LIVERMORE HOME – DEEP ENERGY RETROFIT

Deep Energy Retrofit means taking a "whole house" approach, super insulating it and achieving more than 50% energy savings.

I. Basic Information about home and its location

1. City or town, province or state, country
Gloucester, Massachusetts, USA

2. Site description (urban, suburban, rural; description of terrain and density) and home orientation (front door faces which direction? If there's a longer axis, does it run between N&S or E&W?)
SubRural (outskirts of suburbia), Density: 1166/mi² (450.2/km²), Terrain : Gloucester is a natural harbor. So it is essentially a coastal area and the land closer to shores is marshy.
Home orientation : The long axis of the house is along NW – SE. Therefore, two long facades are SW and NE. The main entrance door is located on SW facade.

3. New construction or retrofit?
Retrofit – Originally 1972, Garrison Ranch House

4. Conditioned area in ft2 and m2
2430 sq ft (on both levels); 225.75 sq m

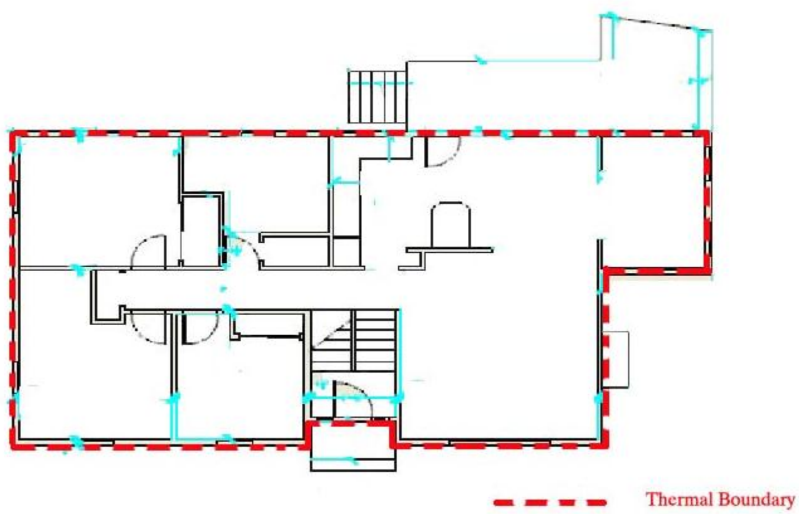
5. Number of bedrooms and number of occupants during metering period
3 occupants during metering period, 4 bedrooms

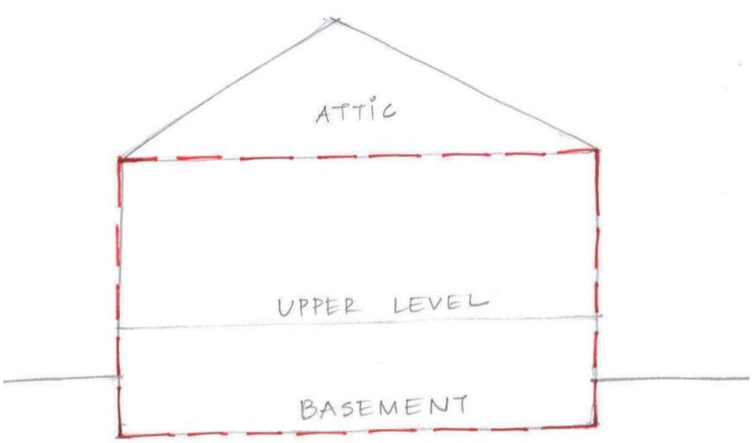
6. HDD(65)/HDD(18)
5641 HDD

7. CDD(65)/CDD(18)
678 CDD

II. Building Envelope

1. Draw and describe the thermal boundary for the house.
Opaque surfaces (walls , basement) were insulated. Floor of attic was insulated too. Sketch showing the thermal boundary in plans and section attached.

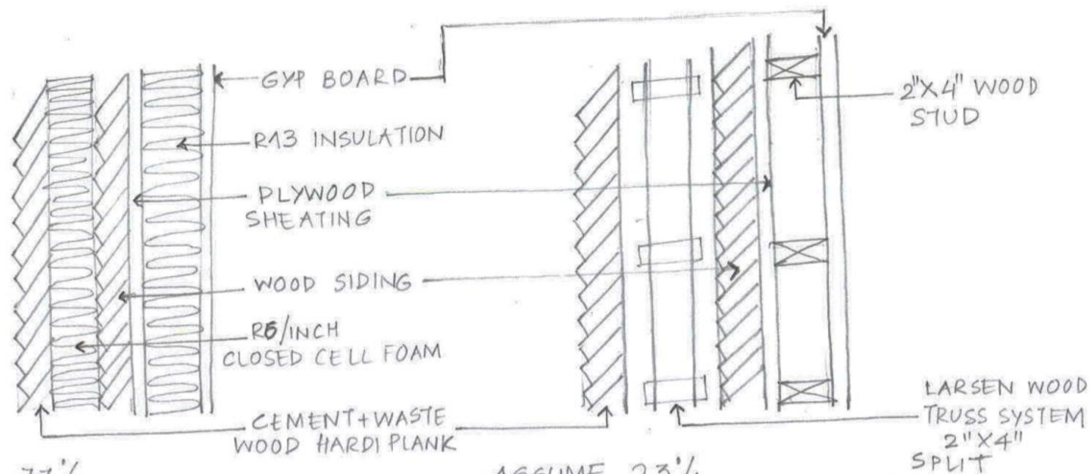




2. Hand draw the wall, roof and foundation assembly layers, from outside air layer to inside air layer. Show your calculated R-value for each.

Sketch and calculations showing wall, roof and foundation assemblies with the R values are attached.

Wall Assembly



ASSUME 77%

	R-VALUE
OUTSIDE AIR	0.17
HARDI PLANK	0.51
CLOSED CELL FOAM - 5"	30.00
WOOD SIDING	0.79
PLYWOOD SHEATING	0.62
INSULATION	13.00
GYP BOARD	0.32
INSIDE AIR	0.68
TOTAL R	46.09

ASSUME 23%

	R-VALUE
OUTSIDE AIR	0.17
HARDI PLANK	0.51
WOOD STUD	6.82
WOOD SIDING	0.79
PLYWOOD SHEATING	0.62
WOOD STUD	6.82
GYP BOARD	0.32
INSIDE AIR	0.68
TOTAL R	16.73

0.77 (46.09) = 35.489

0.23 (16.73) = 3.84

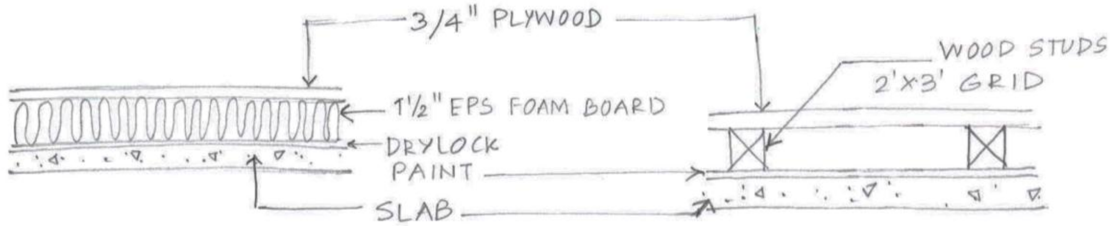
WEIGHTED R = 35.489 + 3.84 = 39.32

R = 39.32

TARGETED R = 43

Foundation Assembly

Floor:



	R VALUE		R VALUE
INDOOR AIR	0.68	INDOOR AIR	0.68
PLYWOOD	0.62	PLYWOOD	0.62
EPS FOAM (3.85/in)	5.77	STUDS	3.41
PAINT	—	PAINT	—
TOTAL R	7.07	TOTAL R	4.71

0.77 (7.07) = 5.44

0.23 (4.71) = 1.08

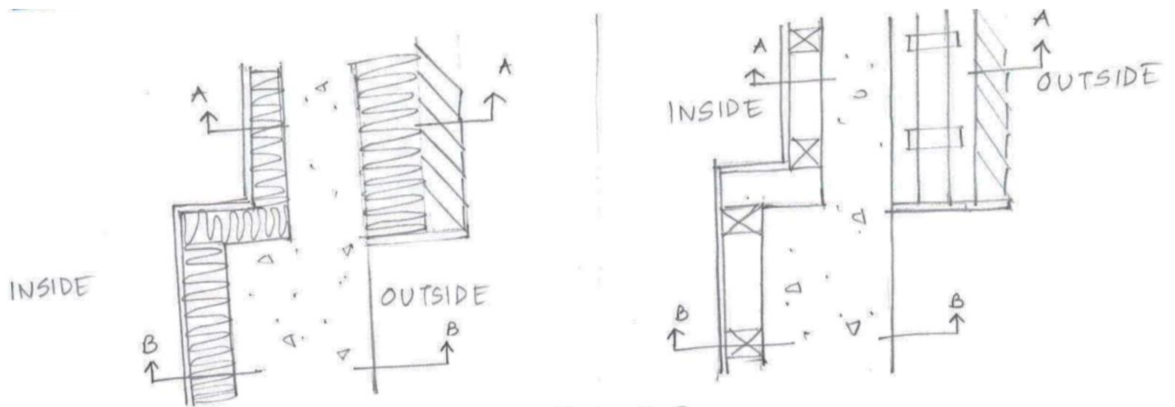
TOTAL WEIGHTED R FOR BASEMENT FLOOR

= 5.44 + 1.08

R = 6.523

PROJECTED R = 7.5

Walls:



PROJECTED R = 22

	R VALUE
INSIDE AIR	0.68
PLYWOOD	0.62
EPS FOAM	5.77
CONCRETE	1.11
CELL FOAM	30.00
SIDING (HARDI PLANK)	0.51
OUTSIDE AIR	0.17
TOTAL R	38.86

0.77(38.69) = 29.53

	R VALUE
INSIDE AIR	0.68
PLYWOOD	0.62
STUD	3.41
CONCRETE	1.11
STUD	6.82
SIDING	0.51
OUTSIDE AIR	0.17
TOTAL R	13.32

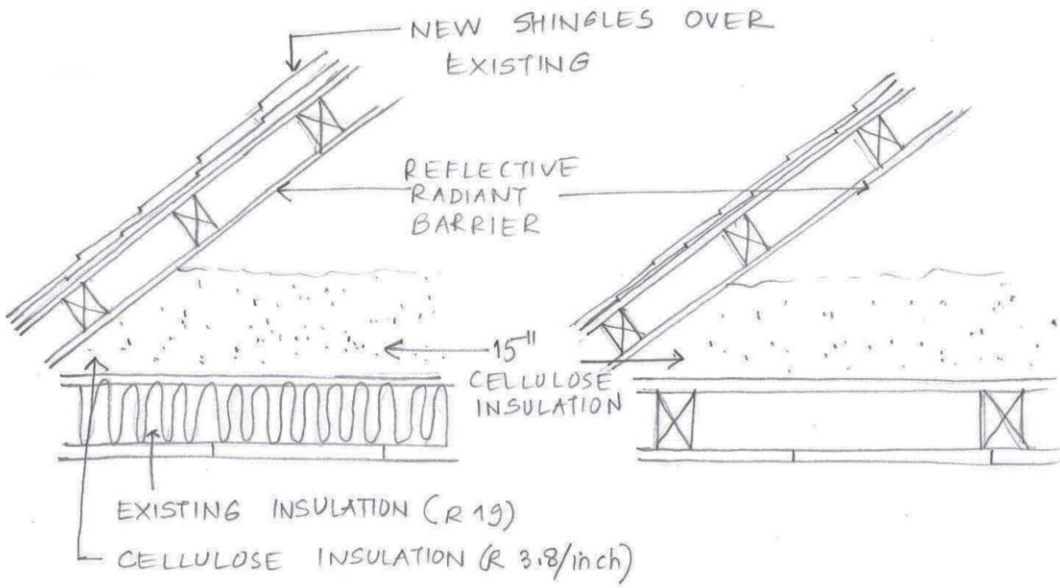
0.23(13.32) = 3.06

TOTAL WEIGHTED R = 29.53 + 3.06

R = 32.65

IF CALCULATED AT SECTION BB, R VALUE CALCULATION WOULD DIFFER.

Roof Assembly



PROJECTED R = 76

THEREFORE, R 76 − EXISTING INSULATION (R 19)
= R 57

CELLULOSE INSULATION (R 3.8/ inch)
∴ R57/R3.8 = 15 inches.

	R VALUE		R VALUE
OUTSIDE AIR	0.17	OUTSIDE AIR	0.17
CELLULOSE	57	CELLULOSE	57
PLY	0.62	PLY	0.62
EXISTING INSULATION	19.00	WOOD STUD	6.82
GYP BOARD	0.32	GYP	0.32
INSIDE AIR	0.68	INSIDE AIR	0.68
TOTAL R	77.79	TOTAL R	65.61
.77(77.79) = 59.89		0.23(65.61) = 15.09	

TOTAL WEIGHTED R VALUE = 59.89 + 15.09 = **74.98**

3. Describe the wall, roof and foundation assemblies.

Wall :

Innovative Larsen truss wall framing system was used over the existing exterior wall construction of 2”x4” wood stud with R13.

Regular 2” x 4” wood studs were cut in half. The distance between the two studs could vary depending on the thickness of the insulation required. The studs were held in place with the help of plywood gussets. These studs were installed over the existing wood siding so as to eliminate construction waste. This truss system helped reduce the thermal bridging and reduced the amount of wood framing required.

5” thick closed cell insulation was sprayed within this truss system to achieve solid insulation. The closed cell insulation has an R value of 5 per inch and is agriculturally based. Along with this, aluminimum mesh strips were nailed to the bottom of the trusses with a U bent so as to drain the excess moisture that would gather on the closed foam surface.

The finishing touch was given by installing the siding which is a composite material made out of cement and waste wood products.

Wall Truss system

Closed cell foam with Aluminium Mesh

Roof:

The attic with R19 was further insulated by adding cellulose insulation, air sealing and a reflective radiant barrier (bubble wrap). This increased the insulation tremendously and the reflective barrier helped in reflecting or re emitting the summer heat rather than absorbing it and hence reducing the cooling load.

The gable roof was extended so as to provide the necessary overhang for the new truss wall construction over the existing one.

Attic showing reflective bubble wrap and cellulose insulation

Foundation:
Earlier there was no insulation in the basement. During retrofit, the basement floor was insulated by putting two coats of waterproof paint, installing a 2'x3' wood stud grid and fitting 1 ½" thick EPS foam within it. This assembly was then covered with ¾" plywood sheets. The foundation walls are insulated using the same technique. EPS has an R value of 3.85 per inch. Thus it proves to be a good insulating material. The walls are treated in the similar fashion.

4. Why were these assemblies used in this climate/location?
As we can see from the HDD / CDD, Gloucester is predominantly a humid, cold climate. To achieve comfort, high insulation is required. The walls, the attic and the basement are insulated to have minimum heat loss and least air leakages.
The insulation used in the wall construction is closed cell foam. Closed cell foam is better than open cell foam as, unlike open cell foam, closed cell foam does not have air gaps. It is filled with gas and can expand to get greater insulation. Being humid, there might be good changes of moisture leaking. To cater to this problem, aluminium mesh has been installed.
The attic floor is insulated instead of the sloping roof to minimize the exposed area to reduce heating load since this house is in a predominantly cold region. The attic has cellulose as insulation along with the radiant barrier.Cellulose insulation helps controlling the heat loss. It also helps in sound insulation.The reflective bubble wrap would re emit the heat during summer and help in reducing the cooling cost.
To insulate the house further and reduce infiltration, the team also insulated the chimney.

5. Describe the windows, their U-factor, SHGC and other characteristics that may be critical to their performance.
The windows selected for the project are triple pane, low emissivity, argon filled glazing with foam filled fiberglass frames. The R value of glass is 5 with U equal to 0.2 and SHGC 0.47.
In general, the area of window openings was reduced to achieve more insulation by avoiding air leakages. The window frames were extended due to the wall trusses.

6. What is the window to floor area ratio, and window to wall area ratio? Give these as a percent.
Southwest, Northeast – approx 40% of wall area is window. Southeast , Northwest– 10%.

7. Describe the window orientation and distribution on the façade.
Maximum windows are seen on the south and north facing walls. Massachusetts receives maximum wind annually from west and north west. The windows on the east and west are narrower and have less area. They also changed the sliding windows to clerestory to reduce the area of glass & maximize the opportunity for insulation. From the photographs, plans and sections, I think there is almost 50% glazing on southwest and northeast facades and not more than 20% on the smaller sides.

III. Conditioning and Water Heating strategies and systems

1. How is ventilation provided? Describe passive and active methods.
Clerestorys, operable windows can provide natural ventilation (passive method) to the house during beningn outdoor conditions.
17W Panasonic bath fan (50cfm) is installed on the ventilation schedule controlled by digital timer. This is an active (mechanical) method for ventilation. The programmable controller is set to provide whole house ventilation at regular intervals. The ducted fan system helps in removing stale indoor air containing pollutants and VOCs (volatile organic compounds) at regular intervals in air tight homes. These fans are located near the source of moisture, in this case, the bathroom to remove the pollutants. It has a built in damper to prevent backdraft and it ensures quiet operation.
Since the house is air tight, it is easy to maintain good relative humidity.

2. How is heating provided? Describe passive and active methods.
Small Danish woodstove using biobrick kept in the basement is the sole heat source for the entire house (active method). Biobricks are 100% wood, renewable, cheaper than fuel oil and less polluting. One pellet of biobrick can bring as much heat as one cord of wood : 4’x4’x3’ biobricks replace 4’x4’x8’ stack of wood. Also, the heat loss through chimney is very less. The team insulated the chimney from outside.
Due to good insulation and reduced heat loss, the internal surface temperatures of exterior walls is higher and hence the comfort level is a lot more at relatively lower air temperature during the heating season.

3. What fuel/energy source(s) are used for heating?
Renewable energy source – biobrick (wood pellets) is used for heating

4. How is heating distributed throughout the house to building occupants?
Firm information on the distrubution could not be found. However, the possible ways for heat distribution according to me are: A blower motor and duct system to feed the heat to the whole house. Or there might be outlets at the upper floor level and the ventilation fan in the house that circulates the indoor air, helps in distribution of heat.

5. How is cooling provided? Describe passive and active methods.
There is no specific information on cooling provided. Also the available information and the energy spread sheets suggest that they have not used any cooling strategy. However, from the general understanding and reading the related literature, I think, they use the same ventilation fan system as described in section III question 1 with ERV system where, during summer, the hot air is cooled before supplying inside the house.

6. What fuel/energy source(s) are used for cooling?
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7. How is cooling distributed throughout the house to building occupants?
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8. How is water heated for domestic hot water (DHW) use?

An active solar domestic hot water system with circulating pumps and controls has been used. It is a two tank system powered by 3 solar panels. There is a 110 gallon Stainless Steel solar tank which heats up the water to 145° F. Cold water entering the tank gets preheated (close to the desired temperature) due to the coil which receives energy from the solar panels before entering the conventional boiler. Due to this, the reliance on fossil based fuel gets reduced drastically. Also, during the days that receive ample solar energy, the conventional boiler use can be completely offest.

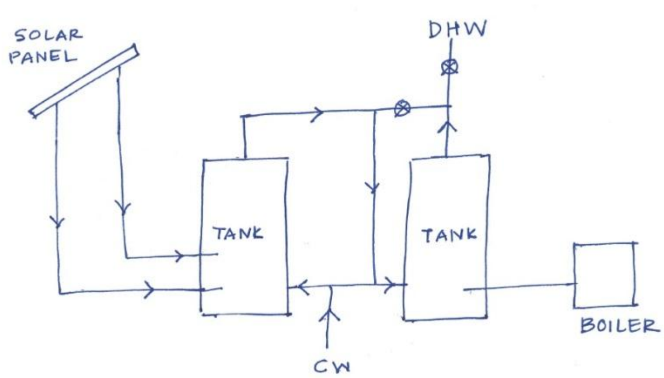
3 solar panel system

110 SS solar tank

9. What fuel/energy source(s) are used for DHW?

Active solar panels are used to generate energy for DHW as the passive strategy and natural gas is used as for the fuel based boiler. Pre retrofit, oil furnace was used for DHW. This was replaced by gas boiler.

10. Draw a "cartoon" that shows the strategies and systems you've listed in a-I within the home.



Solar DHW system

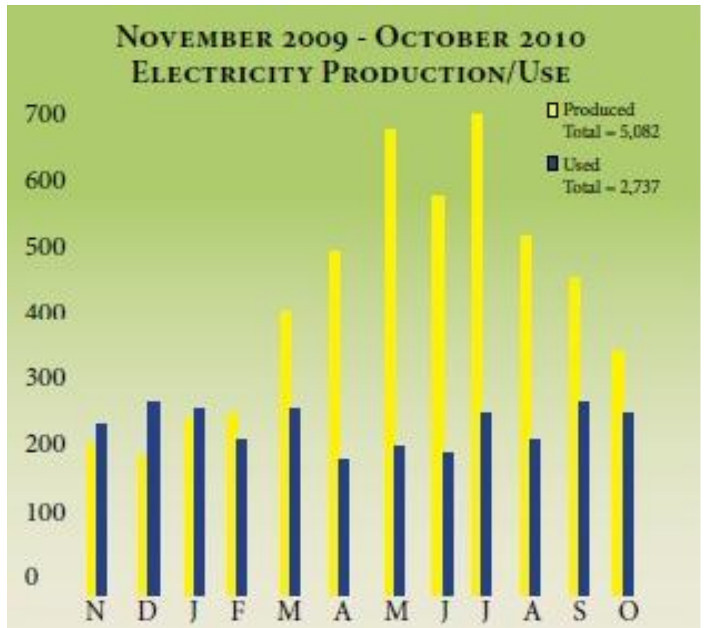
IV. Energy Consumption and Generation

1. What was the metering period (beginning to ending date)?

Metering Period – October 2008 to September 2009. The graph below shows the eletricity production and consumption from November 2009 to October 2010.

PV Prod. (kWh)	PV Cumul. (kWh)	Exterior Meter Reading (kWh)	Total calculat. Electric Usage (kWh)
342	342		
234	576		
151	727	210	
166	893	375	331
329	1222	303	257
434	1656	69	200
548	2204	-290	189
570	2774	-673	187
476	3250	-968	181
586	3836	-1333	221
559	4395	-1712	180
494	**4889**	**-1986**	220

October 2008 – September 2008



November 2009 – October 2010

2. Complete and include the energy balance spreadsheet as an Excel file.

	Site Energy (include renewable energy consumed)			Source Energy		
Natural gas, oil, propane,	**MBTUs**	**MJ**	**kWh**	**MBTUs**	**MJ**	**kWh**
Natural gas	3,000		879	3,276		960
Wood Pellet	23,100		6,768	25,225		7,390
Electricity (kWh)			**kWh**			
			2,903			9,768
Total Energy Consumed (kWh)			**10,550**			**18,118**
Renewable Energy	**MBTUs**	**MJ**	**kWh**			
Produced on site			4,889			16,451
Imported or derived from on-site processes						
Purchased						
Total Renewable Energy			**4,889**			**16,451**
Net Balance in kWh (Renewable Energy Provided-Total Energy Consumed)			**5,661**			**1,667**
US Residential Avg EUI: 44 MBTU/ft^2 at site		**Site EUI**	**14.81**		**Source EUI**	**25.44**
		MBTU/ft2			MBTU/ft2	

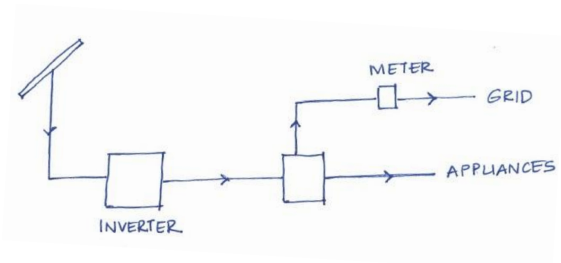
3. Calculate the EUI for conditioned area in MBTU/ft2 and kWh/m2

EUI : 14.81 MBTU/ft² - Site, 25.44 MBTU/ft² - Source

EUI : 46.73 kWh/m² - Site, 80.25 kWh/m² - Source

4. How much did the anticipated energy consumption differ from the actual energy consumption and why?
Anticipated energy consumption was 0 kWh/yr. However, with the help of PV arrays more electricity was generated than the amount consumed. This electricity (1986 kWh) was sold back to the grid.

5. If a PV system is used, what type and size? How much electricity does it generate per year?
4.3 kW PV system is used in this house. 14 panels each of dimensions 1892mm x 1283mm x 50mm (50.5 x 74.5 x 2 in) and 310 watt are used. The PV arrays are connected to the solar inverter which converts the direct current to alternating current which can be then supplied to power all appliances in the house. This house produces a lot more electricity through this system than the actual need and hence it sells the excess electricity back to the grid. Annually it produces 4889 kWh electricity.



Solar PV system

6. If a solar hot water system is used, what type and size? How is the solar hot water used and how much energy does it contribute to home use? (this may not be given; what you're looking for isn't the total energy production, but how much of what's produced can be used to reduce fossil-fuel based sources.
An active solar domestic hot water system with circulating pumps and controls has been used. It is a two tank system powered by 3 solar panels. There is a 110 gallon Stainless Steel solar tank which heats up the water to 145° F. Cold water entering the tank gets preheated due to the coil which receives energy from the solar panels before entering the conventional boiler. Due to this, the consumption of fossil based fuel gets reduced drastically. <u>In this house, the gas use post retrofit is 30 therms as against 180 therms pre retrofit. This offsets 150 therms of gas annually by providing over 70% of annual hot water needs.</u> From April through October, this system provides for100% hot water needs. To support this system, the type of faucets used in the house are also high performance. For example, the showerhead used is a water saving, low flow technology.

7. If a wind turbine is used, what type and size? How much electricity does it generate per year?
Not used.

8. If other renewable energy sources are used, what are they? How, and by how much, are they reducing fossil-fuel based consumption?
Biobricks as explained in section III question 2.

Extra Credit:

1. What was the construction cost per square foot and square meter. What are the utility costs per month? (in US$ equivalent if possible)

This is a retrofit design, the owner has built over the existing assemblies and the structure as a whole. Therefore, the "retrofit" construction cost is $25/sqft or $263.58/sqm

<u>Project Cost Breakdown (Approximate)</u> is as follows: (The cost factors in all rebates and tax credits.)

Lumber + Materials	$ 9000
Closed cell foam insulation	$ 7000
Thermotech windows/doors	$ 19000
Solar hot water system	$ 11500
Solar PV system	$ 9000
Project Assistant's Labor	$ 4000
Total	**$ 59500**

2. Were there unexpected difficulties in design and/or construction? Describe them and their resolution.

Using Larsen truss in order to avoid the construction waste, posed some difficulties for the team. They found it hard to level the truss to finish it with siding. This was also a time consuming solution. The solution for this could be using L brackets instead of trusses.

3. How does actual energy consumption compare to the original energy simulation? If it differs, why does it differ?

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4. What changes have been made to the building and its systems since it was built or renovated?

During the process of retrofit, the attic was insulated to achieve R30, however, after 2007, they added radiant barrier (reflective bubble wrap). This helped them achieve R76. All incandescent lights in the house were replcaed by LEDs or CFLs. Being an old ranch house, all the applicances previously were vintage. These were replaced by EnergyStar rated appliances. They also insulated the chimney with mineral wool which consumed a lot of time and the project engineer reflected back upon it to conclude that they should have torn down the chimney.

5. What changes have the occupants made in how they live in the house since it was built or renovated?

There is one behavioral modification seen in the occupants since they retrofitted the house. Since they use EnergyStar rated washing machine, they get clothes that can be dried in less than 24 hours without a dryer. So, they voluntarily eliminated the dryer use which consumes a lot of energy and saved 15% of the annual electricity usage.

6. Is the house comfortable year-round? (you will need owner/occupant information for this)

Yes, the house is comfortable around the year due to the super insulation that keeps the house warm during the winter along with the woodstove with biobrick kept in the basement. The Livermore's say that in December 2008, they were able to have a comfortable 65°F inside the house when it was 15°F outside with just the woodstove in the basement. Also, due to certain techniques like use of reflective

bubble wrap which reduces the heat gain during summer, the indoor temperature can be maintained easily.

7. How is maintenance of this house different from maintenance of a prior home or homes the owner has had? (you will need owner/occupant information for this)
Due to the addition in overall insulation, higher comfort levels were achieved in every season. With new building exterior, there were no ice dams and hence the maintenance was reduced exponentially. The owners found it easy to maintain the Relative Humidity within the house. Due to this, there were significantly less number of instances of cold and viruses.

8. What one thing would the owner/occupant change if s/he were to repeat this in the future? (you will need owner/occupant information for this)
The owner/ designer of this retrofit says that he has learnt few lessons after this project which he will keep in mind for his next venture. He says, it is important to start the construction earlier to August so as to finish before the winter starts because a lot of productive time is lost during that period. He says that it is important to know the target to be achieved and the tasks need to be divided from the early stages.
In terms of construction, the owner says that next time, he would use L brackets in place of Larsen wood truss system to save construction time.

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