Net-Zero House Powered by Green Energy

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Outline

- Introduction
- Project Description
- Detailed Design
    - House Design
    - Energy Consumption
    - Energy Storage Battery
    - Energy Acquisition
- Cost Analysis

Introduction

- Fossil Fuel is still the most reliable/affordable energy source;
  - Coal and Natural Gas Fuel;
- Issues associated with fossil fuels;
- Renewble energy;
  - Solar energy;
  - Wind energy;
  - Bio-energy;

Net-Zero House Concept

A Net-Zero House is defined as a house which use “zero” electricity/energy from fossil fuel fuel sourse;

Senario 1: A house which does not use elecricity from grid and does not consume fossil fuel;

Senario 2: A house which consumes fossil fuel sources electricity and fuels but contributes the equivalent amount of green energy to the grid;

Technologies Leading toward Net-zero House

- Design and Construction of House to Minimize Energy Consumption;
- Selection of Energy Efficient Appliance and Fixture Lighting;
- Production of Electricity using Green Energy;
- Choice of Energy Storage System or Interaction with Grid;

Objective of This Project

The objective of this project is to design a zero-net house powered by green energy.

- House platform;
- Analysis of energy consumed;
- HVAC energy consumption;
- Energy storage system;
- Solar energy system;
- Cost analysis

House Specification

Project House Design Specifications:

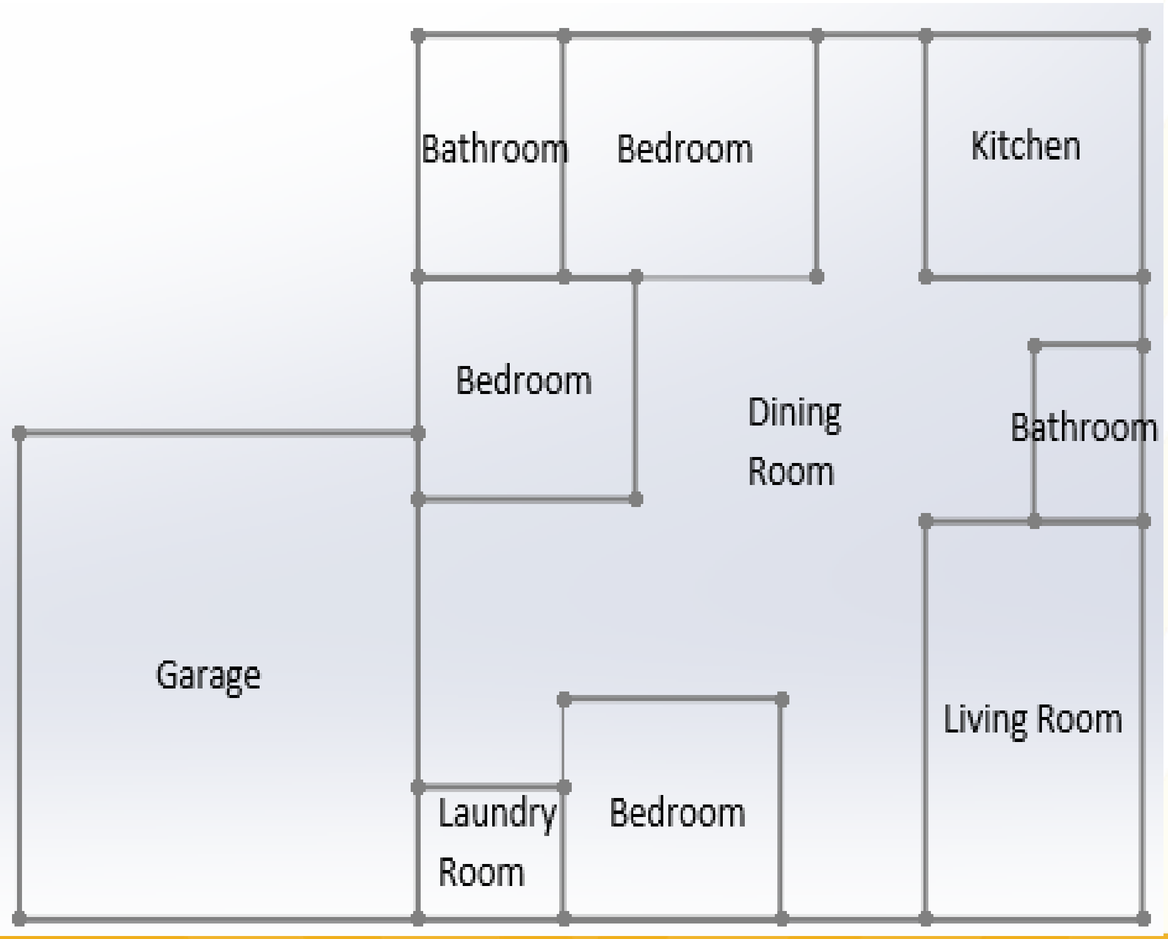
- Three bedroom compact house for a family of 3;
- About 1600 ft^2 attached with a two car garage;
- 2 plug-in hybrid cars that run 30 miles/day (each).
- Must have a battery to store electrical energy;
  - Energy needed at night;
  - Car battery charging;
  - In the event of a power outage due to bad weather;

Main Design Works

- Design house structure to be as efficient as possible to reduce energy loss;
- Determine appliances needed and energy consumption;
- Design an energy efficient heating/cooling system;
- Size a battery to store enough energy to maintain heating or cooling and appliances;
- Size the solar panel system for energy acquisition.

House Layout

- Garage for 2 Hybrid (
- 3 Bedrooms;
- Two bathrooms
- Kitchen
- Dining room
- Laundry room
- Living room



House Design: Structure

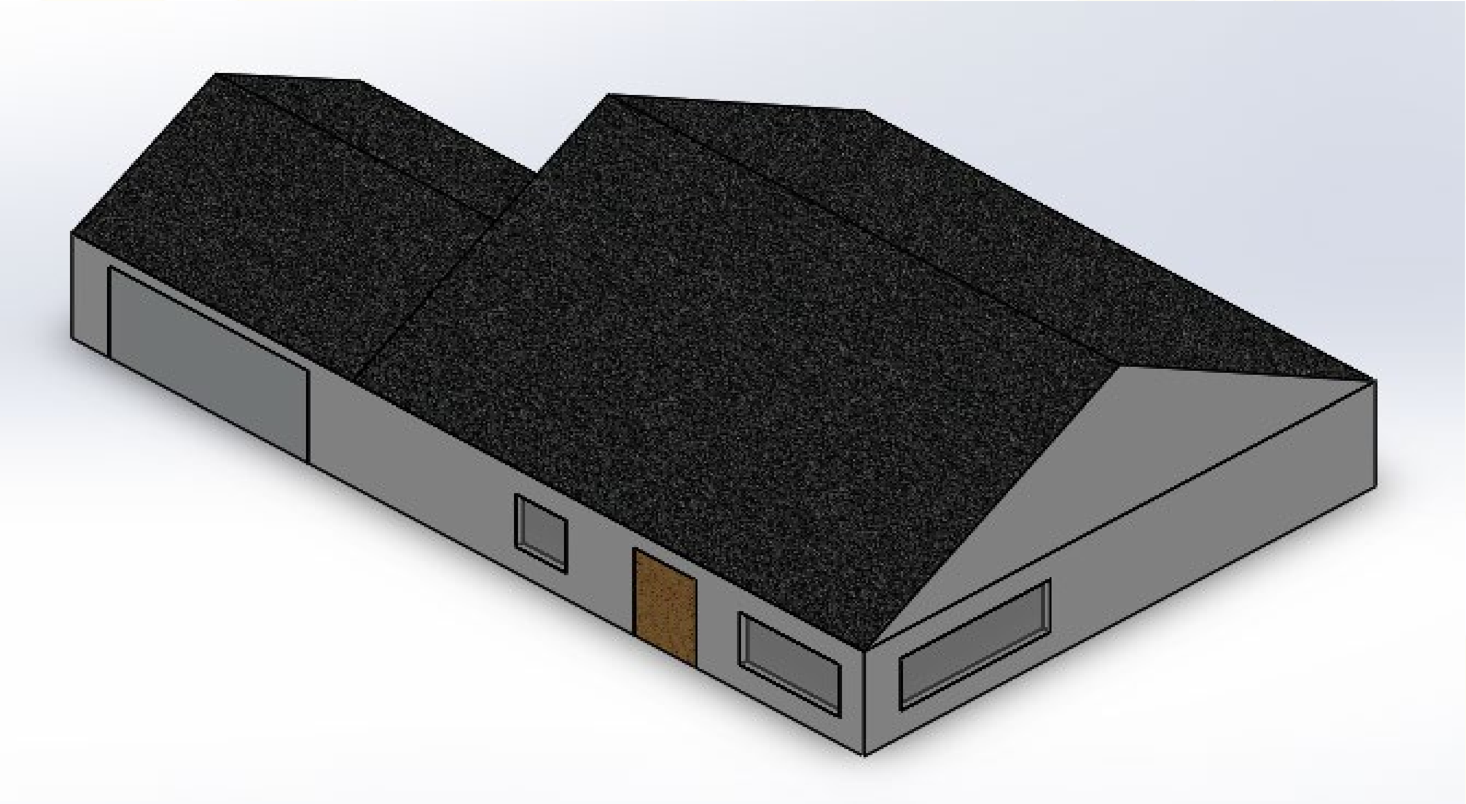
- House Dimensions: 40 ft. by 40 ft.
- Garage Dimensions 22 ft. by 22 ft.
- Roof Angle = 27°

Structural Surface	Minimum R-value (ft^2*°F*hr/BTU)	House R-value (ft^2*°F*hr/BTU)
Outer Walls	20	30.6
Roof	38	44.35
Floor	30	30.19

Table 1: International Energy Conservation Code **(**IECC) Recommendations for House Structural Surface Minimum R-value with House Design Actual R-value [1, WVEC]

1. 2009 International Energy Conservation Code. (2009). West Virginia Energy Code.

Final Model



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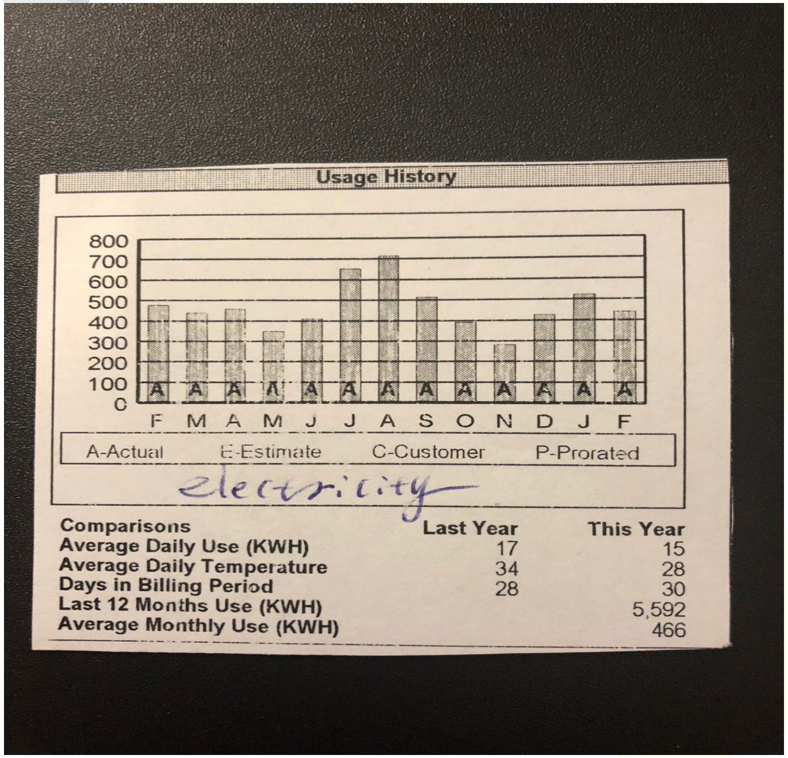
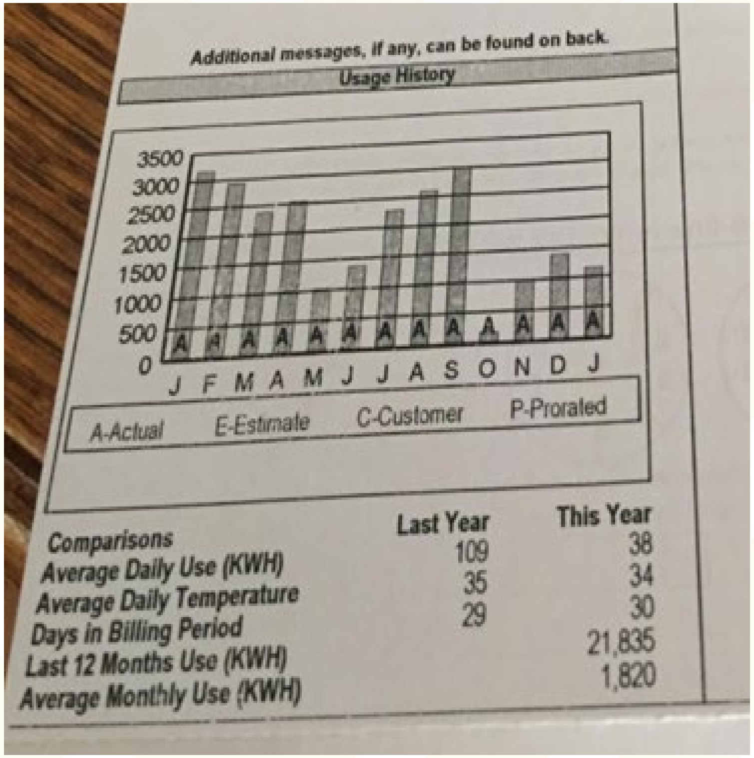
Utility Bill Analysis

- Four electricity bills from the area were collected, each of a different size and living arrangement.
- Each house was broken down into the following categories:
    - Size (square footage) [ft^2]
    - Yearly Consumption [kWh]
    - Average Monthly Consumption [kWh]
    - Winter Consumption (Dec. – Mar.)
    - Summer Consumption (May – Sept.)
    - Energy Consumed per Square Foot [kWh/ft^2]

Examples of Utility Bill





Electricity Bill Break Down and Comparison

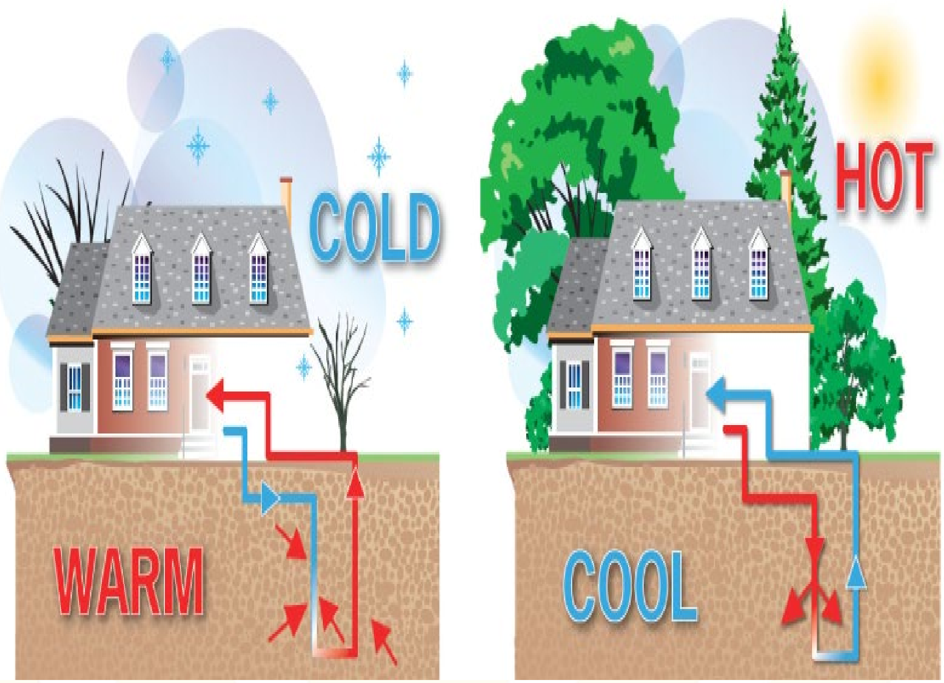
House	Square Footage	Yearly Energy Consumption [kWh]	Monthly Avg. [kWh]	Winter Consumption (Dec.- Mar.)	Summer Consumption (May - Sept.)	Energy per square foot [kWh/ft^2 (yearly avg.)]
1	5,000	21,835	1,820	10,000	10,300	4.367
2	1,875	22,831	1,903	6,500	10,600	12.18
3	4,700	8,605	717	3,350	3,450	1.831
4	?	5,592	466	1,780	2,610	?

Electricity Bill Break Down and Comparison

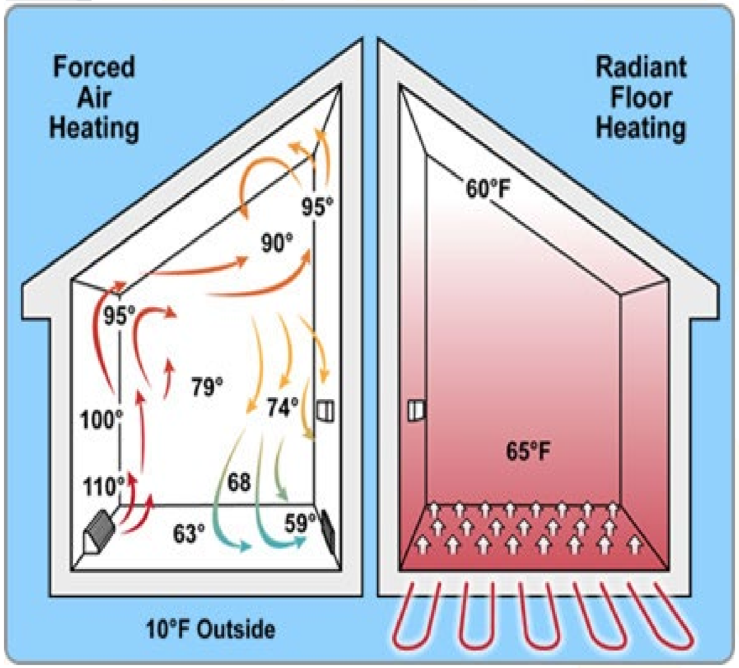
Appliance Energy Usage Yearly Estimation (kWh):	6,782.24		**Total Energy Usage Yearly Estimation (kWh):**
HVAC Energy Usage Yearly Estimation (kWh):	19,068.16		918.10
Nissan Leaf Energy Usage Yearly Estimation (kWh):	3,484.09		29,334.49
Toyota Prius Energy Usage Yearly Estimation (kWh):	4,738.36		30,588.77
Chevy Bolt Energy Usage Yearly Estimation (kWh):	3,663.27		29,513.68

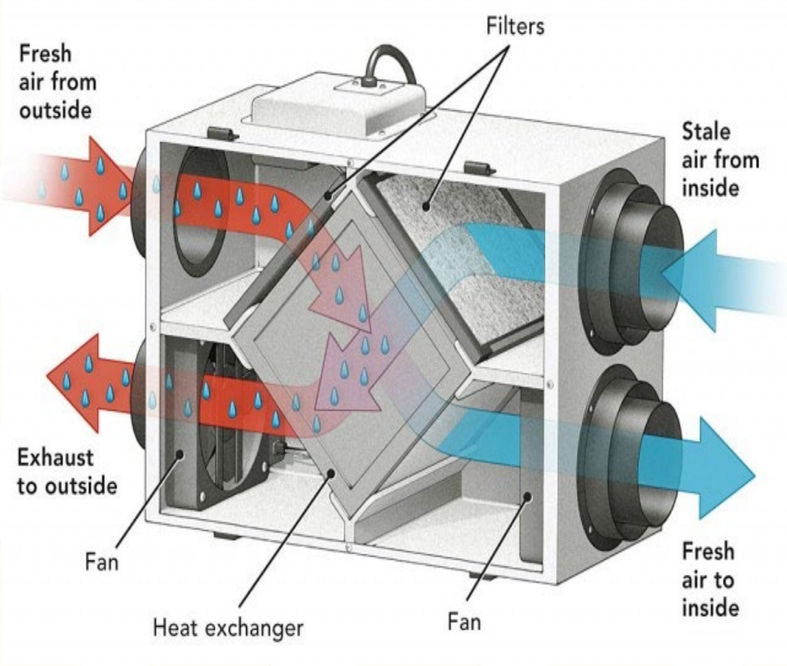
Geothermal Heat Pump

- More efficient than traditional air heat pumps
  - Save 30-60% heating costs compared to traditional heat pumps
- Installation cost: $10,0000-$30,000
- Ground temperature: 43ºF



Heated Floor and Energy Recovery Ventilation





Heated floors save 15% on heating costs.

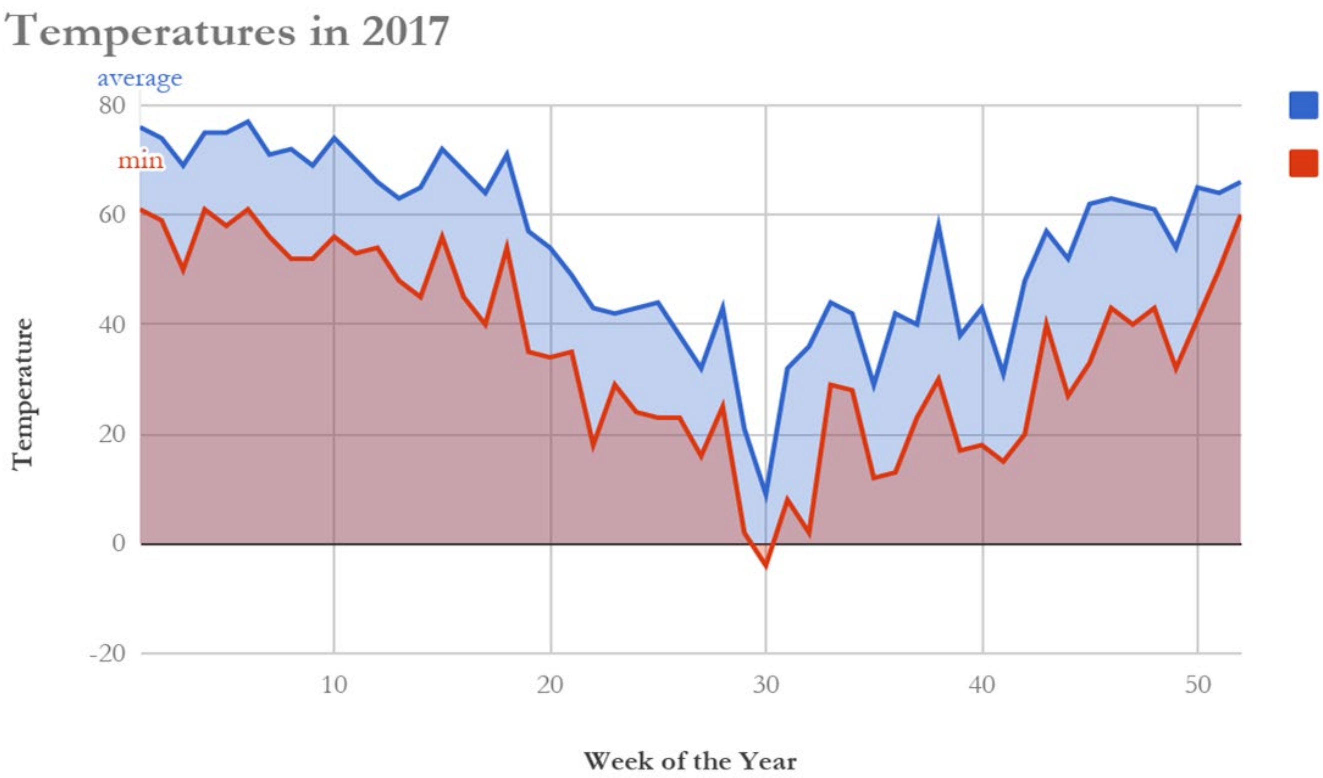
ERV saves nearly 50% on heating costs.

Heating and Cooling Systems First Pass Analysis Cont. . .

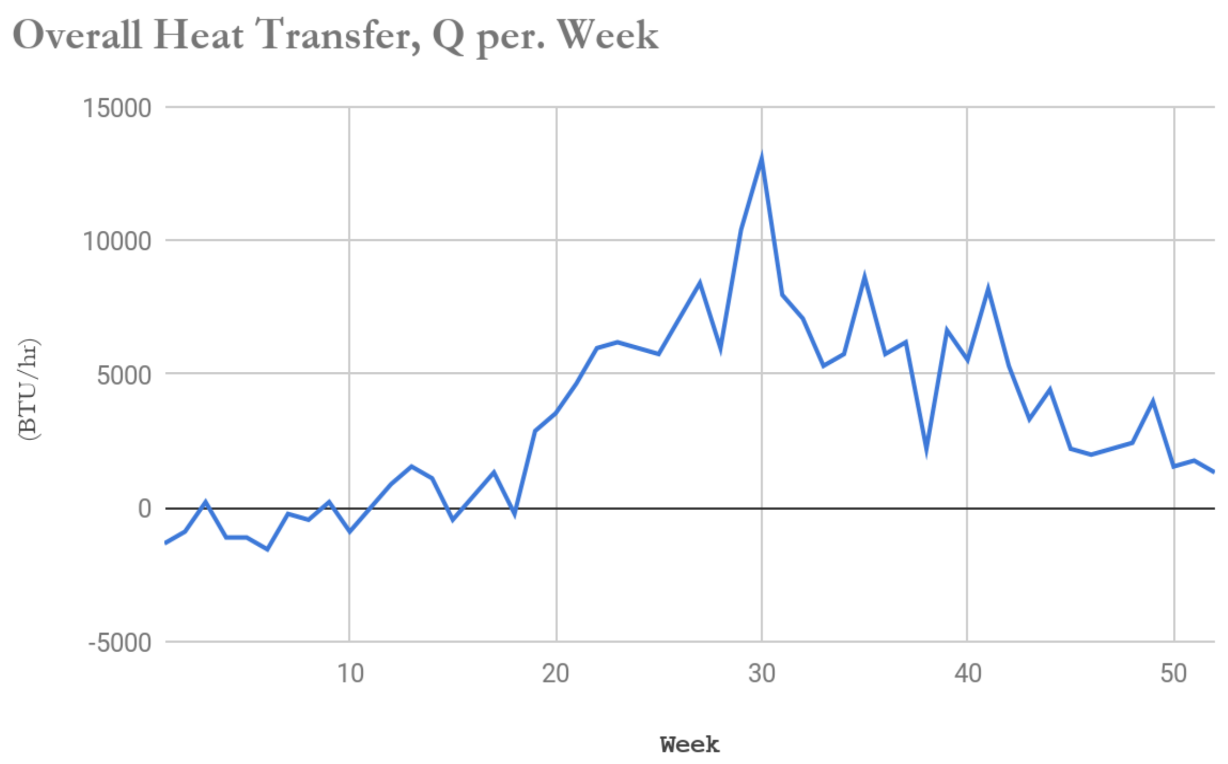
	Summer			Fall		
	Heat pump	ERV	Heated Floor	Heat pump	ERV	Heated Floor
Wattage (W)	2000	40	0	2000	40	12
Hrs in a day	1.75	5	0	0.5	3	3.5
kWh	3500	200	0	1000	120	42
Seasonal Consumption	343000	19600	0	89000	11760	3738

	Winter			Spring		
	Heat pump	ERV	Heated Floor	Heat pump	ERV	Heated Floor
Wattage (W)	2000	40	12	2000	40	12
Hrs in a Day	1.5	1.5	2.5	1.5	3.5	2.5
kWh	3000	60	30	3000	140	30
Seasonal Consumption	267000	5880	2640	267000	13720	2700

Heating and Cooling Systems
Heat Transfer Analysis Cont. . .



Heat Transfer Analysis Cont. . .



Appliances Selection

- Which appliances to choose?
  - Necessities
  - Luxuries
- How to choose among competing brands?
  - Energy Usage (Estimations)
  - Cost
  - Aesthetics
- Methodology
  - Determining energy usage over a period of time
  - Multi-packaged products

Examples of Appliances Selection

Appliance	Option	Estimated Monthly Energy Usage			Energy Cost/Year			Cost	Energy Cost/Year (9.2 cents*kW*hr)
		Power (kW)	Usage (Hours)	kW*hr	Power (kW)	Usage (Hours)	kW*hr		
Oven/Stove	Whirlpool	1.975	30.00	59.25	1.975	360	711.00	$439.20	$65.41
	Frigidaire	1.925	30.00	57.75	1.925	360	693.00	$398.70	$63.76
	Samsung	1.920	30.00	57.60	1.920	360	691.20	$648.90	$63.59
Vacuum	Shark	1.200	4.00	4.80	1.200	48	28.80	$149.99	$2.65
	Hoover	1.440	4.00	5.76	1.440	48	34.56	$99.99	$3.18
	Dyson	1.400	4.00	5.60	1.400	48	33.61	$399.99	$3.09
Ceiling Fan	Kensgrove	0.031	180.00	5.58	0.031	2160	66.96	$299.00	$6.16
	Altura	0.094	180.00	16.92	0.094	2160	203.04	$229.00	$18.68
	Fenceham	0.031	180.00	5.58	0.031	2160	66.96	$229.00	$6.16

- Estimations
- Selection Matrix - Factors and Weights

Plug-in Hybrid Vehicles

Vehicle	Energy Consumption per 100 Miles	Yearly Energy Cost	Price
2018 BMW i3 REX*	31 kWh	$373.40	$47,450.00
2018 Chevrolet Volt*	31 kWh	$373.40	$33,220.00
2018 Honda Clarity	31 kWh	$373.40	$33,400.00
2018 Hyundai Ioniq	28 kWh	$337.26	$22,200.00
2018 Kia Niro	32 kWh	$385.44	$23,340.00
2018 Kia Optima	33 kWh	$397.49	$22,600.00
2018 Ford Fusion	35 kWh	$421.58	$22,215.00
2018 Chrysler Pacifica	40 kWh	$481.80	$26,995.00
2018 Audi A3	41 kWh	$493.85	$39,500.00

* - Fully Electric Vehicle
** - All numbers provided by Department of Energy (www.fueleconomy.gov)

Energy Storage: Battery

Selection Criteria

	(1-5) Selection Grade				
Type	Size	Capacity	Reliability	Lifespan	Price
Lead Acid	4	4	5	3	5
Lithium	5	2	4	3	2
Nickel Cadmium	3	2	3	2	1
Nickel Iron	2	3	3	3	1

Battery Selected

- The system used for this particular house is a golf cart battery system.
- Capacity: 1.2 KWh per unit.
- Needed is 27 batteries to store enough power for 3 days.
- Cost: $100-150 per unit.
- Total Cost: $4100 Max.

DC/AC Conversion: Magnum Energy MS4448PAE Inverter

- Solar Panels Generate DC, but Houses Use AC;
- An Inverter is Needed to Convert DC Power to AC;
- Continuous Power Output = 4.4 kW
- Cost of Inverter = $2,195;

Energy Acquisition: Solar Panels

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System Selection

- **Meeting our energy requirements**
- Both theoretical and collected local data will be compared and provide a base total energy consumption.

- **Daily energy production**

- Knowing how much a particular system can produce will help answer the “black-out” scenario as well as the battery system required to meet the homeowners needs.
- This also determines how close the house can come to running at net zero for the year.

- **Design Phase**
- Can a system meeting the previous needs be integrated into the house design? (how many systems will be needed and how much area will they require)

7 kW Solar Panel System

- Useful or productive sunlight per day for the West Virginia regions is typically considered to be **4-5 hours**.
- Consists of 28 260W panels 28*260 = **7,280 kw**
- Space Required: **500** ft^2
- $(7kw)(4\ hrs)(360\ days) = \mathbf{10,000 - 10,500}\ \boldsymbol{kwh\ per\ year}$
- Daily Production = **27.8 kwh**
- Includes Micro-Inverter system to allow solar panels to continue producing individually. Typically if one panel breaks or becomes covered (shade, dirt, snow) the whole system will be rendered useless. Increasing downtime and wasted power.

Solar Panel Options

- Solar Panel Systems are typically categorized and sold by the number of kilowatts the system produces. Ranging from **1kw to 15kw** sized systems.
- There are also a number of materials or processes used that separate the performance and reliability of one system to another
  - Monocrystalline
  - **Polycrystalline***
  - String Ribbon

* Simple and cheaper to manufacture, so cost is less and will perform under the given conditions.

Mono systems are more expensive and require a microinverter system to combat shade or coverage issues. Better for higher temp areas which is not a concern for us.

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How this Relates to the Power Outage and Battery System

- Assumption 1 – Project House (30,000 kwh yearly)
  - **83.3 kwh** average daily usage
  - $(83.3\ kwh)(3\ days) = \mathbf{250\ kwh}$ (3 days off grid)
  - $\frac{250\ kwh\ (house)}{27.8\ kwh\ (solar)} = \mathbf{9\ days}\ to\ charge\ up\ battery$
  - **7 kwh System** provides **1/3** of the yearly consumption
- Assumption 2 – Average of Project House to Local Electricity bills (20,148 kwh yearly)
  - **56 kwh** average daily usage
  - $(56\ kwh)(3\ days) = \mathbf{168\ kwh}$ (3 days off grid)
  - $\frac{168\ kwh\ (house)}{27.8\ kwh\ (solar)} = \mathbf{6.04\ days}\ to\ charge\ up\ battery$
  - **7 kwh System** provides **0.496 or 50%** of the yearly consumption
- Assumption 3 – Energy Conscious (10,000 kwh yearly)
  - **27.8 kwh** average daily usage
  - $(27.8\ kwh)(3\ days) = \mathbf{83.3\ kwh}$
  - $\frac{83.3\ kwh\ (house)}{27.8\ kwh\ (solar)} = \mathbf{3\ days}\ to\ charge\ up\ battery$
  - **7 kwh System** provides **100%** of the yearly consumption

Final Solar Panel Design

Design

- The ranch style home design allows for maximal roof surface area at a low pitch that allows for an ideal mounting angle.
- With **921.6** ft^2 of roof (per side) available the **7kw solar system** will require only **half** of the usable space, allowing plenty of room for mounting or additional systems.

Meeting Consumption Requirements

- The **7kw system** will meet a **1/3** of the energy consumption needs at extreme and theoretical assumptions and **Net Zero** values at lower energy conscious scenarios.

Off Grid/ Net Zero

- With the correct battery system the house should be able to produce and store sufficient energy to power the house in the case of emergency. Assuming 3-6 are allowed to recharge the batteries between black outs.
- Energy can be produced during the summer months **(4,200 kwh)** and sold to the grid while buying back in the winter months to achieve Net Zero and backup protection.

Final Results: Cost

	Cost	% of Total Cost
Structure	$204,020.90	81.22%
Heating/Cooling System	$18,180.95	7.24%
Solar Panels	$15,676.75	6.24%
Battery and Inverter	$6,295.00	2.51%
Appliances	$7,025.81	2.80%
Total Cost	$251,199.41	100%

Conclusions and Recommendations

- The Net-zero House System is Achievable but Expensive.
- The Variation of Solar Engine Available with Seanon is Challenging in Solar System Capacity Design;
  - It is difficult to achieve “Net-Zero” Operation all of the time, but can be mitigated by selling extra electricity to grid and buy back when more electricity is needed;
- A battery is necessary in dealing with the extremly bad weather in case of grid power is not available;
- Current vehicles are similar enough in energy consumption that cost should be main purchasing factor.

Conclusions and Recommendations

- Major amount of energy consumption comes from heating and air conditioning (~45-50% in typical homes). This house's HVAC accounts for 40.8% of total use.
  - Most of this total happens in the colder months.
- Structure plays a vital role. Energy lost to the environment leads to more HVAC costs.
- Current vehicles are similar enough in energy consumption that cost should be main purchasing factor.
- Appliance energy consumption can be reduced if cost is not a factor.
- 7 kW solar system best meets the energy needs of the house.
  - Additional systems can be added if necessary;

Future Work

- Survey of Solar Panel Operation Data;
  - Provide better input to solar capacity selection;
- Evaluate more options of energy storage/back-up system;
  - Battery System;
  - Traditonal Generator + more solar cell;
- Further Optimize the Design of the House Structure;
- Further examine the impact of life style/meal recipe on Energy Consumption;

Final Results: Cost

https://www.mtvsolar.com/wp-content/uploads/2015/07/mtvpic3.jpg

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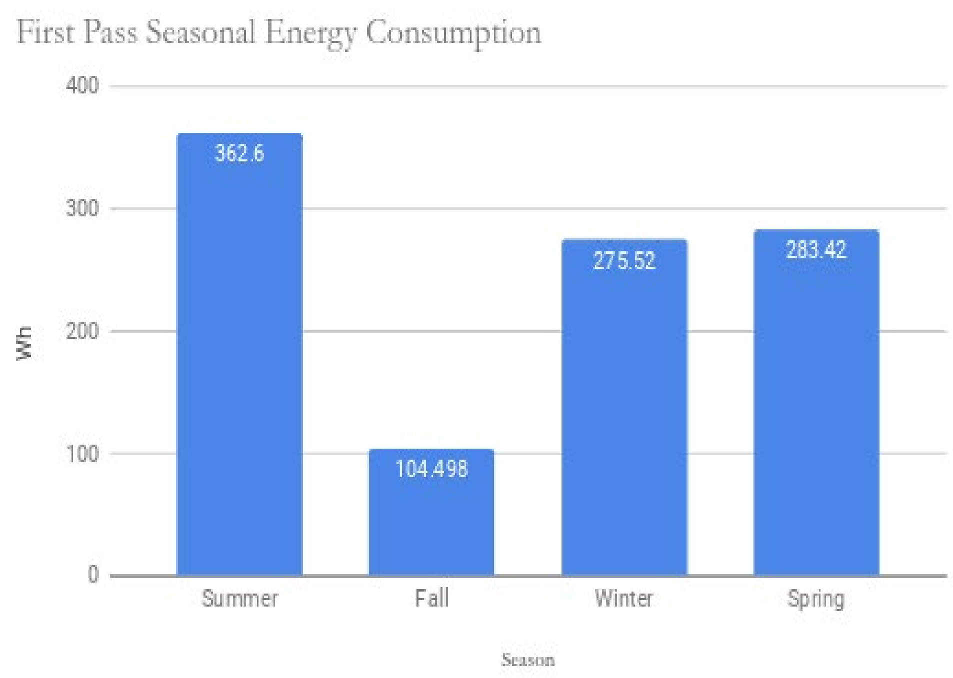
Heating and Cooling Systems
First Pass Analysis Cont. . .

- Follow trend of actual energy nsumption actual values;
- Yearly kWh consumption: 1026.04 kWh
- Cost for the year: $110.81
- Estimate likely to be an overestimation



Heating and Cooling Systems
Heat Transfer Analysis

- Estimated heat escape
  - $Q = h*A*\Delta T*U$
  - $U=(1/R)$
- Average heat loss per temperature of the week in 2017
- Ideal case, doesn't consider:
  - Thermal capacitance furniture
  - Heat generated by appliances, people, electrical components
  - Drafts Solar gain