Zero Energy Home

E-Design 100 Section 14

Team 2 Pure Life Frogs

Submitted to Wallace Catanach

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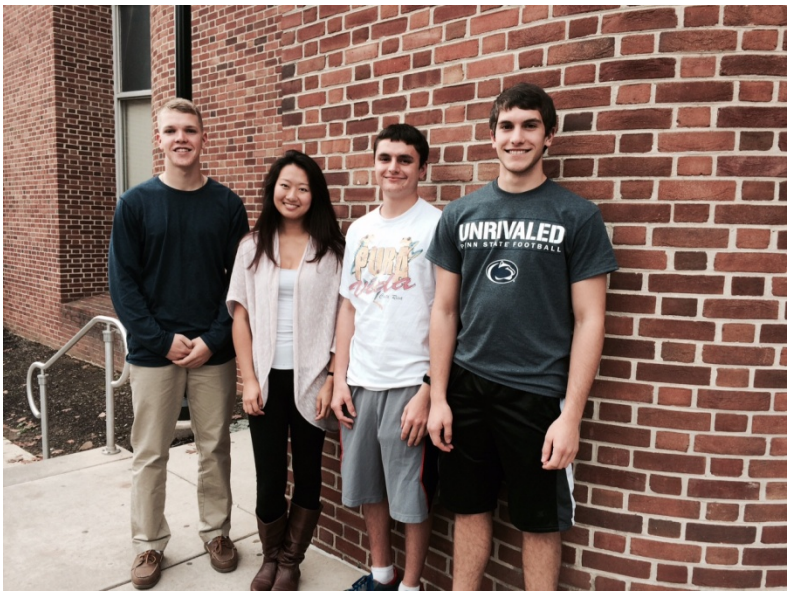


Pure Life Frogs

Index

Executive Summary……..3

Introduction……3

Customer Needs Analysis……..4

External Research……5

Harrisburg Background Information……13

Benchmarking……..17

Product Dissection……18

Global Marketplace……18

Concept Generation……19

Concept Selection ……23

Embodiment Design……24

Energy Calculator……25

House Systems Game……28

Final Design Description……29

Conclusions……29

References……30

Introduction:

Pure Life Frog Engineering has designed a Zero Energy Home for use in Harrisburg, PA in order to provide a home that will better serve the occupants and the community. This home will not only use zero energy, but will create excess energy to send back into the grid. The home will be comfortable for a family of four and cost less than $140,000. The home will be aesthetically pleasing and increase the quality of life for the occupants within it. Some of the features included are large South facing windows, solar panels, energy efficient appliances, a tank of water that retains heat, two bedrooms, a bathroom and a large living area. The total square footage of the house is 700 square feet one a single level.

Executive Summary:

The Pure Life Frogs were tasked with building a zero energy home to accommodate to their customer's needs. In 2010 humans produced 36.7 billion metric tons of CO2. The customer would like to have a zero energy home to live ecologically, and possibly put energy back into the network. The objective for this project is to build a home that over a course of a year, uses less energy than it produces to sustain livable conditions for a family of four and cost under 140,000 dollars total.

In developing a design for the house, several steps were taken. First external searches were conducted, this influenced brainstorming internally. Then the customer needs were found and placed in order of importance targeting the house specifications. The final concepts were then scored using a matrix. After scoring the concepts the final design will be 700 square feet, using a wider and less deep design to maximize sunlight. There will be a large mass area with a slab floor and masonry walls.

Several risks are presented while building this product. Failure to build a good prototype will result in more complications in the future. This could mean the family could not sustain in such house. To reduce this risk there will be a three dimensional, scale model build along with a CAD design. The final prototype is scheduled to be delivered to the customer no later than December 21, 2014.

Customer Needs Analysis

The house accommodates a family of four.

The house costs less than $140,000.

The house uses net zero energy over the course of a year.

The house has a 3 dimensional scale model.

The house has a solidworks prototype.

The house is in Harrisburg, Pa.

The house has all basic appliances.

The house will be aesthetically pleasing.

The house has highly insulated walls.

The house has an energy conscious design.

The house will keep its structure through normal weather conditions.

The house allows sensitivity to adjustment.

The house is affordable for an eco-minded consumer.

The house can be maintained with readily available tools.

The house lasts a long time.

The house is safe in a storm.

External Research

House 1:

Location (city, state)	Bend, OR
House size (floor area in square feet)	1534
Number of floors	1
URL of web site where info is found	http://www.zerohomes.org/craftsman-net-zero-energy-home/
Number of occupants	
Number of bedrooms	
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Ductless mini-split heat pump,
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity, Earths natural heat
Size of photovoltaic system (kilowatts)	5.64kW
Solar water heater (yes or no)	Yes
R-value of wall insulation	R50
R-value of ceiling insulation	R60
Ventilation air heat recovery (yes or no)	Yes
Predicted or measured annual energy use	0
Any other pertinent info	Continuous filtered-fresh air ventilation from an Energy Recovery Ventilator (ERV)

House 2:

Location (city, state)	Fraser, Colorado
House size (floor area in square feet)	5232
Number of floors	2
URL of web site where info is found	http://www.jetsongreen.com/2011/01/net-zero-energy-house-fraser.html
Number of occupants	
Number of bedrooms	7
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Solar thermal
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity, Earths natural heat
Size of photovoltaic system (kilowatts)	17kW
Solar water heater (yes or no)	Yes
R-value of wall insulation	R60
R-value of ceiling insulation	R85.5
Ventilation air heat recovery (yes or no)	
Predicted or measured annual energy use	0
Any other pertinent info	Makes enough electric to power two all electric plug-in vehicles

House 3:

Location (city, state)	New Paltz, New York
House size (floor area in square feet)	4000 sq ft
Number of floors	3
URL of web site where info is found	http://www.realestateshows.com/flyer.php?id=514226
Number of occupants	
Number of bedrooms	4
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Geothermal heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Not specified
Size of photovoltaic system (kilowatts)	Not specified
Solar water heater (yes or no)	No
R-value of wall insulation	Not specified
R-value of ceiling insulation	Not specified
Ventilation air heat recovery (yes or no)	Yes
Predicted or measured annual energy use	Not specified
Any other pertinent info	

House 4:

Location (city, state)	Truro, Massachusetts
House size (floor area in square feet)	6200 sq ft
Number of floors	2
URL of web site where info is found	http://www.zeroenergy.com/p_truro.html
Number of occupants	2
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Geothermal heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Not specified
Size of photovoltaic system (kilowatts)	Not specified
Solar water heater (yes or no)	No
R-value of wall insulation	Not specified
R-value of ceiling insulation	Not specified
Ventilation air heat recovery (yes or no)	Yes
Predicted or measured annual energy use	Not specified
Any other pertinent info	Permeable Driveway, Water Conserving Fixtures, Rapidly Renewable Materials, Low Maintenance Materials

House 5:

Location (city, state)	Turners Falls, MA
House size (floor area in square feet)	1152 square feet
Number of floors	1
URL of web site where info is found	http://www.builditsolar.com/Projects/SolarHomes/MAZeroEnergy/MAZeroEnergy.htm
Number of occupants	1 family
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Solar and heat pump.
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Solar: Dark concrete slabs absorbs sun's heat and southern windows gather solar energy.
Size of photovoltaic system (kilowatts)	26 0.190-kilowatt panels and a 4.94-kilowatt inverter
Solar water heater (yes or no)	No
R-value of wall insulation	R=30
R-value of ceiling insulation	R=100
Ventilation air heat recovery (yes or no)	No.
Predicted or measured annual energy use	1949 kWh
Any other pertinent info	• Produced 4892 kWh of energy.

House 6

Location	Perkiomenville, PA
House size	2216 square feet
Number of floors	
URL of website	www.citilogs.com/.../consillience_philadelphia_sustainability_awards.pdf
Number of occupants	Single family.
Number of bedrooms	
Type of heating system	Geothermal and radiant floor heating system
Main heating fuel	Geothermal
Size of photovoltaic system	5.25 kW grid connected photovoltaic system
Solar water heater	
R-value of wall insulation	
R-value of ceiling insulation	
Ventilation heat recovery	Yes.
Predicted or measured annual energy use	2845 kWh
Any other pertinent info	• clad wood Energy Star windows • stained concrete floors • tankless on-demand water heating • Energy Star appliances and lighting • Passive cooling and geothermal air conditioning

House 7:

Location (city, state)	Needham, Massachusetts
House size (floor area in square feet)	3100
Number of floors	Two
URL of web site where info is found	http://www.zeroenergy.com/p_needham.html
Number of occupants	n/a
Number of bedrooms	3
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Air source heat pumped, ducted and ductless
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	8kw
Solar water heater (yes or no)	No
R-value of wall insulation	R45
R-value of ceiling insulation	R3
Ventilation air heat recovery (yes or no)	yes
Predicted or measured annual energy use	Net positive
Any other pertinent info	Windows U0.22, foundation R26,slab R17

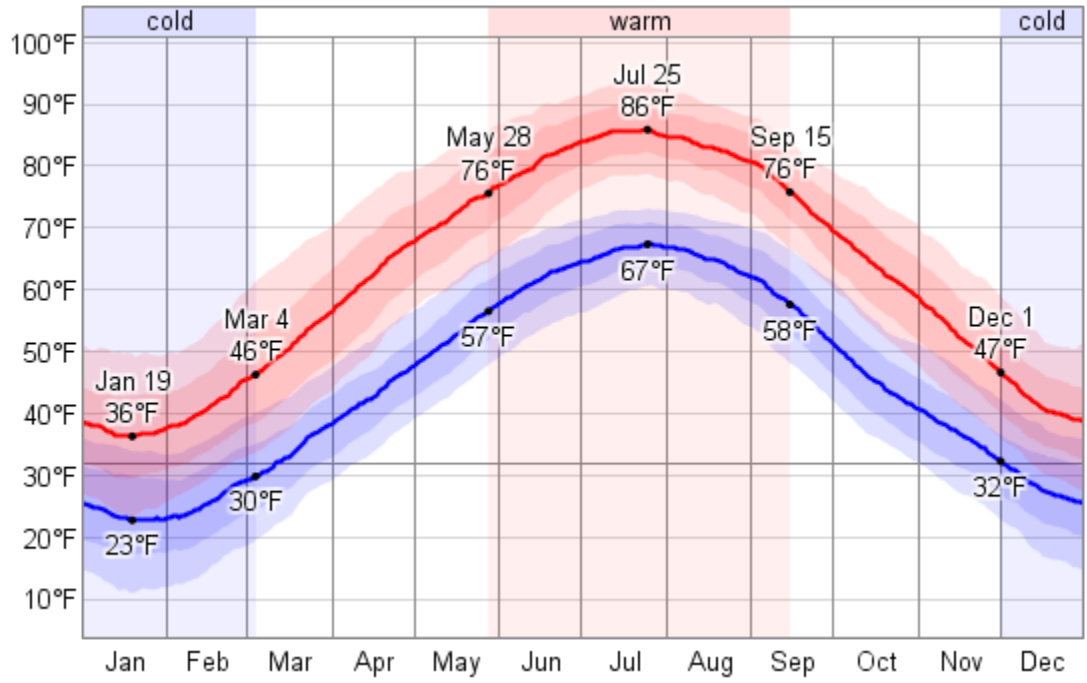
House 8:

Location (city, state)	Charlotte, VT
House size (floor area in square feet)	2970sq ft
Number of floors	Two
URL of web site where info is found	http://zeb.buildinggreen.com/overview.cfm?ProjectID=1019
Number of occupants	“typically 4”
Number of bedrooms	4
Type of heating system (forced air, hydronic, radiant floor, heat pump, etc.	Ground source heat pump
Main heating fuel (electricity, natural gas, wood, oil, etc.)	Electricity
Size of photovoltaic system (kilowatts)	5kw
Solar water heater (yes or no)	No
R-value of wall insulation	R40
R-value of ceiling insulation	R58
Ventilation air heat recovery (yes or no)	n/a
Predicted or measured annual energy use	7779kWh
Any other pertinent info	Turbine

Harrisburg, Pennsylvania

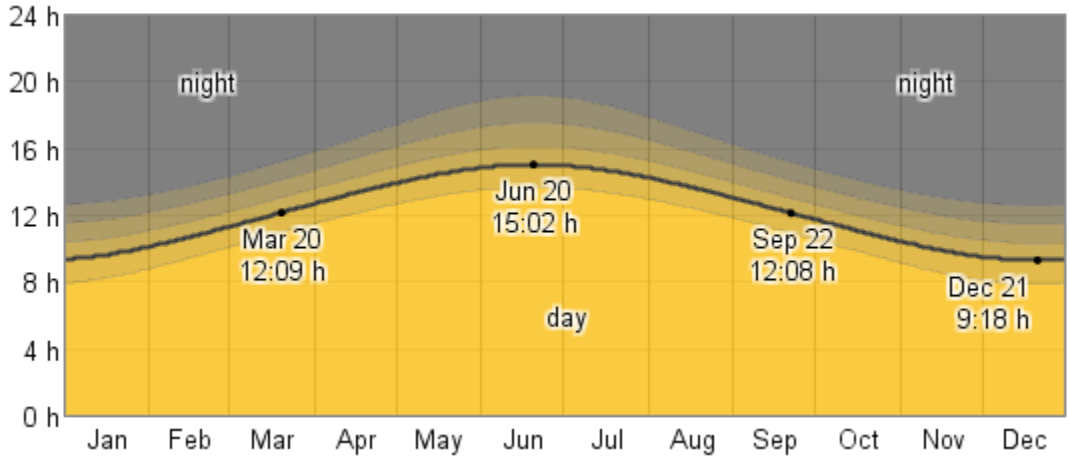
Harrisburg is the capital of the state Pennsylvania. With a population of nearly 50 thousand people it is the ninth largest city in Pennsylvania. The city lies in Dauphin County on the east side of the Susquehanna River. Harrisburg city is one hundred percent urban, however, rural areas surround the city and are within a few miles. With Cumberland and Perry Counties just on the other side of the river and the outskirts of Harrisburg being more suburban there are many options. Weather in Harrisburg as shown on the graph varies from cold winter months to vary warm summer months.

Daily High and Low Temperature



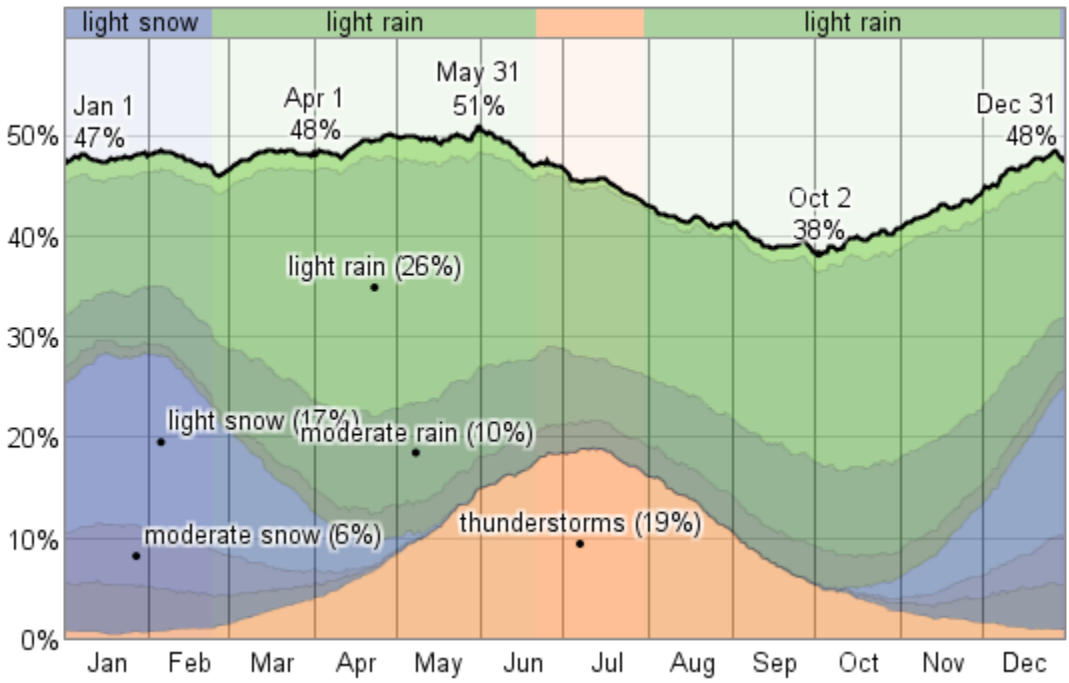
Hours of sunlight also depends on the season, with the shortest day of the year having nine hours and eighteen minutes of sunlight while the longest had about fifteen hours.

Daily Hours of Sunlight and Twilight



Precipitation in Harrisburg along with the rest of the weather depends on what season it is, light rain and snow make up forty six percent of the precipitation, while light snow falls in third.

Probability of Precipitation at Some Point in the Day

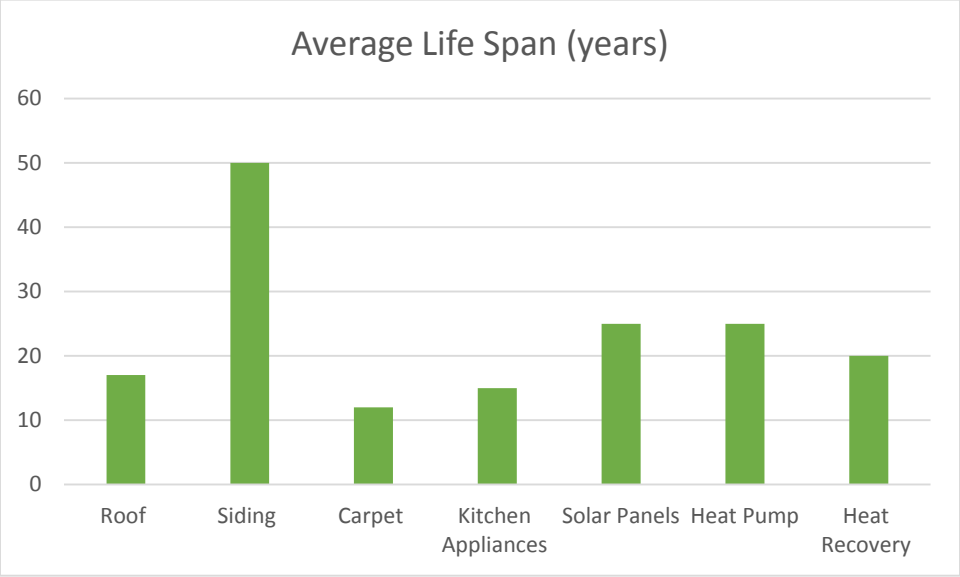


Basic utilities in Harrisburg cost approximately 232.55 dollars per month, including electricity, heat, water, and garbage for a two hundred eighty square foot apartment. Three Mile Island, a nuclear power plant that had a meltdown scare in the late 70s is just south of Harrisburg, producing electricity and supplying it to much of the city.

								Energy Efficient Survey									
These eight questions were asked to 25 people then converted percent yes or no																	
Question 8 was asked and the survey takers had the following three answers to give, their response is given in percent																	
														YES (%)		**NO(%)**		
Q1: Do you believe you and/or your family could sustain in a more energy efficient way without changing your/their routines?														100		0		
Q2: Do you believe you have been taught, throughout you years of grade school, enough about conserving energy, and how to conserve energy?														44		56		
Q3: Would you pay more for energy efficient appliances and accessories in your house if they payed themselves off within their life span?														88		12		
Q4: Did you know that space heating on average uses the most energy in an home in the United States?														12		88		
Q5: knowing this would you be willing to turn the temperature in your home down?														96		4		
Q6: On a daily basis do you unplug your phone charger from the wall?														16		84		
Q7: Would you consider buying into a ZEH?														100		0		
														COST (%)		**KNOWLEDGE(%)**		**LIFESTYLE(**
Q8: What do you think holds people back from living in a ZEH?														40		24		36

Maintenance

With owning a zero energy home, like any home, there come maintenance mandatory for keeping your home livable. As any home a zero energy home will have items constantly needing replaced depending on how they are treated, and used. These items may include but are not limited to countertops, furniture, paint, doors, and cabinets and so on. Also there will be the small items that will need checked and replaced on a monthly basis such as lights, and batteries in fire alarms. Zero energy homes, however have some special things that keep it zero energy, these include a heat recovery system, solar panels, and electric geothermal heat pump. The chart below shows the life span of most of these key features in a zero energy home including some large priced features such as a roof, siding and carpet.



Along with replacing these items, there will be spot checks needed to insure the appliances, and systems are working properly. These are usually monthly deeds done specified by the manufacturer's instructions.

Manufacturing/Benchmarking

When building any home there a basic timeline used. This timeline shows the events in which building takes place versus installation and inspection. Below shows an approximation of the timeline.

1) Acquire the correct building permits
2) Prepare site and pour the foundation
    - Inspection 1 occurs
3) Complete rough framing
4) Complete rough plumbing, electrical, and HVAC
    - This is where the biggest change will take place in a ZEH vs a normal home, the energy efficient units will be sought after and the correct electrical plumbing and HVAC will be installed for the energy efficient units.
    - Inspections 2,3, and 4; separate inspections for plumbing, electrical and HVAC
5) Insulation Install
    - This will again differ from normal homes, because most ZEH have thicker, more efficient insulation, however, the process is similar.
6) Drywall and interior textile completion, start exterior finishes
7) Finish interior trim and install driveways and walkways
8) Install hard surface flooring and countertops; complete exterior
9) Finish mechanical trims, and install bathroom fixtures
10) Install fragile items (mirrors/shower doors), finish flooring, and exterior landscaping
    - Final Inspection
11) Walkthrough home with builder

Our House/Product Dissection

1. This a new construction home, here has not be any previous construction at the house location.
2. There are no existing renewable energy sources, this house will be built to include various renewable energy sources and have an energy efficient design

Review- This will be a new construction home with new state of the art renewable energy technology such as solar panels and a geothermal heat pump. There will also be various passive solar techniques used to maximize efficiency within the house and maximize the free, green energy of the sun.

Global Market Place

In the Global Marketplace Zero Energy homes and buildings are being pursued by governments, corporations, and individuals to minimize he carbon footprint of their buildings. Zero energy building revenue is expected to grow from $629.3 million in 2014 to $1.4 trillion by 2035. The goal of designing zero energy buildings is for it to consume as much energy as it produces through on-site and renewable energy systems. According to Pike Research "A number of countries and regions have already established long-term targets and regulations requiring zero energy building construction that will come into effect over the coming years, some as soon as 2016." The European Union is a leading force in creating Zero Energy Homes. "Following the surge in LEED and other green building certifications worldwide over the last few years, zero energy building has emerged as the 'holy grail' in green building design," says research analyst Eric Bloom. "Technically, zero energy building design is feasible for many building types in many regions, but concerns about the upfront cost continue to impede it in the market."

Concept Generation

Product Specs Metrics-Matrix

#		Need	Imp
1	The house	Accommodates a family of four.	1
2	The house	Costs less than $140,000.	1
3	The house	Uses net zero energy over the course of a year.	1
4	The house	Has a 3 dimensional scale model.	3
5	The house	Has a solidworks prototype.	3
6	The house	Is in Harrisburg, Pa.	2
7	The house	Has all basic appliances.	2
8	The house	Will be aesthetically pleasing.	2
9	The house	Has highly insulated walls.	2
10	The house	Has an energy conscious design.	1
11	The house	Will keep its structure through normal weather conditions.	1
12	The house	Allows sensitivity to adjustment.	2
13	The house	Is affordable for an eco-minded consumer.	1
14	The house	Can be maintained with readily available tools.	3
15	The house	Lasts a long time.	2
16	The house	Is safe in a storm.	1

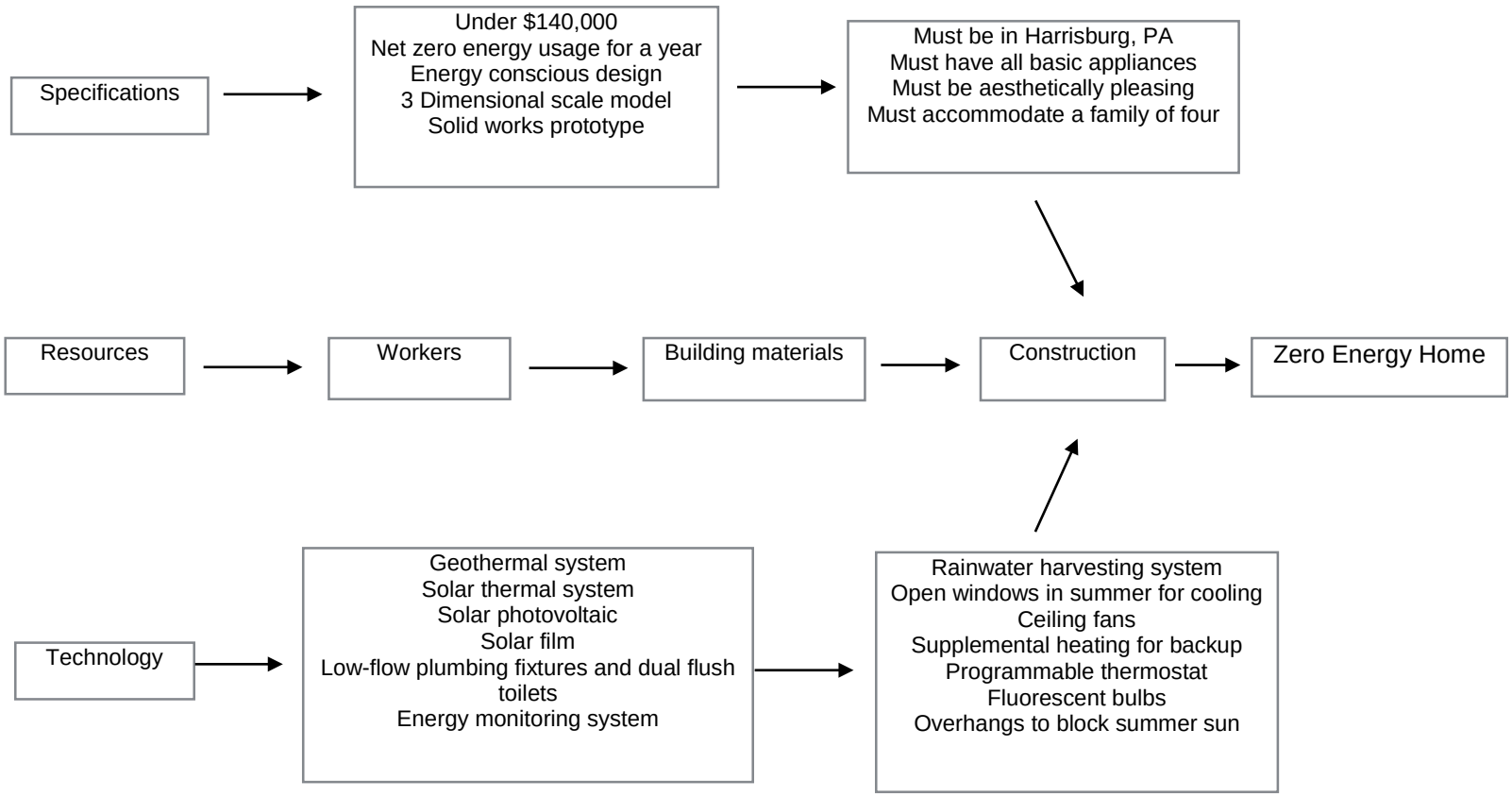
Metric #	Need #'s	Metric	Imp	Units
1	1	Total rooms	1	rooms
2	2,13	Total Price	1	$
3	3	Energy Usage	1	kW/h
4	4,5	Modeling	3	cm:ft
5	6	Location	2	Latitude, Longitude
6	7	Appliances	2	# of applicanes
7	8	Beauty	2	0-10
8	9	Insulation	2	R-value
9	10	Energy Conscious design	1	Light Penetration %
10	11,16	Weather test	1	Hurricane category
11	12	UV test	2	hours
12	14	Specific tools required for maintenance	3	list
13	15	Cycles till failure	2	# of cycles

	Metric	Energy Star Appliances	Number of Rooms	Uses Renewable Energy	Total Cost of Home	Subject Appearance Rating	Moderate Climate	House insulation
Need#	Need Statement							
1	The house accommodates a family of four.		X		X			
2	The house costs less than $140,000.				X			
3	The house uses net zero energy over the course of a year.	X		X			X	X
4	The house has a 3 dimensional scale model.				X	x		
5	The house has a solidworks prototype.				X	X		
6	The house is in Harrisburg, Pa.				X		X	
7	The house has all basic appliances.	X			X			
8	The house will be aesthetically pleasing.					X		
9	The house has highly insulated walls.						X	X
10	The house has an energy conscious design.			x	X	x		
11	The house will keep its structure through normal weather conditions.						X	
12	The house allows						X	

	sensitivity to adjustment.							
13	The house is affordable for an eco-minded consumer.				X			
14	The house can be maintained with readily available tools.				X			
15	The house lasts a long time.				X		X	
16	The house is safe in a storm.				X		X	X

Concept Generation

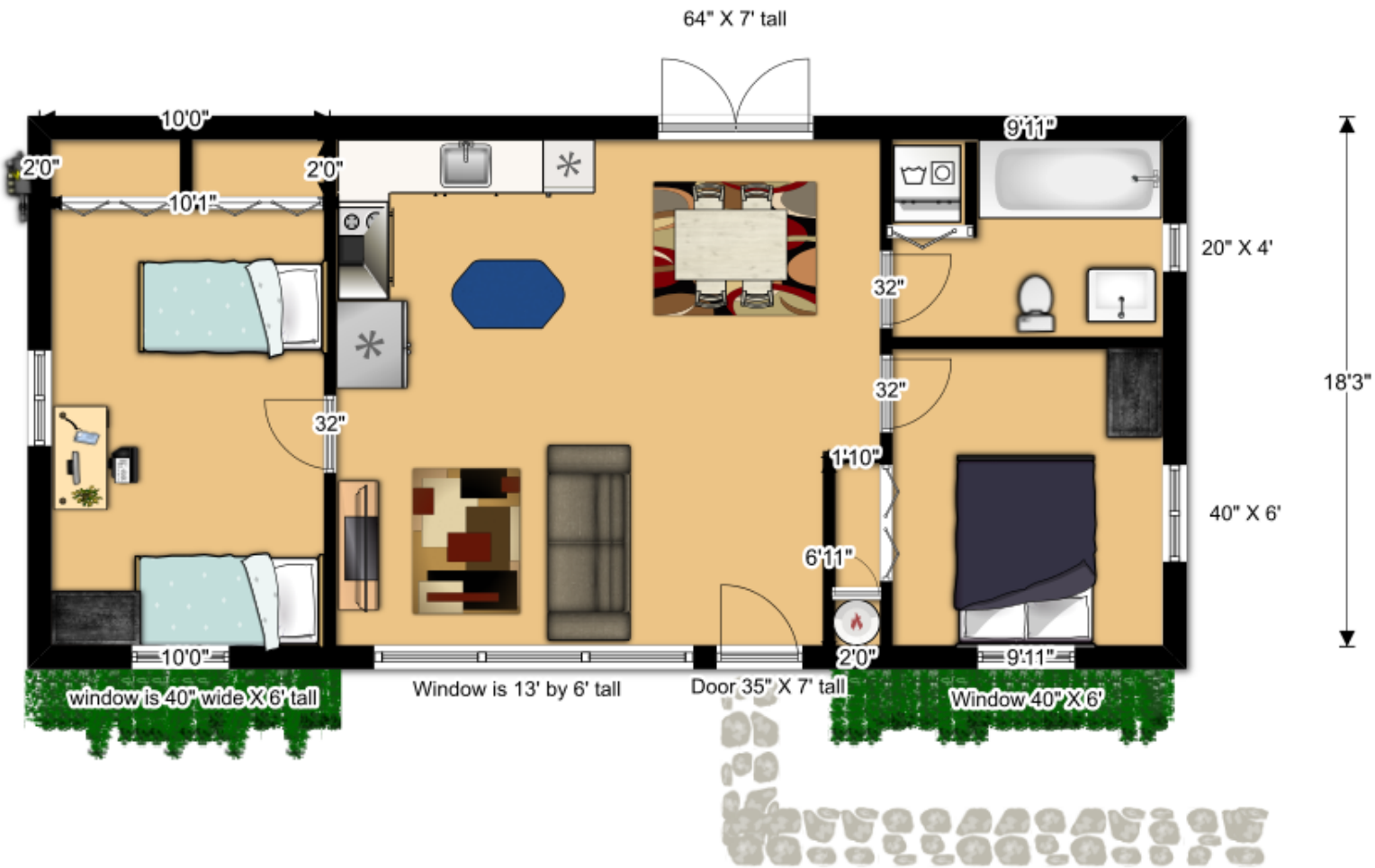
Problem: The customer needs a zero net energy usage home for under $140,000.



Concept Selection

Selection Matrix

Selection Criteria	Solar panels	2 story home	1 story home	pool	wood	bricks	wooden floors	concrete floors	Garage	Electric Geothermal	Large Windows	Average sized wind	Solar Water Heater	Hot Tub	ventilation air heat r	energy star windows
>$140,000		0 minus	plus	minus		0	0	0	0 minus		0	0	0	0 minus	0	0
uses net zero energy	0	0	0	0	0	0	0	0 plus		0 plus	plus		0 plus	minus	plus	plus
accommodate a fam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In a location with a c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
has all basic appliar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
aesthetically pleasin	0	0	0	0 plus	0	0	0	0	0	0 plus		0	0 plus		0	0
R=60 walls	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
energy conscious de	plus	0 plus	plus	minus		0	0	0 plus		0 plus	plus		0 plus	minus	plus	plus
Sum +'s	1	0		2	1	0	0	0	2	0	2	3	0	2	1	2
Sum 0's	7	7		6	5	8	8	8	6	7	6	5	8	6	4	6
Sum -'s	0	1		0	2	0	0	0	0	1	0	0	0	0	3	0
Net Score	1	-1		2	-1	0	0	0	2	-1	2	3	0	2	-2	2
Continue?	Yes	No	Yes	No	Combine	Combine	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes


64" X 7' tall
10'0"
2'0"
2'0"
10'1"
9'11"
20" X 4'
32"
32"
32"
18'3"
1'10"
40" X 6'
6'11"
10'0"
2'0"
9'11"
window is 40" wide X 6' tall
Window is 13' by 6' tall
Door 35" X 7' tall
Window 40" X 6'

Energy Calculator

Penn State Center for Sustainability

General Info

Location	Harrisburg
Electricity cost ($/kwh)	0.1
House type	1 story
Conditioned floor area (sq.ft.)	700
Number of bedrooms	2

Envelope Details

Wall construction	Double 2x4 with 10" foam
Ceiling Insulation	R60
Window type	Triple low-e
Upper floor ceiling area (sq.ft.)	700
North wall area (gross) (sq.ft.)	400
East wall area (sq.ft.)	175
South wall area (sq.ft.)	400
West wall area (sq.ft.)	175
North window area (sq.ft.)	30
East window area (sq.ft.)	25
South window area (sq.ft.)	63
West window area (sq.ft.)	25
Air tightness	Tight with heat recovery

Appliances

Refrigerator	Best
Clothes Washer	Best
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

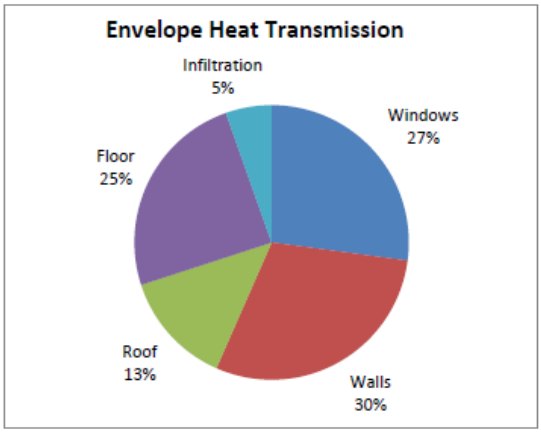
Solar Technologies

Size of PV system (kw)	3.87
Solar water heater	Yes

Behavior

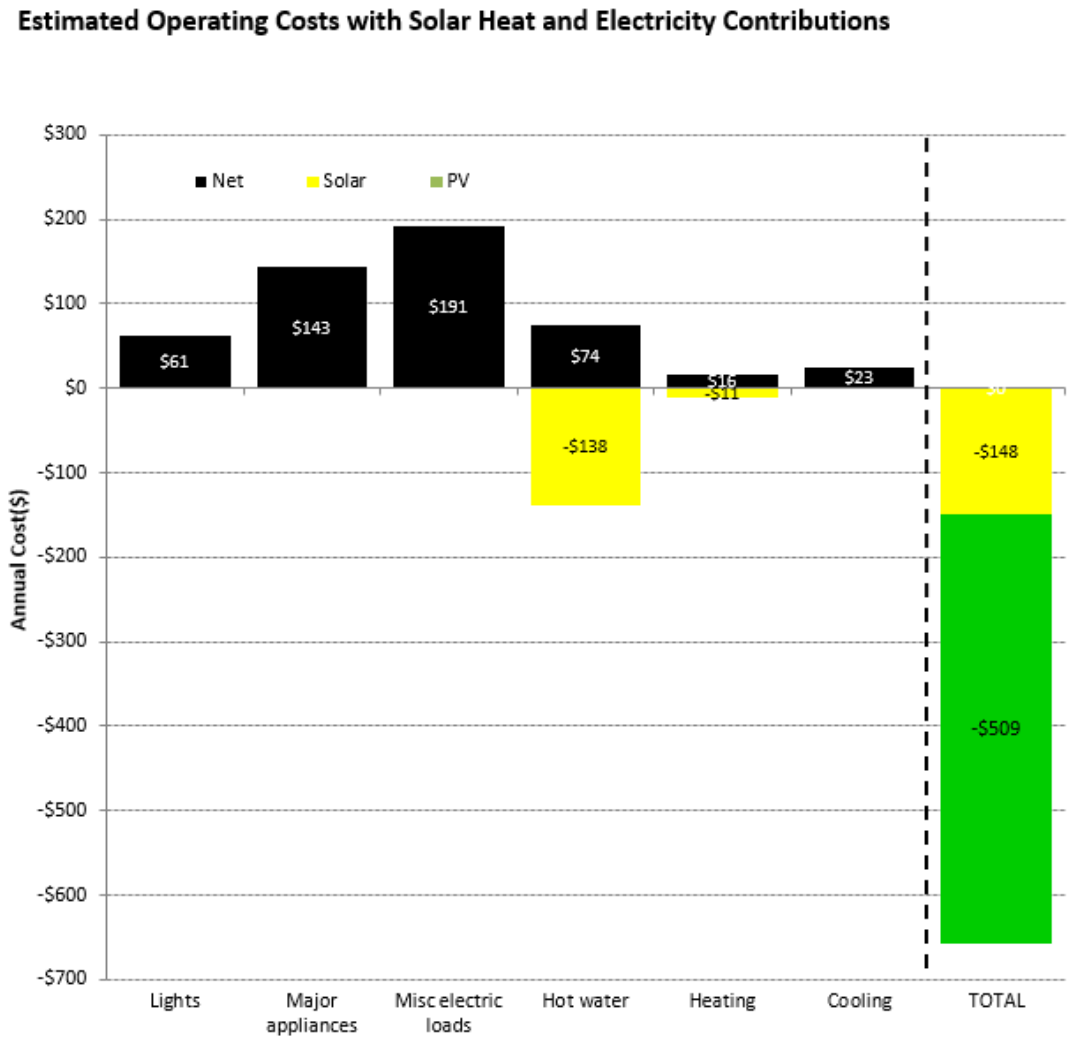
Water conservation	A lot
Uses clothesline	A lot
Thermostat setback	A lot
Heat thermostat setting (F)	68
Cool thermostat setting (F)	70

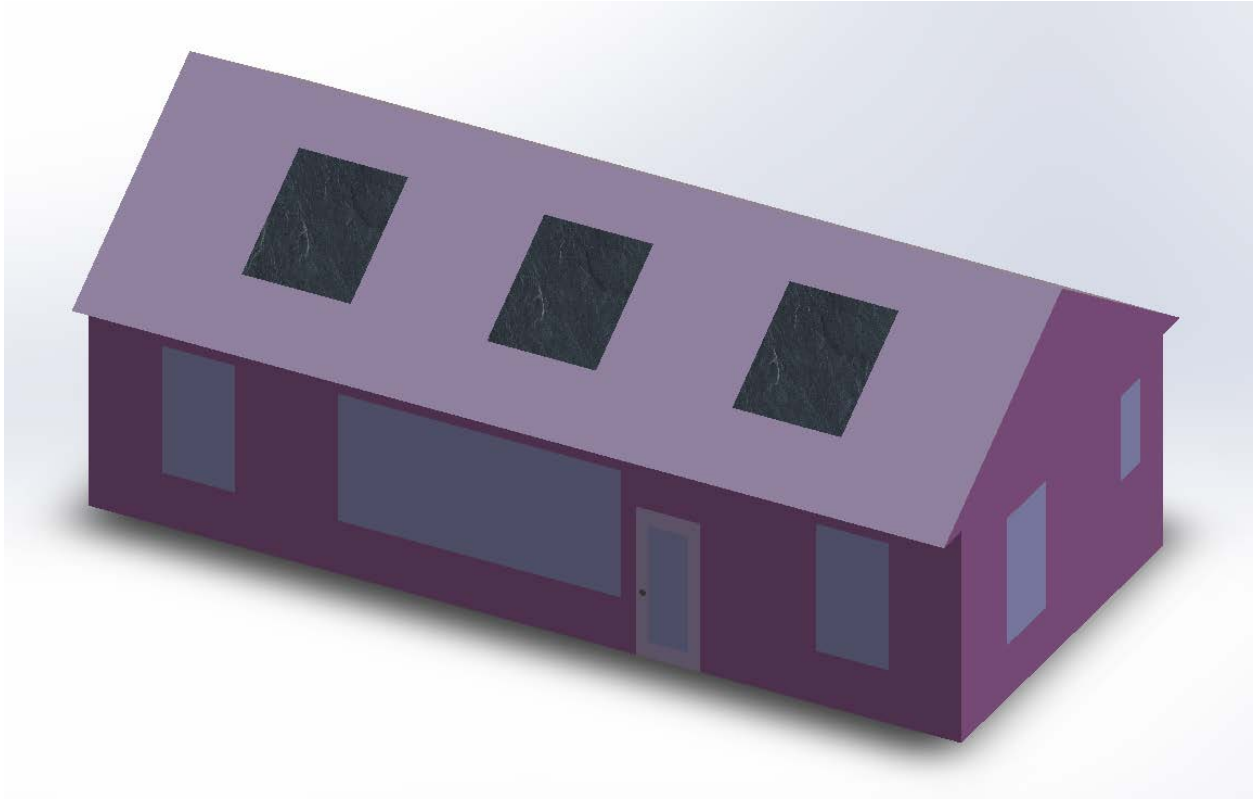
Results



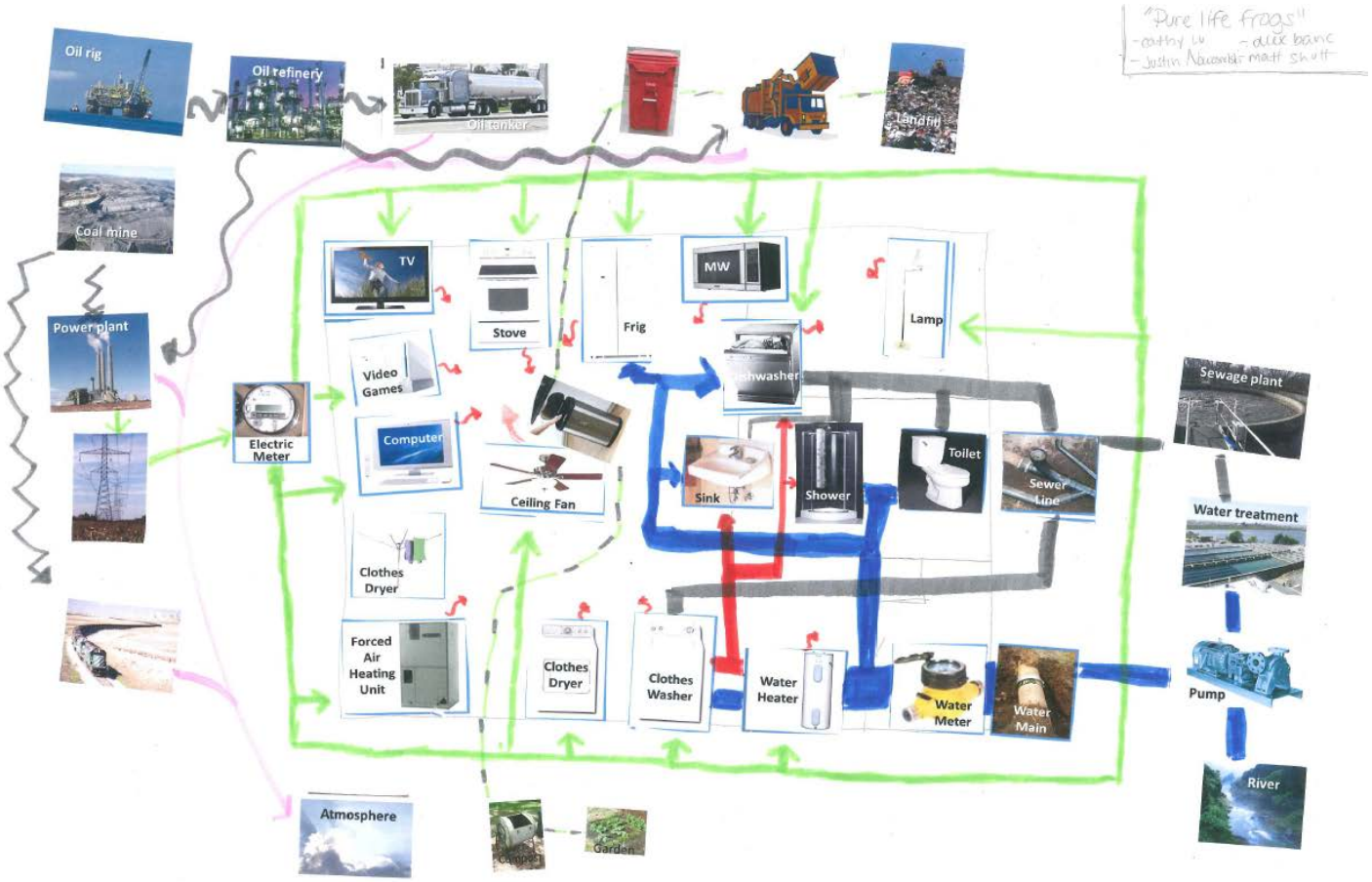
Base House Cost	**$**	**99,740**
PV Cost	**$**	**19,364**
Upgrade Costs	**$**	**18,470**
Total House Cost	**$**	**137,574**

Zero Energy Home Operating Costs





House Systems Game



The house systems game helped us learn how different aspects of the house are connected and how everything has an input and output. Using appliances and items that maximize efficiency we can reduce the amount of energy, water, or fossil fuels going in and in turn decrease the amount of excess heat, waste water, and carbon emissions released into the environment. Creating a zero energy home requires maximum use of resources and having the littlest impact possible on the surrounding community.

Final Design Description

We chose to use a small floor plan to specifically accommodate a family of four. We did this to keep the cost under $140,000 and to minimize energy costs. We used large South facing windows in addition to heat retaining masses within the house to maintain a comfortable living environment within the house. We used a geothermal heat pump to minimize energy usage for heating. We used highly insulated walls with tight seals to prevent drafts and maintain internal temperature. The house contains energy efficient appliances and lighting sources, which receive energy from the solar panels on the roof. There is a 1.5 foot overhang in order to minimize sun exposure in the summer and maximize sun exposure in the winter. All these features help to maintain a net zero energy usage within the home.

Conclusions

During the course of this project our team collaborated to design a home that has a net zero energy usage. We learned about the various resources used for creating a zero energy home. We researched the technologies that is commonly used in the design of a zero energy home, such as solar panels, geothermal heat pumps, and energy efficient appliances within the home, and selected the technology to incorporate into our own design. There are various approaches that could be used to create a design for a zero energy home. Doing this project helped us learn how to create a cost model, product metrics, matrix chart, and selection matrix, and we became better acquainted with the 8-step engineering process.

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