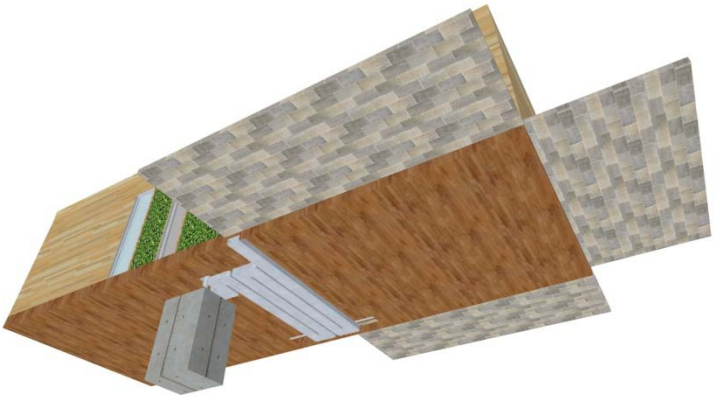
Nexus: Technical Core

Borton-Lawson Solar Decathlon 2009

EDSGN 100 Section 007

Team Mongitech



Submitted To: Andrew Lau

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Abstract

For the 2009 Solar Decathlon, we have designed a technical core (mechanical room, kitchen, laundry, and bath area) that will not only use significantly less energy than a standard house, but will also have less of an impact on the environment by reusing much of its waste. This paper discusses the appliances used that were most energy efficient and used the least amount of water. It also shows the advantages of a composting toilet along with the idea to use warm grey water to heat incoming cold water. Furthermore, it shows a system that takes heat from appliances and uses it to heat the house. This paper discusses the advantages to using such appliances and systems in a solar house.

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Problem Statement:

The overall goal is to design a house that uses solar energy as its sole source of power. We will design a technical core – the essential components of the house which includes machine room, bathroom, and kitchen/laundry area – suitable to the average two person home's needs. We are going to minimize energy usage while attempting to reuse all or most of the waste. Our technical core will be energy efficient while still keeping the house comfortable, convenient, and suitable for healthy living.

Appliances Used in House

Appliances	Electricity Used (KwH/year)	Water Used (Gal/day)
Generic Clothes Washer [1]	140	18.6
Asko W6222 Washer[2]	100	4
Generic Clothes Dryer[3]	1114	N/A
Miele T1413[4] w/ Hydromatic Dryer Miser Hydronic Dryer Conversion[5]	392	N/A
Generic Dishwasher[1]	274	2
Bosh Evolution 800 Series[6]	190	2
Generic Refrigerator[3]	669	N/A
Sun Frost RF12[7]	106	N/A
Generic Faucet[1]	N/A	20.8
Eartheasy .5 GPM faucet aeretor[8]	N/A	1.5
Generic Toilet[1]	N/A	19
Sun-Mar Excel NE[9]	N/A	0
Generic Shower[1]	N/A	20
Shower with Chicago Faucet Econo-flow[10]	N/A	6
Generic Stove[3]	806	N/A
Viking 30" All-Induction Cooktop - VICU [11]	365	N/A
Generic Microwave[3]	135.1	N/A
Generic Oven[3]	540	N/A
Generic Oven + Microwave	675	N/A
GE Profile 1.7 Cu. Ft. Convection Microwave[12]	485	N/A
Generic Total	3678	80.4
Solar Total	1638	13.5

[1] www.harvesth2o.com/www/www/big_pipe_figuire6
[2] http://www.askousa.com/laundry/family_size_laundry/w6222-washer/#
[3] Building America
[4] http://shopping.yahoo.com/p:Miele%20W1203%20Touchtronic%20Series%20Washing%20Machines%20Washer:2002331735
[5] http://www.dryermiser.com/Home/tabid/55/Default.aspx
[6] http://www.boschappliances.com/products/specs_dimensions_popup.aspx?product_id=693
[7] http://www.sunfrost.com/refrigerator_specs.html
[8] http://eartheasy.com/store/proddetail.php?prod=AERATOR
[9] http://www.sun-mar.com/prod_self_exce_ne.html
[10] http://www.homeannex.com/prodView.asp?idProduct=414841&idF=1776261&utm_source=GoogleBase&utm_medium=CPC&utm_campaign=GoogleBase&Eng=CA&a64=GoogleBase&mn9=Chicago%20Faucets&keyword=414841-1776261&CAWELAID=235268704
[11] http://www.vikingrange.com/consumer/products/product.jsp?id=prod110164
[12] http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SPECPAGE&SKU=JVM1790SK&SITEID=GEA&CHANNEL=CH0000

The data in water and electricity usage for our house came from the technical specifications of our various appliances. We adjusted these numbers to make them reflect usage in a house occupied by two individuals. Upon totaling those numbers we able to get an accurate estimate of the total water and electricity usage for our house. As far as the national averages go, we researched online to find various facts and statistics on the average usage for a normal household. Again we adjusted them to fit a house of our size and occupancy.

The selection of our appliances was driven mainly by the most efficient energy and water usage. Websites such as energy star were used as a guiding force and for technical specifications on some products. Further research was then done to select the best product, find its usage numbers, and decide on any modifications that may need done. Through this search process we came up with the above mentioned statistics and choices.

Composting Toilet

The idea of installing a composting toilet is a simple one time investment that has far reaching effects for the environment and the running of the house. The idea of a composting toilet is to replace convention means of human waste management with a new, more environmentally friendly system. It works by using peat and other organic substances to safely turn the waste into more usable compost. A pipe then safely removes the odors of the house. This toilet reduces the water usage in our home by 19 gallons[13] per day. This has direct benefits in that it reduces wasted water and also has farer reaching benefits by saving electricity costs of water heating. Pictured below is the model we chose, the Sun-Mar Excel NE(information taken from the Sun-Mar website[14)]:

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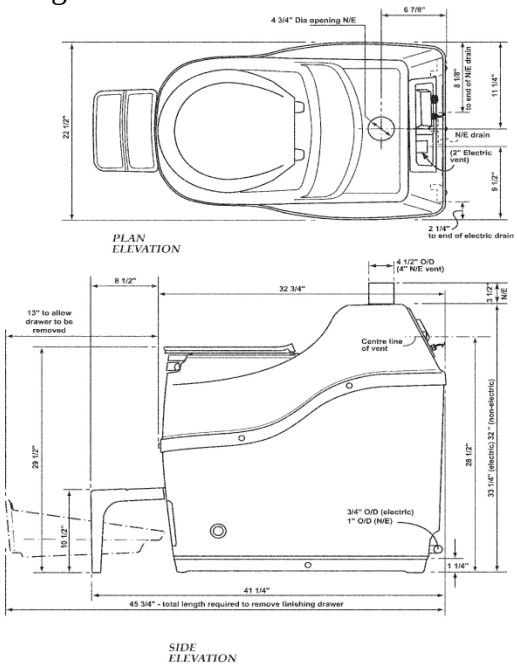
13 www.harvesth2o.com/www/www/big-pipe_figure6

14 http://www.sun-mar.com/prod_self_exce_ne.html

Picture:

Diagram:



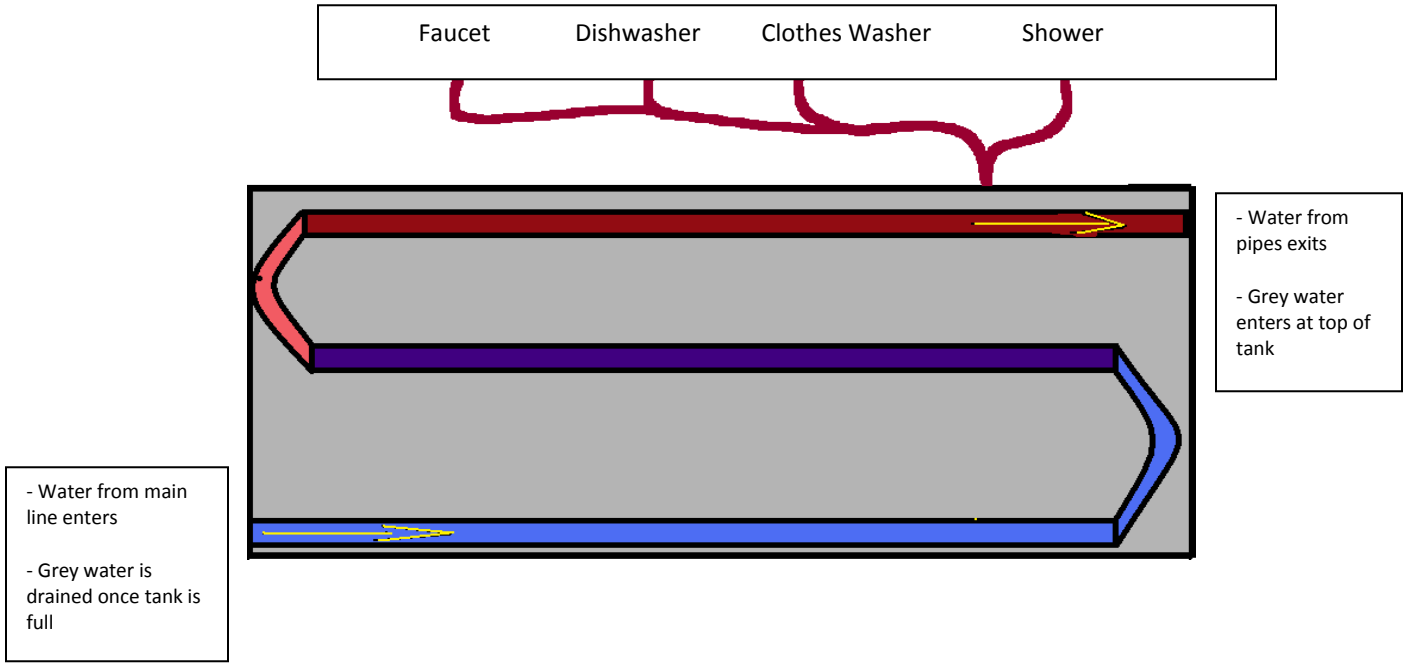
From this design we made several modifications to improve upon its design. First a 12 volt, 1.4 watt fan will be install and attached to a switch to control use. This can be used as a way to eliminate odor if needed. The toilet is designed to not need one, but the switch will allow the user to control smell if necessary for minimal energy cost. Furthermore, the exhaust pipe will protrude 4 feet out of the roof of the house and will have a conic roof of radius 3” and height of 3” covering the exhaust. This will protect the pipe from the elements and will act as a base for photogenic cells. The pipe and roof will line with these cells completely and will produce an average of 6.23 watt-hours of energy per day. This will completely cover energy cost of some use of the fan or reduce the amount needed for continuous use. This number was calculated using the equation $E_{sol} = (I_t)(A)(\eta)(t)$ where: I_t = long-term average solar per day per unit area at specific tilt and orientation from 2b above (W/m^2-day, or Btu/ft^2-day), A = total area receiving

sun (m^2 or ft^2), η = annual efficiency of converting sunlight to useful energy (see Table at right), t = time, if I_t is annual average per day and analysis is for a year then t=365 days.

WATER REUSE SYSTEM:

The idea behind the water reuse system is to reclaim the heat from the grey water to help in the heating of the cold water coming in through the main line to the house. The idea is to run all of the hot/warm grey water in the house into a tank where it will be stored. The grey water will come from faucets, the dishwasher, the clothes washer, and the shower in the house. Their drainage pipes will be linked to the tank where the grey water will be contained, and the grey water will flow into the top of the tank on the far end of the tank. There will be pipes running through the tank with the fresh colder water coming into the house. The grey water will heat up the cold water and will reduce water heating costs. The pipes will wrap around to the other end and to the top of the tank where it will leave the tank for use. Where the cold water will be leaving the pipes for use is where the warm grey water will enter the tank to maximize the effect of heating on the cold water. Once our tank is filled to capacity with grey water, it will be drained out of the back end of the tank beside where the main line runs into the tank.

Diagram:



One of the things we needed to find was the average temperature for the main water line year round. We found that the average temperature of the main line during summer months was approximately 75° F and was 40° F during winter months.[15] Since the temperatures vary, we decided to estimate the temperature in the main line year round to be 60° F. From the resources provided to us for the project, we found the water heater set point to be 120° F. Also, we needed to find average temperatures for the water that is put into the appliances used in this system. For the faucet, we found that the water coming out of the faucet is about 120° F.[16] We wanted to account for the fact that water used from the faucet can as cold as 60° F, so we used an average faucet water temperature of 90° F. In our research, we found varying temperatures

[15] http://books.google.com/books?id=NAdQGV-imRAC&pg=PA404&lpg=PA404&dq=tap+water+temperature+from+pipes:+summer+vs.+winter&source=web&ots=voQNnj102g&sig=X4tIiRJ4x0xZBaqRkl0Xf3b3Rig&hl=en&sa=X&oi=book_result&resnum=10&ct=result#PPA404,M1

[16] http://www.askmehelpdesk.com/interior-home-improvement/shower-hot-water-temperature-standard-apt-56067.html

for the average temperature of shower water, so we estimated the shower water to be 100° F. We found that dishwashers should be set at least 120° F, so this is the temperature we used in our research.[17] Finally, we found that the clothes washer can have varying temperatures for the water depending on whether a hot cycle (130° F +), warm cycle (110-90° F), or cold cycle (80-60° F) were used to wash clothes.[18] Since the water temperatures of a clothes washer vary greatly, we chose to use 100° F in our research.

We used all of these findings to calculate a variety of things such as the energy needed to heat the daily hot water used in an average house versus the solar house using the equation $E_{in} = V\ d\ c\ (T_{hot} - T_{cold})$, where V = volume of water, d = density of water = 8.3 lb/gal, and

c = specific heat = 1.0 Btu/lb-° F. The water volumes used in the following calculations are from our findings of daily water usage used in the following chart (#'s also located in previous chart):

	Average House (gal)	Solar House (gal)
Faucet	20.8	1.5
Shower/Bath	20	6
Toilet	19	0
Clothes Washer	18.6	4
Dishwasher	2	2
Water Usage (Daily)	**80.4**	**13.5**

Calculations to heat house water: (without water reuse system incorporated in design)

Solar House: 13.5 gal/day (8.3 lb/gal) (1.0 Btu/lb-° F) (120-60° F)

= 6,723 Btu/day / 3,413 Btu/kwh = 1.97 kwh/day (~ 720 kwh/year)

[17] http://www.frigidaire.com/support/FAQ-Dishwasher.asp
[18] http://housekeeping.about.com/od/laundry/a/laundry_h20temp.htm

Average House: 80.4 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (120-60°F)

= 40,039.2 Btu/day / 3,413 Btu/kwh = 11.73 kwh/day (~ 4,280 kwh/year)

Calculations of energy in water in each appliance:

Faucet: 1.5 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (90°F) = 1,120.5 Btu/day

Shower: 6 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (100°F) = 4,980 Btu/day

Dishwasher: 2 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (120°F) = 1,992 Btu/day

Clothes Washer: 4 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (100°F) = 3,320 Btu/day

Total Energy of all appliances added together: 11,412.5 Btu/day = 3.34 kwh/day

Calculation of temperature of grey water that will be drained into tank:

$(T_{\text{faucet grey water}} + T_{\text{shower grey water}} + T_{\text{dishwasher grey water}} + T_{\text{clothes washer grey water}}) / 4$

= (90°F + 100°F + 120°F + 100°F) / 4 = 102.5°F ~ 100°F

Calculation to heat solar house water: (with water reuse system incorporated in design)

13.5 gal/day (8.3 lb/gal) (1.0 Btu/lb-°F) (120-100°F)

= 2,241 Btu/day / 3,413 Btu/kwh = 0.66 kwh/day (~ 240 kwh/year)

Calculation for reducing the energy water heating cost of solar house: (solar house with the water reuse system incorporated vs. solar house without water reuse system)

1 – (0.66 kwh/day / 1.97 kwh/day) = 0.66 x 100 = 66 % (energy water heating cost will be reduced by 66 % with the water reuse system incorporated in solar house vs. not having one in the solar house)

Analysis:

With the energy efficient appliances that we have chosen for our solar house, the results show that our house is much more energy efficient when it comes to heating the water to the desired

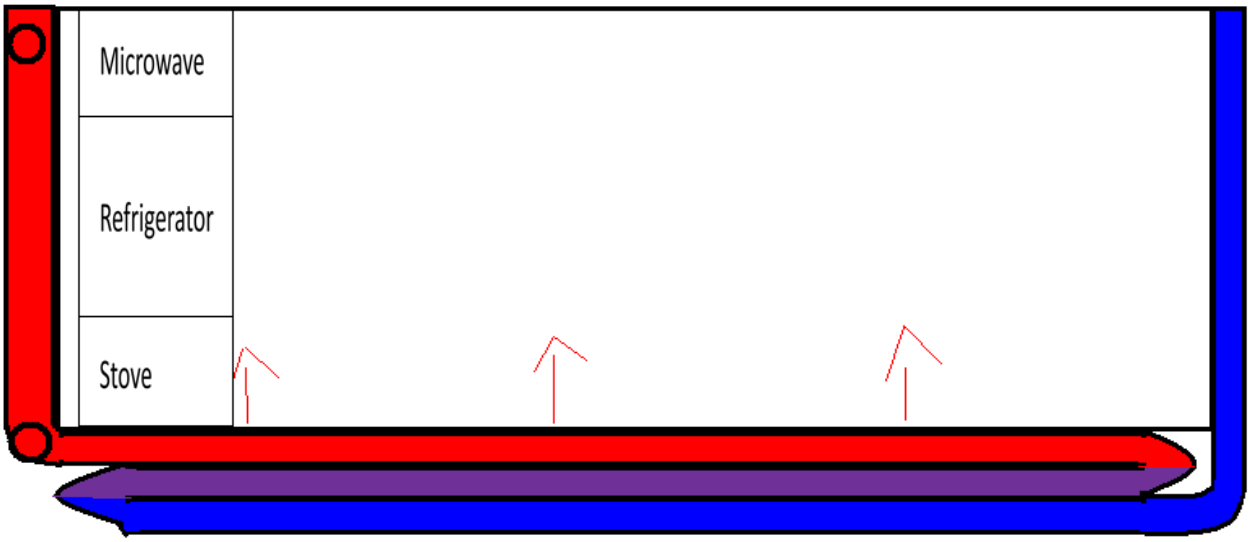
120° F than it is for the average house with ordinary appliances. Without the water reuse system incorporated into the solar house, the results still show that the solar house will only use 720 kwh/year as opposed to the average house which uses 4,280 kwh/year (saving 3,560 kwh/year). Clearly our solar house is much more energy efficient than the average house. With the water reuse system incorporated in the design of the solar house, we can cut down the energy used to heat the water to 120° F from 720 kwh/year to an astounding 240 kwh/year, thus further reducing energy costs to heat the water. The reason for this is without the water reuse system, we will have to heat the water to 120° F from starting at 60° F coming in through the main water line. Instead with the water reuse system, the starting temperature to heat the water to 120° F will be 100° F rather than 60° F by reusing the energy already in the warm grey water. We can reclaim more energy with the water reuse system than it takes to heat the water coming into the house (3.34 kwh/day vs. 1.97 kwh/day); it will only take 0.66 kwh/day to heat the water coming into the solar house as opposed to 1.97 kwh/day with the water reuse system used in the design. We will be reducing the energy water heating cost for the solar house by 66 %. We are basing our results on a 100 % efficient system, but the numbers for the energy saved to heat the water will still be beneficial with the water reuse system used in the solar house.

IMPORTANT POINTS OF THE WATER REUSE SYSTEM:

- Warm grey water is drained into tank which heats cold water flowing into house
- Cold water flows into house from main line and wraps around warm grey water in tank
- Water in tank is about 100 degree Fahrenheit
- Will reduce energy heating cost by 66%

Appliance Heat Transfer:

The heat transfer system works by taking the excess heat from the refrigerator, microwave/oven, and the stove. The heat is transferred through fans and pipes. The heat is first taken from the appliances and pushed into the pipe behind the appliances. If the room does not need to be heated the fans in the pipe force the hot air out of the house. If the room needs to be heated than the heat is pushed down below the floor with the fans. The pipes go back and forth underneath the floor, wrapping underneath each other which gives more time for the heat to rise. The heat rises from the pipes up into the room through conduction. The now cool air continues to move through the pipes and eventually out of the house. Filters are used to reduce the amount of environmentally harmful emissions that escape the house.



Research:

In order to calculate how much energy was being created by the appliances the wattage was found for each device, and the amount of time that it would be used per day was estimated. Since all electricity that is used to power the appliance is converted into heat, all the energy used by each appliance can be used to heat the house. The Sun Frost RF12 refrigerator's daily energy consumption was found on the Sun Frost website. [19] The GE Profile™ 1.7 Cu. Ft. Convection Over-the-Range Microwave Oven's[20] energy consumption was found in two parts. First the microwave energy usage was calculated in which the wattage for the GE microwave was found to be 1000 watts. It was estimated that the microwave would be used on average of 10 minutes per day, so the entire energy used by the microwave was estimated at .165KwH or 106 KwH per year. The oven had an power rating of 870 watts with an estimated daily usage of 45 minutes per day, which comes out to 1.163 KwH per day. So the energy used per day from the microwave convection oven is 1.328 KwH per day or 485 kwh per year. The Viking 30" All-Induction Cooktop - VICU stovetop was found to have an average wattage of around 2000 watts based on the information on the Viking website.[21] It was also estimated that the stove would be used 30 minutes a day making the daily energy usage of 1 KwH per day or 365 KwH per year. This means that the total energy that the system is reclaiming is 2.618 KwH per day or 956 KwH per year. An average house of the size of the solar house using electric heating at an efficiency of 1 would need 5700 KwH to heat it. It was also found that it takes about 4.4 KwH per day or 1600 KwH per year to heat the house using a ground source heat pump with an efficiency of 3.5.

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[19] http://www.sunfrost.com/refrigerator_specs.html

[20] http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SPECPAGE&SKU=JVM1790SK&SITEID=GEA&CHANNEL=CH0000&TABID=2

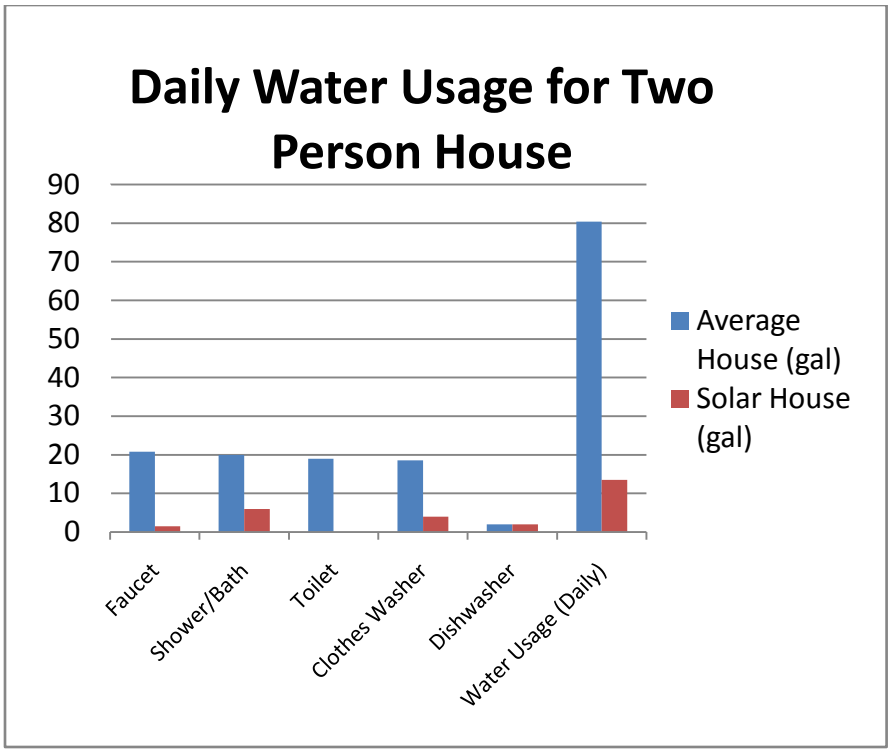
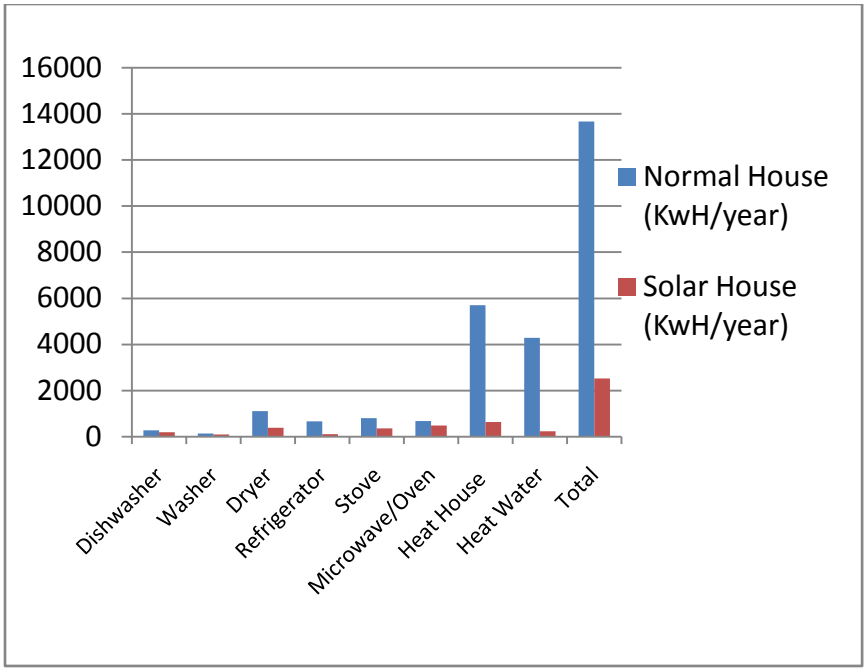
[21] http://www.vikingrange.com/consumer/products/product.jsp?id=prod110164

Analysis:

The appliance heat transfer system shows the capability of being able to greatly reduce the amount of energy needed to heat the house. The original 1600 KwH needs to heat the house is reduced to 644 KwH, or about 60 percent. This is much more energy efficient than the original house without the system in place. If the system with the ground source heat pump is compared to the house with just electric heating, the system with the ground source heat pump reduced the energy needed to heat the house from 5700 KwH to 644KwH or by a little less than 90%. Since heating the house along with heating the water is the largest source of energy consumption in the solar house, the system reduced the total energy needed by 67% compared to electric heating alone. When compared to a house using a heat pump and no appliance heat reuse system, this system reduced the total energy usage in the house by 20%. It is also important to note that the heat transfer system will also reduce energy needed to cool the house in summer by moving the heat created by the appliances from the house to outside the house.

Main Points of Solar House

- Appliances cut energy usage per year by 55% and water usage by 83%
- Composting toilet saved 19 gallons of water per day
- Water reuse system cut energy usage to heat water by 66%
- Appliance heat transfer system cut energy use to heat the house by 60% compared to a house with a heat pump but without the system
- Total energy usage of the house was reduced by 11,139 kWh/yr, or 77%
- Graphs to show this data below



Energy Usage Per Year