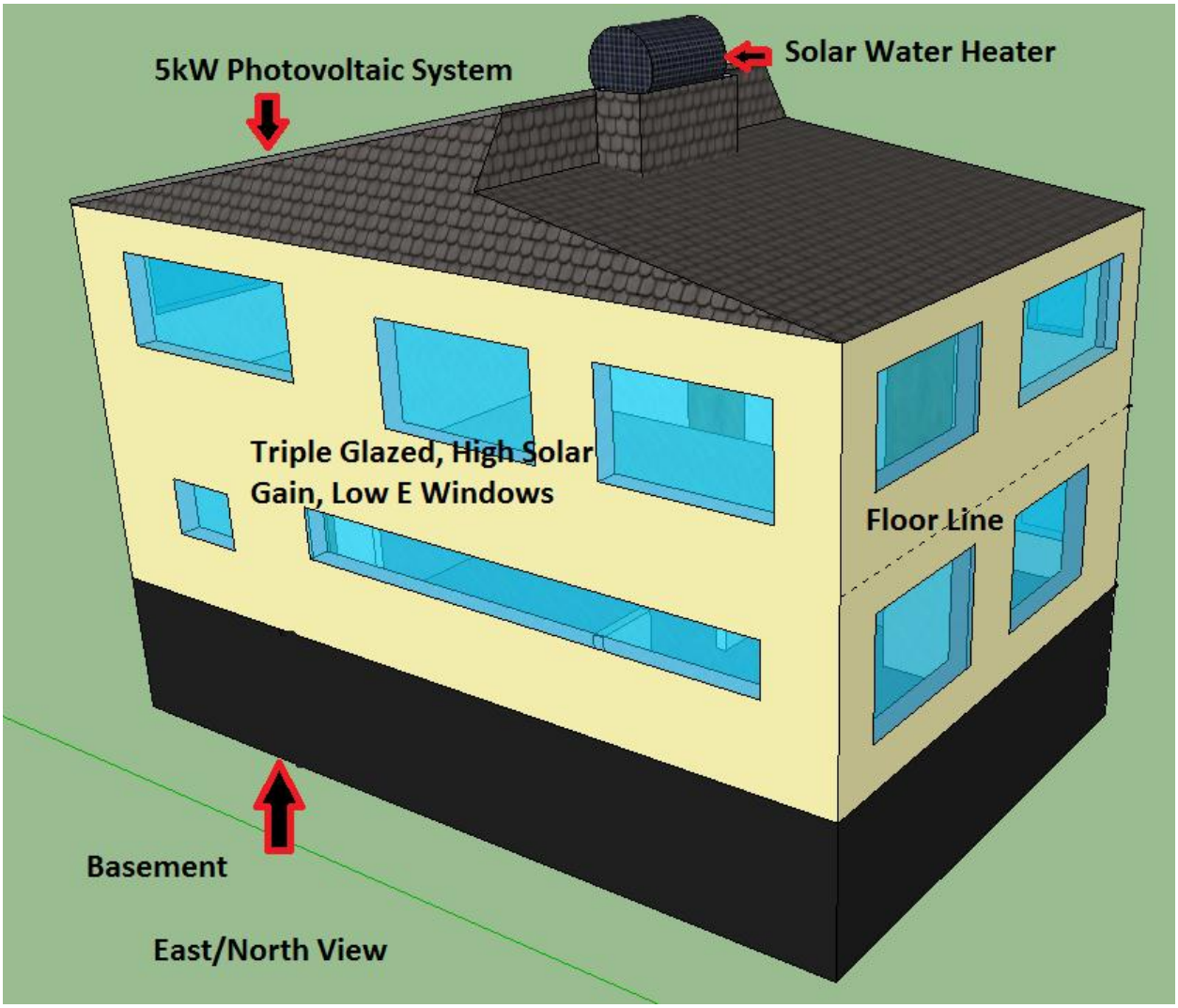
Descriptive Images of the Prototype:

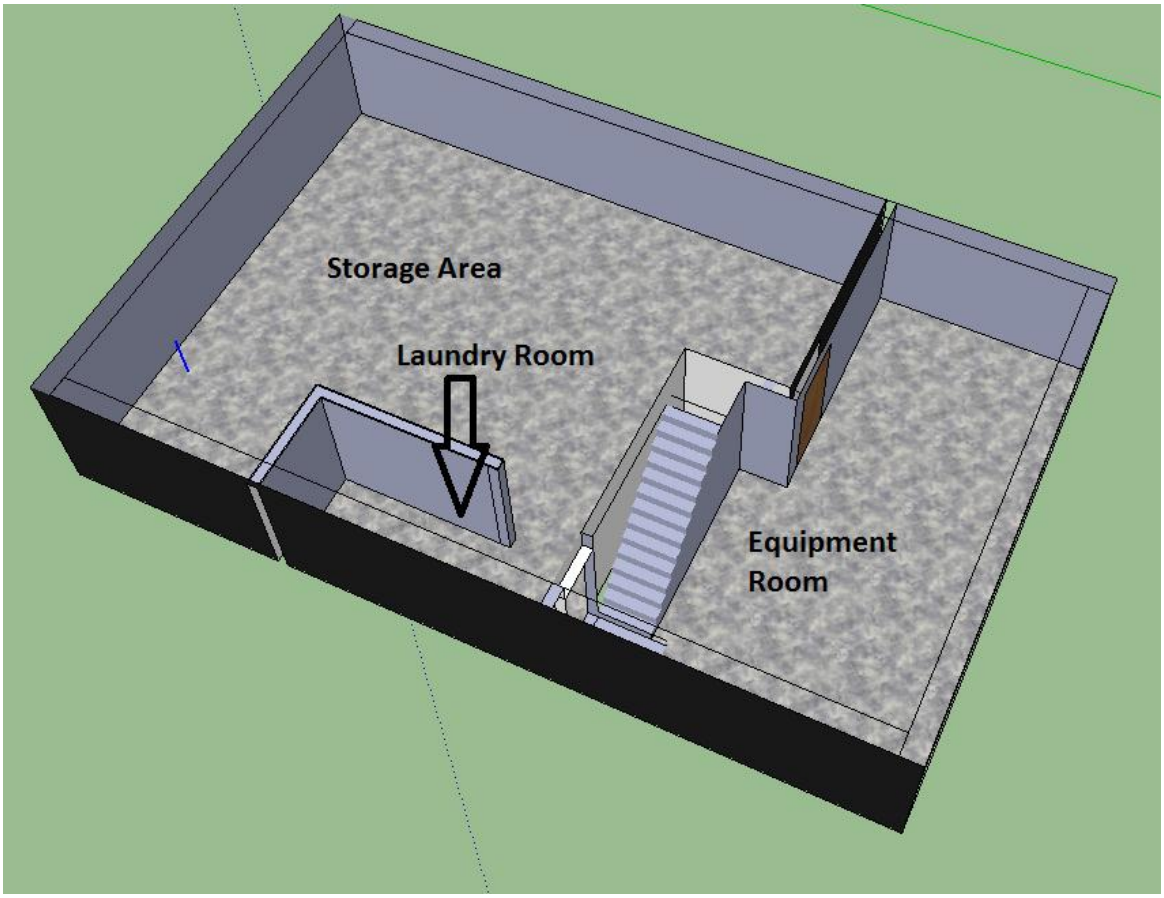
West and South Outside View

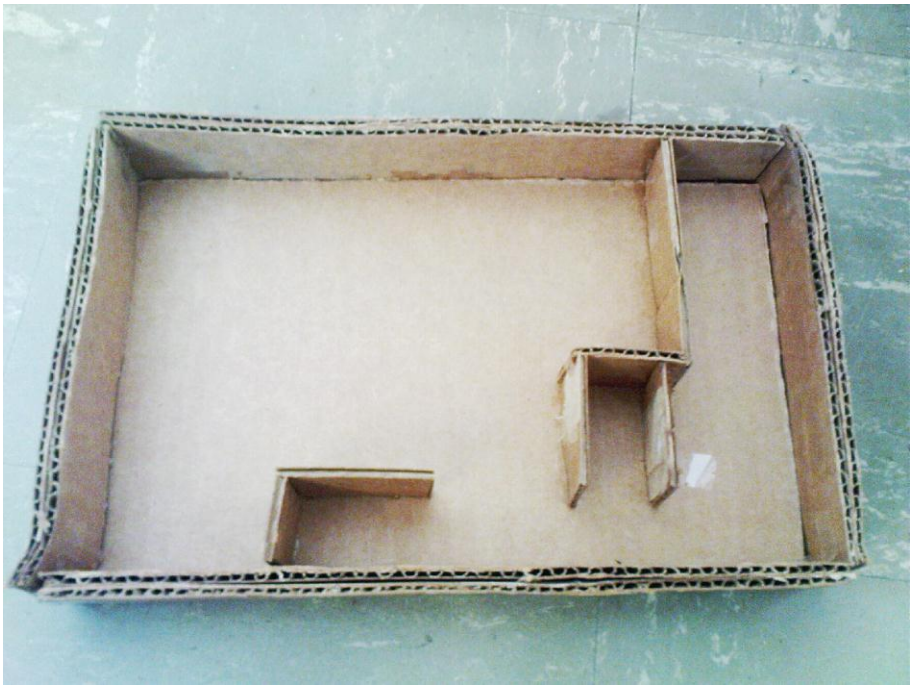


East and North Outside View

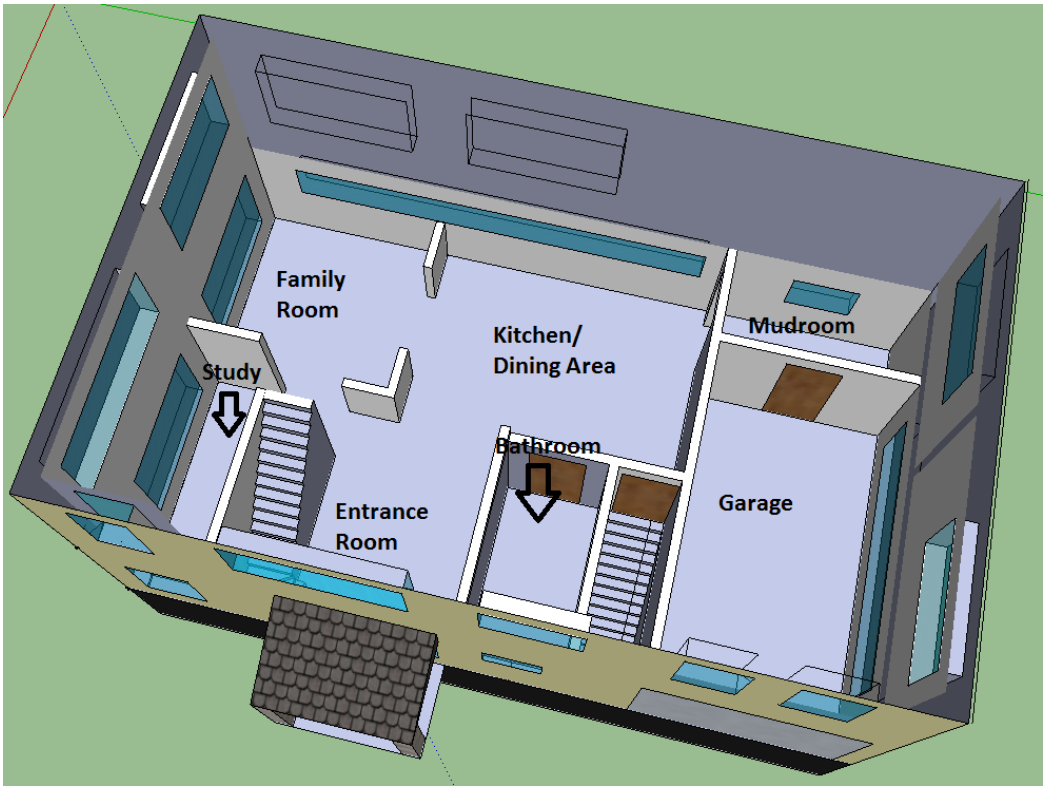


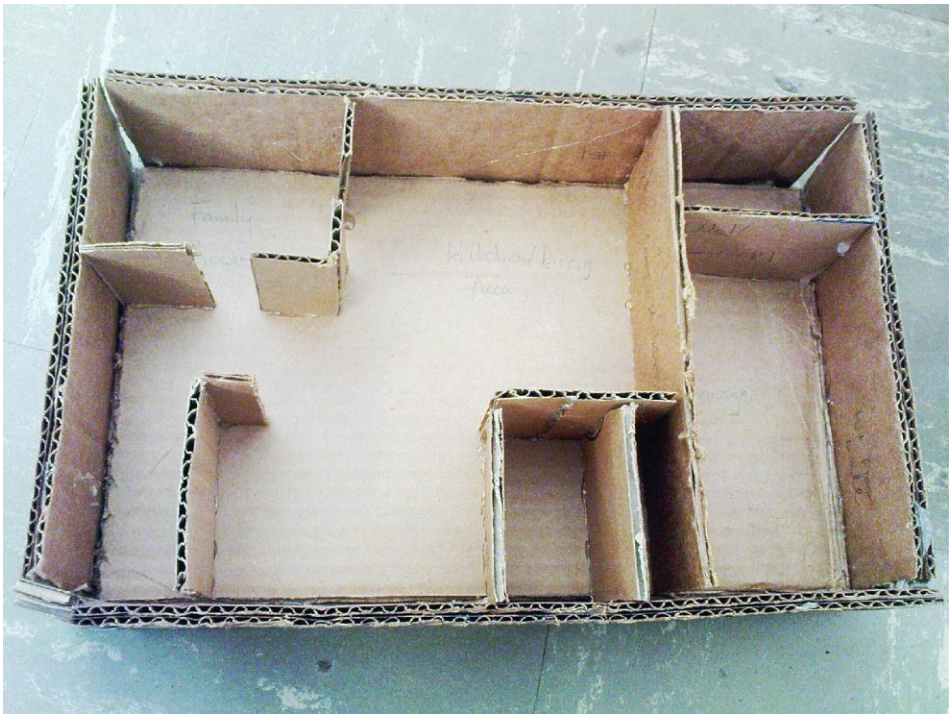
Basement Floorplan



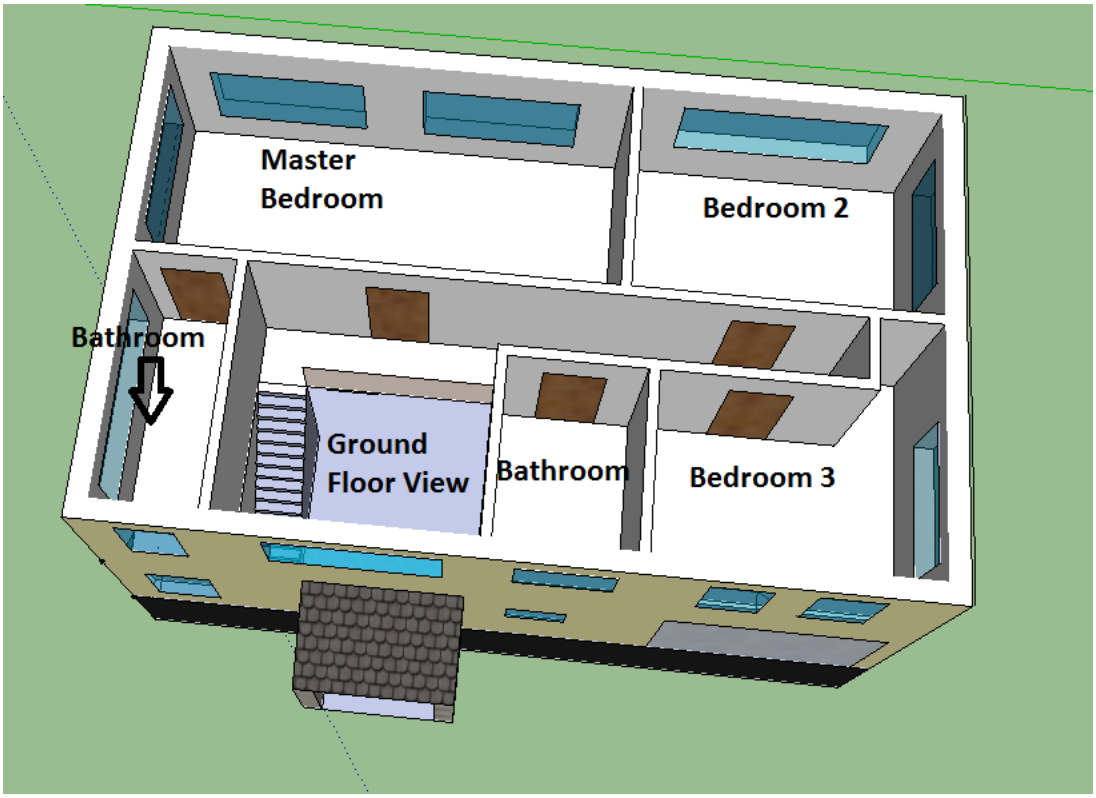


First Floor


Family
Room
Kitchen/
Dining Area
Mudroom
Study
Bathroom
Entrance
Room
Garage



Second Floor



Abstract:

Team 6 of EDSGN 100 Section has designed and built a model for a zero energy home. The home will be able to meet the needs of a family of four as well as provide, on average, as much energy as it consumes. The final home design was based on what was needed to fulfill the customer requirements and how to do so in the most effective manner. The components of the home were research and analyzed in order to find the most effective methods in order to achieve a zero energy home status. Some of the components used to achieve this zero energy status include photovoltaic systems, solar water heaters, wind turbines, and also several building methods designed to minimize energy consumption and energy loss.

Introduction:

Zero energy homes are houses that are designed to have an average net zero energy consumption. Many factors must be taken into consideration in order to successfully achieve this goal, ranging from energy efficiency applies to installation of renewable energy resource harvesting systems. Although zero energy homes are currently rare in the United States, the number should increase as the abundance of natural resources decreases. Designing a zero energy home which is both affordable and able to meet the needs of an average family should help speed up this process as we work towards a sustainable future.

Mission Statement:

Product Description	A home that runs on zero net energy
Benefit proposition	Uses less energy than average homes, decreasing the owner's ecological footprint & saving them money on energy bills
Key business goals	Product introduced Oct. 5, 2011 Home uses little energy as possible without being dramatically expensive
Primary market	Family of 4 interested in decreasing environmental impact
Secondary market	Family of 4 interested in saving money on energy bills and receiving tax benefits
Assumptions	Meets needs of family of 4, suburban residential area
Stakeholders	Construction company, retailer, home owner, IRS

Customer Needs Analysis:

Based on the customer requirements and a poll given out randomly to Penn State students, the following are the customer needs that were incorporated when designing this zero energy home:

- The house is able to meet the needs of a family of four. Importance=5
- The physical appearance of the zero energy home is astatically pleasing. Importance=3
- The house is built using green energy principles. Importance=4
- On average, the house is able to supply as much energy as it consumes to achieve a zero energy status. Importance=5
- The cost for the house is in the same price range as other houses with a similar size and perks. Importance=3
- The amount of work and maintenance needed for the zero energy house is no more than a regular home. Importance=3

Needs-Metric Matrix Metric

. Need	1800+ sq feet	Solar Panels	Wind Turbine	Geothermal Heater	Solar Water Heater	Wall Insulation	Ceiling Insulation	Window/Awnings	Cost Effective Material	Two Full Baths	Water Conservation	Energy Star	Rain Draining System	Three Bedrooms	Up to date look
Meet needs of family of four	X									x				x	X
Ascetically Pleasing	X							X				X	X		
Built Using Green Energy Principles		X	x	X	x	X	x	X			X	X	X		X
Net Zero-Energy Use		x	X	x	X	x	X	X			X	X			X
Similar Price Range	X								x			x			x
Work/maintenance is average	X			x	X			x		x	X		X		

External Research:

Solar Panels (SolarPanelInfo)

- Producers: Sunwize, Evergreen & Mitsubishii Electric
- Ideally: in direct sunlight @ surface of the equator, max efficient photovoltaic cell 1/5m in diameter creates current of approx. 2 amps @ 2 volts
    - Not actually as efficient
    - Get less efficient over time
- Convert solar energy into usable electrical energy & stores it in batteries
- Installed on rooftops
    - Direct sunlight is best
    - Remove branches & other objects blocking sun
- Mounts
    - Flush: for small solar panels on houses & RVs, can't change tilt
    - Roof-ground: for larger solar panels on housings, buildings or on ground, more difficult to install on roofs
    - Pole: panel is on poles in ground
        - Tracking pole mounts: track sun, more efficient
- Cost around $6 to $8 per watt including installation
- Pennsylvania Sunshine Solar Program offers discounts up to $12,000

- Federal incentives offer up to a 30% tax rebate (GetSolar)

Geothermal Heat Pumps (Energy Savers)

- Uses refrigerant to carry heat from outdoor unit to indoor unit
- Use Earth's constant temp as exchange medium (not air temp)
    - Winter: move heat from Earth into home
    - Summer: move heat from house & discharge in ground
- Fluid circles through series of pipes (called loop) & carries heat
    - Horizontal ground closed loops
        - Parallel plastic pipes placed 3-6 ft underground
        - 400-600 ft for each ton of heating/cooling
    - Vertical ground closed loops
        - Small yard space/digging is impractical
        - Vertical holes 150-450 ft deep
        - U-shaped pipe is inserted
        - More expensive than horizontal, but require less piping and space
        - Cost around $15,000 to $20,000 with drilling costs
    - Pond closed loops
        - Fluid circulates through pipes underwater
        - Pipes may be coiled
- Can heat, cool & supply hot water
- Compared to air-source
    - Geothermal=more efficient
    - Quieter, longer laster & require less maintenance
    - More expensive
- Dual source combines geothermal & air-source
    - Cheaper, but less efficient
- Last about 25 yrs
- Can be equipped w/ desuperheater which heats household water
    - In summer heat that would be expelled heats water
    - Need conventional water heater also to meet needs in winter

Solar water heater (Energy Savers Solar Water Heaters)

- Made up of water tank & solar collectors
    - Storage tank must be well insulated
- 2 tank system
    - solar water heater preheats water before it enters the conventional water heater
- 1 tank system
    - back-up heater is combined with the solar storage in one tank
- Residential solar water heaters:
    - Flat-plate collector
        - Glazed
            - insulated, weatherproofed box

            - contain dark absorber plate under one or more glass or plastic (polymer) covers
        - Unglazed
            - typically used for solar pool heating
            - dark absorber plate
            - made of metal or polymer
            - no cover
    - Integral collector-storage systems (ICS or batch system)
        - feature one or more black tanks or tubes in insulated, glazed box
        - cold water first passes through the solar collector, which preheats water
        - water continues to conventional backup water heater
        - provides reliable source of hot water
        - installed only in mild-freeze climates
            - outdoor pipes freeze
    - Evacuated-tube solar collectors
        - parallel rows of transparent glass tubes
        - each tube contains a glass outer tube and metal absorber tube attached to a fin
        - the fin's coating absorbs solar energy but inhibits radiative heat loss
        - used for U.S. commercial applications
- active solar water heaters:
    - Direct circulation system
        - pumps circulate household water through collectors and into home
        - work well in climates where it rarely freezes
    - indirect circulation system
        - Pumps circulate non-freezing, heat-transfer fluid through collectors & heat exchanger
        - heats the water that flows into the home
        - climates prone to freezing temperatures.
- Passive solar water heaters:
    - Have circulating pumps & controls
    - Less efficient than active
    - More reliable & last longer than efficient
    - Integral collector-storage passive system
        - Best where temps usually don't freeze
        - Houses w/ significant day & night hot water needs
    - Thermosyphon system
        - Warm water rises & cold water sinks as water passess through system
        - Requires very heavy storage tank
- Prevent freezing
    - Use antifreeze solution as heat transfer fluid
        - Glycol/water mixtures
    - Manually drain piping

Wind Turbine (WindPower)

- Converts kinetic energy of moving air into other usable forms of energy

- Usually electro-mechanical system that converts wind power to electricity
- Minimum wind speed to function is 8-16 mph
- Shuts off at high winds over 50 mph
- Most have 3 blades
- Horizontal axis (propeller-style)
    - more efficient
    - require tall towers (expensive)
    - must constantly align direction of air flow
    - more common
- vertical-axis (egg-beater style)
    - less efficient
    - don't have to be pointed into wind
    - can be mounted on home's flat rooftop

Insulation (Energy Star Insulation)

- The R-value is the measure of resistance to heat flow. A higher number means lower heat loss and/or entrance (Green Building Advisor)
- R-36 wall insulation corresponds to Double 2x4 with 10" foam installation
- Cost's around $1.5/sq ft
- R-60 ceiling insulation costs around $2,000
- R-36 basement insulation will cost around $2,000

Windows (Haglund)

- Pennsylvania cold enough where most energy is used on heating
- Triple-glazed, high solar gain, low e glass lets in most heat and most light
- Designed for cold locations
- Let's in 50% of solar heat and 65% of visible light
- Costs around $3,000 for all windows

Airtight with Heat Recovery System (

- House needs to be airtight to minimize heat loss/heat entrance
- Ventilation systems are required in airtight houses in order to circulate fresh air for breathing, diluting pollutants, and controlling humidity
- Heat recovery systems are able to control the air flow and also exchange humid inside air for dryer air outside
- As the heat is being transferred out, it transfers the heat to the incoming air in order to lower the amount of energy needed to heat the new air back up to the correct temperature
- Costs around $5,000

Retractable Window Shades (Polar Shades)

- Able to raise and lower at command
- Provides shade and blocks the sun's heat from entering
- Only would install on east/west windows
- Cost is around $3,000

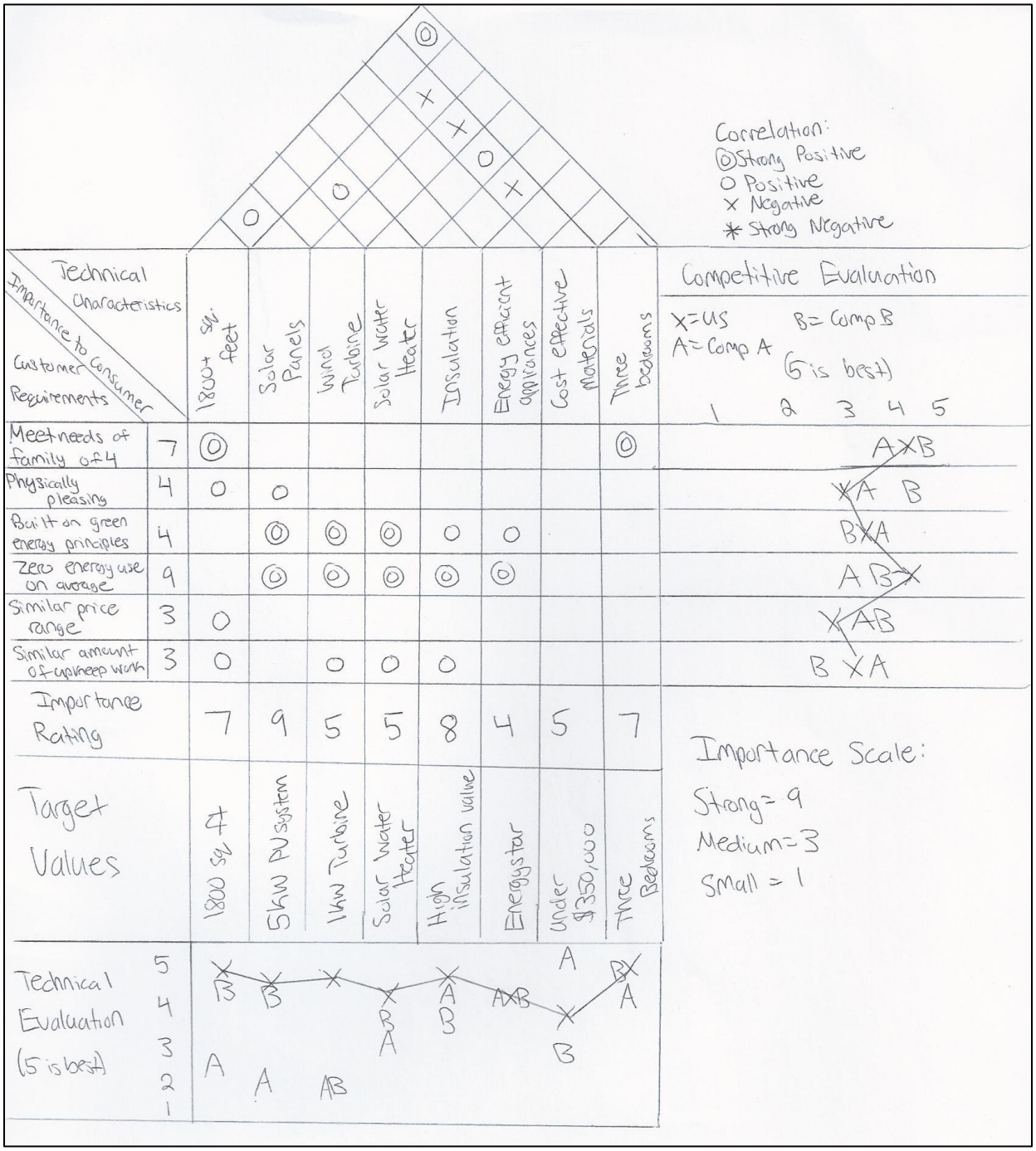
Energy Efficient Appliances (EarthEasy)

- Use the very best Energy Star appliances
- Use energy saving techniques such as cold water washing, energy saving modes, having a smaller refrigerator/freezer, using clothes lines instead of the dryer, running only full loads
- Energy Start CFL lighting uses 75% less energy and lasts 10x as long as traditional light bulbs

Water Saving Appliances and techniques (Moen)

- Low pressure faucets and showerheads conserve water
- Low water volume flush toilets to save water

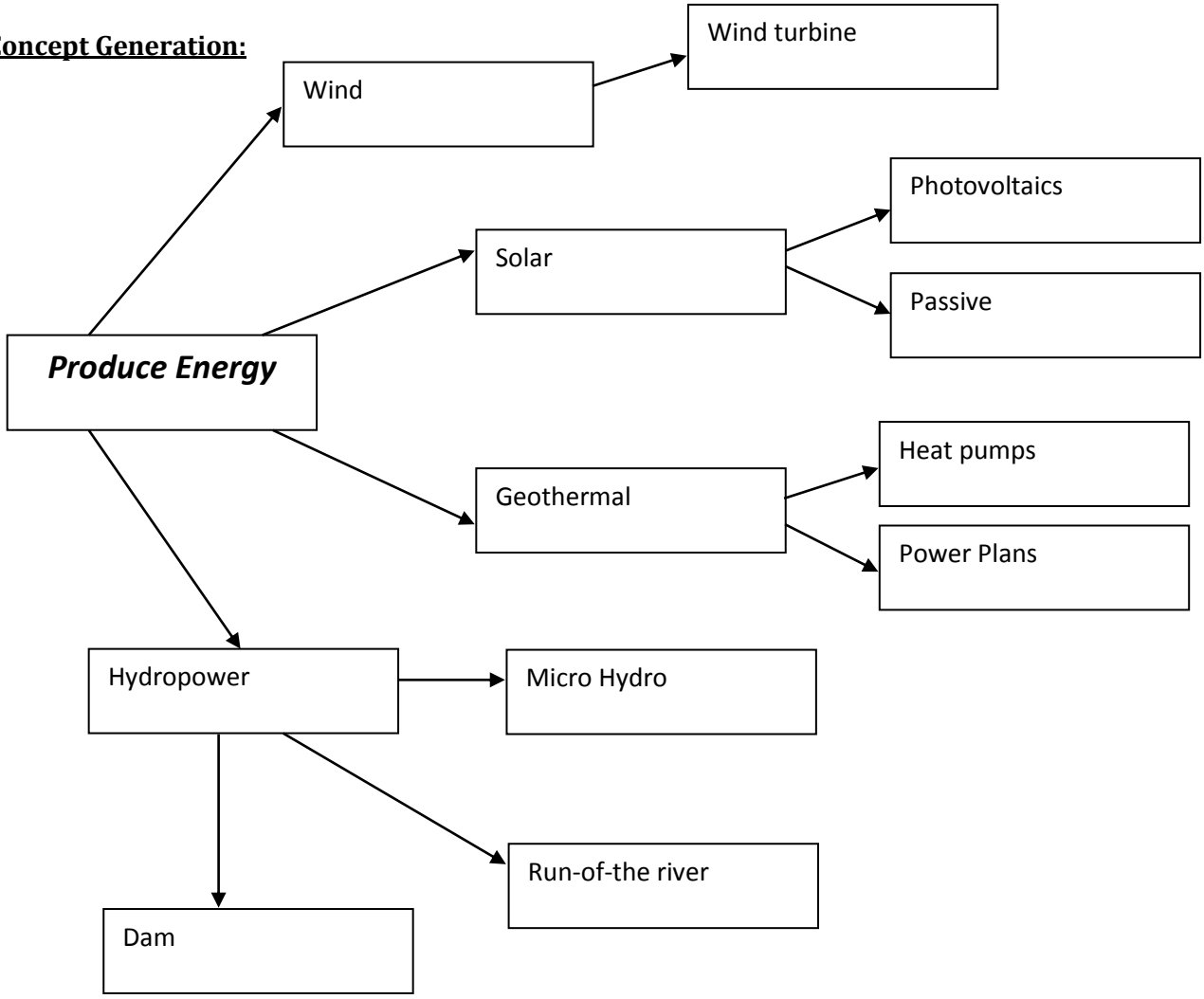
House of Quality

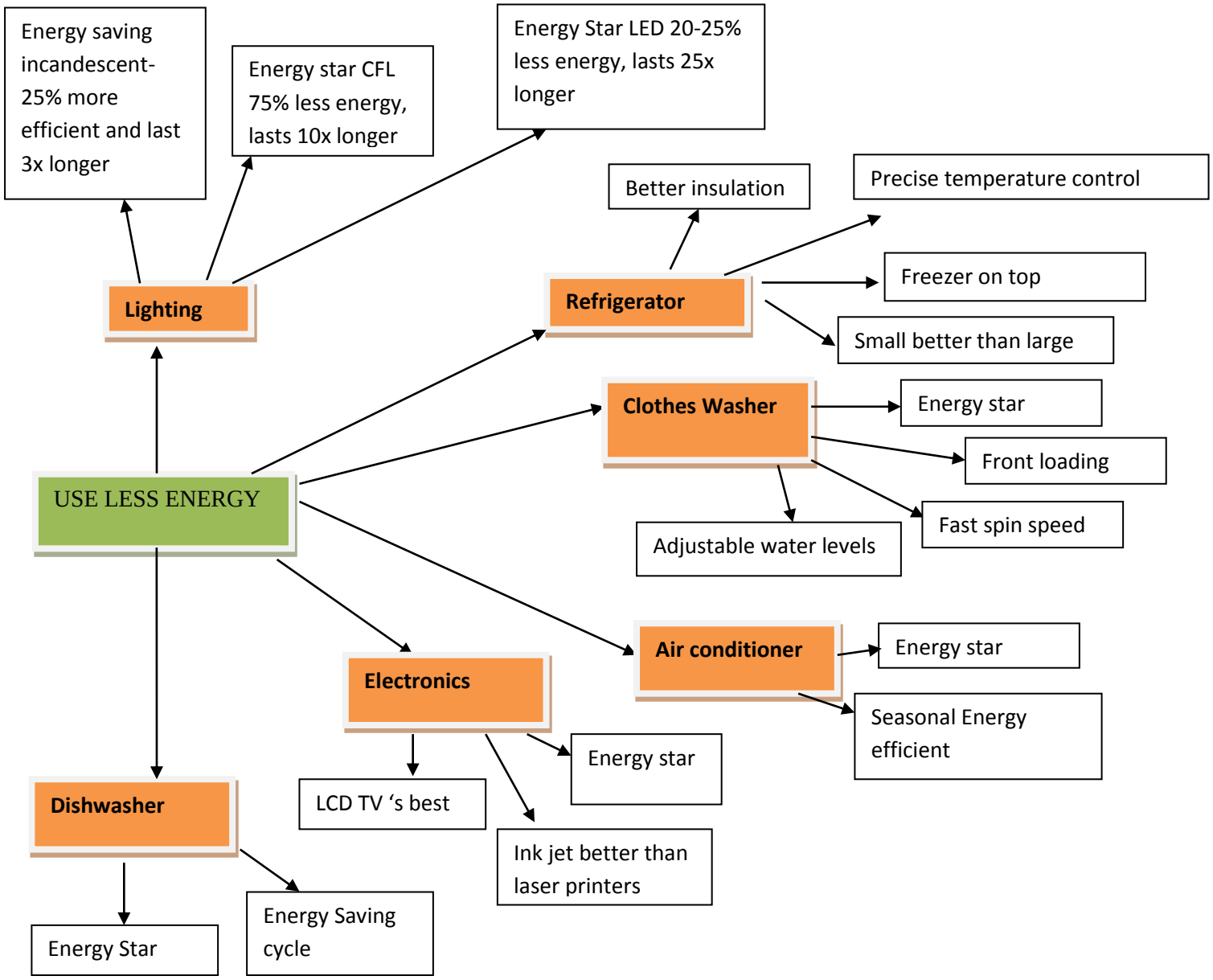


Location (city, state)	**Pittsburgh, PA**	Denver, Colorado	Lawrence, MA	Ann Arbor, Michigan	Lebanon, NJ	Charlotte, Vermont
House size (floor area in square feet)	**1807.5**	1,200	2080 square feet	2200/1300	4,200 square ft	2,800 square ft
Number of floors	**3**	1	3	2	2	2
URL of web site where info is found		http:www.nrel.gov/docs/fy06osti/39678.pd	http://www.zechallenge.com/BR-overview.htm	http://web.me.com/kellygrocoff/missionzerohouse/About.html	http://www.collegepublishing.us/jgb/samples/JGB_V5N2_b01_hoque.pdf	http://www.collegepublishing.us/jgb/sample.pdf
Number of occupants	**4**	3	Single Family	3	Single family	Single family
Number of bedrooms	**3**	3	3	3	4	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	**Electric Geothermal heat pump, solar thermal,**	Active solar thermal with radiant floor, baseboard heaters, ground-coupled heat pump, natural gas furnace, electric resistant baseboard heating	Boiler system	Geothermal heating, air conditioning	Thermal mass element	Geothermal heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	**Electricity**	Natural gas, electricity.	electricity	Electricity	Solar	Wind
Size of photovoltaic system (kilowatts)	**5 kW**	1.1	3.42kW	8.1 kW	9.8 KW	None
Solar water heater (yes or no)	**Yes**	Yes	No	Yes	yes	No
R-value of wall insulation	**R-36**	R-40	Foundation insulation: R10 Wall Insulation: R19	R-13	35 °F-ft^2-hr/BTU	40 °F-ft^2-hr/BTU
R-value of ceiling insulation	**R-60**	R-60	R30	R-7.41	35 °F-ft^2-hr/BTU	56 °F-ft^2-hr/BTU
Ventilation air heat recovery (yes or no)	**Yes**	Yes	Yes	Yes	yes	yes
Predicted or measured annual energy use	**7385 kWh/ yr**	Not stated	72.5 MM Btu/yr	10,000 kWh used, over 10,500 kWh produced for an annual energy use of below zero	N/A	6500 kWh per year
Any other pertinent info	**All appliances used are EnergyStar. Energy efficient windows**	Windows have been moved to provide solar heating,	Part of a series of six affordable houses striving to achieve zero energy use	House is over 100 years old, special energy windows, automatic lights to save energy, $47,000 investment after government incentives and tax returns		

Global Marketplace

Concept Generation:




USE LESS ENERGY
Lighting
Energy saving incandescent- 25% more efficient and last 3x longer
Energy star CFL 75% less energy, lasts 10x longer
Energy Star LED 20-25% less energy, lasts 25x longer
Refrigerator
Better insulation
Precise temperature control
Freezer on top
Small better than large
Clothes Washer
Energy star
Front loading
Fast spin speed
Adjustable water levels
Air conditioner
Energy star
Seasonal Energy efficient
Electronics
Energy star
LCD TV 's best
Ink jet better than laser printers
Dishwasher
Energy Star
Energy Saving cycle

Concept Selection:

After considering all of the possibilities and options, we narrowed our final specifications down based on cost effectiveness and usefulness. We then entered these specifications into an Excel Document to predict our average energy use and consumption. We redefined our specifications until we were able to achieve a net zero energy use in the cheapest and most effective manner.

Location	Harrisburg
Electricity cost ($/kwh)	0.1
Conditioned floor area (sq.ft.)	1807.5
Number of bedrooms	3

Envelope Details

Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	1000
North wall area (gross) (sq.ft.)	720
East wall area (sq.ft.)	450
South wall area (sq.ft.)	720
West wall area (sq.ft.)	450
North window area (sq.ft.)	147.5
East window area (sq.ft.)	147.75
South window area (sq.ft.)	101.5
West window area (sq.ft.)	132.75
Air tightness	Tight with heat recovery

Appliances

Refrigerator	Best
Clothes Washer	Best
Dishwasher	Best
Amount of other appliances	Less

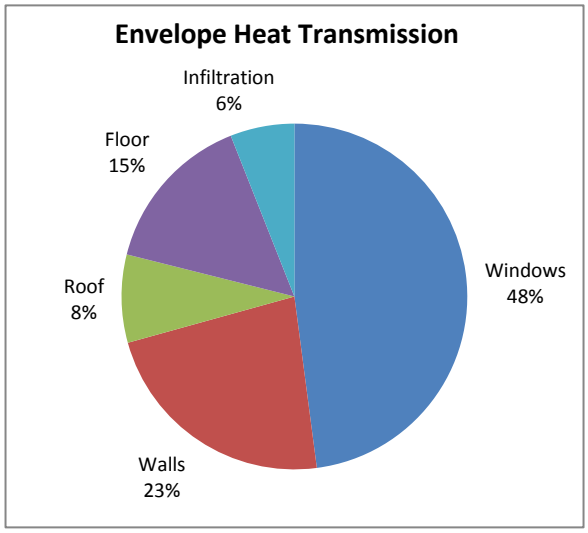
Type of heating & cooling system	Electric geothermal heat pump

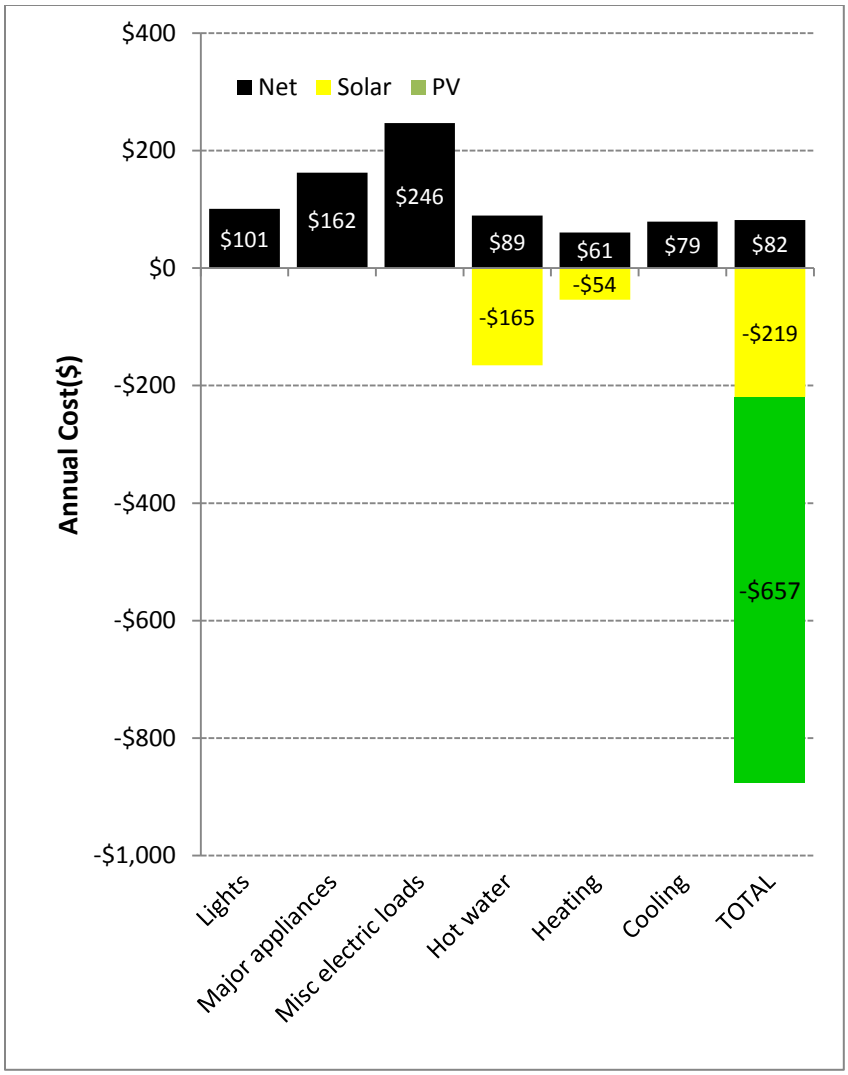
Solar Technologies

Size of PV system (kw)	5.0
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





Lights	1007	kwh
Major Appliances	1,625	kwh
Misc Electric Loads	2,465	kwh
Water Heat	891	kwh
Heating	607	kwh
Cooling	791	kwh
Total Electric	7385	kwh
PV output	6570	kwh
Wind Turbine Output	1000	kwh

Embodiment Design and Final Design Description:

Our final design incorporates many methods in order to achieve all of the customer requirements. The first component of our design is a 5kW photovoltaic system. This system is installed on the roof in order to maximize energy production by reducing shade. The system is angled directly south and at an angle of 35 degrees to produce the most energy. The cost of the system is around $30,000 to $40,000, but with the Pennsylvania Sunshine Solar Program rebate and federal tax incentive rebates, the final cost will be around $20,000. The system will be able to produce around 6,570 kWh/year.

The next component is a 1kW wind turbine. Pittsburgh has a high enough average wind speed to make a turbine useful. The system uses horizontal propellers with three blades and is able to produce between 60 to 150 kWh's/month, for an estimated yearly production of 1,000 kWh. The turbine can be between 64 to 104 feet depending on the height of surrounding trees and buildings. The cost for this 1kW wind turbine is around $4,500, including installation.

Also included in our design is a solar water heater. The integral collector-storage system uses black tanks in an insulated, glazed box in order to preheat cold water which passes through it. The preheated water then goes to the backup electric water heater in order to heat it more if needed. The system saves a huge amount of energy regarding heated water, but must be shut off in winter to avoid freezing.

An electric geothermal heat pump provides the heating and cooling for the home. A vertical ground closed loop system was chosen, which includes vertical holes ranging from 150 to 450 feet. The system uses refrigerant to carry the heat from the outdoor unit to the indoor unit. In winter, the system takes heat from the ground and brings it into the home. In summer, the system takes heat from the home and discharges it into the ground. Although the system requires an electrical compressor, the energy needed for this is much less than the energy used in a traditional fuel heating and cooling system. The cost for this whole system ranges from $15,000 to $20,000, including drilling costs.

In order to conserve energy, the house is fitted with very efficient insulation and windows. The wall and basement insulation consists of a double 2x4 with 10" foam insulation for a R-value of 36. The R-value is the measure of resistance to heat flow, with a higher number meaning lower heat loss or entrance. The attic is fitted with R-60 foam insulation. The windows of the house are made of triple-glazed high solar gain, low E glass. These windows let in 50% of the solar heat from the sun and 65% of the visible light. The windows on the east and west walls of the house have retractable window shades. These shades are able to be lowered or raised at command. The shades block out the light and heat from the sun during the summer to keep the temperature lower. The cost for the insulation is around $8,000, and the cost for the windows with the shades is around $6,000.

Pairing up with the high insulation values, the home is airtight with a heat recovery system. The house is airtight to minimize heat loss and entrance so that less work is required to maintain the temperature inside. Since the house is airtight, a ventilation system is required to provide air for breathing, to dilute pollutants, and control the humidity. The heat recovery system controls the air flow and exchanges inside air with dryer outside air. As the air is being recycled out of the

home, it transfers its heat to the incoming fresh air. This lessens the amount of energy needed to bring the new air back to the correct temperature. The cost for this system is around $5,000.

The appliances inside the home are all the most energy efficient appliances available. The refrigerator is Energy Star and also slightly smaller than usual in order to lessen the energy needed. The washer and dryer are also both Energy Star. By using cold water and special energy saving settings, the energy use can be lowered even further. A clothes line is available in the yard to further reduce the need for drying when the weather is right. The lights in the house are Energy Star CFL lights, which use 75% less energy and last ten times as long as traditional lights. All showerheads and faucets are low pressure to reduce consumption of hot water. Combined with low water volume toilets, the use of water is much lower than a regular home.

Conclusion:

Our team's final design is able to meet all of the customer requirements. The house is able to meet the needs of a family of four by being over 1800 sq. feet with three bedrooms and two and a half baths. The physical appearance of the house is on standard with similar sized homes and the roof and amount of windows looks very nice. The house is built using green energy principles by means of using good building materials and has the correct orientation to maximize energy production from the sun. On average, the house is able to supply as much energy as it consumes by means of energy saving techniques, a photovoltaic system, and a wind turbine. The predicted energy use is 7,385 kWh/year, and the estimated energy production is around 7,500 kWh/year. The estimated cost for the home is around $270,000, which puts it in the upper level of the typical home price for Pittsburgh. Although a little more expensive, the money saved by producing all of its own energy means that the cost is on par with similar homes. Lastly, there is little to none extra work required by being energy efficient. All of the energy production and conservation methods used do not need much human work. The work required for this home is no more than any other home.

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