NYSERDA High Performance Development Challenge
Energy Monitoring Report – Hudson Passive Project

The participating home is a single family detached home in Hudson, NY. The house was completed and occupied in October 2011. This report includes an analysis of the energy use of the home for the first year of occupancy. It was occupied by two adults full time during the monitoring period. Electricity is the only fuel used.

The house was built to the German Passive House Standard with the goal of minimizing heating and cooling loads and thereby reducing the scale of the required mechanical equipment. The exterior walls and roof are 12-¼ inch thick structural insulated panels (SIP) with a Neopor expanded polystyrene (EPS) core. The foundation slab is insulated with 12 inches of a combination of EPS and extruded polystyrene (XPS). The infiltration level was tested at 0.16 ACH50. The house has the following mechanical equipment:

- Mitsubishi MUZ-FE09A, ¾-ton heat pump serving the bedroom
- Mitsubishi MUZFE12A, 1-ton heat pump serving the main living area
- Zehnder heat recovery ventilator (HRV)
- Steibel Eltron tankless electric water heater

Figure 1. The Hudson Passive Project in Claverack, NY

Energy bills

The monthly energy consumption and costs from utility bills are shown in Table 1.

Table 1 Electric utility bills

Month	Start	End	Days	Read Type	Total kWh	Total Charges	kWh/day
1	10/31/2011	12/2/2011	32	Actual	625	$98.65	19.5
2	12/2/2011	12/30/2011	28	Actual	571	$89.27	20.4
3	12/30/2011	2/2/2012	34	Actual	767	$104.89	22.6
4	2/2/2012	3/2/2012	29	Actual	607	$78.18	20.9
5	3/2/2012	4/3/2012	32	Actual	613	$71.04	19.2
6	4/3/2012	5/2/2012	29	Actual	617	$76.85	21.3
7	5/2/2012	6/1/2012	30	Actual	607	$85.67	20.2
8	6/1/2012	6/30/2012	29	Actual	563	$85.72	19.4
9	6/30/2012	8/2/2012	33	Actual	798	$118.93	24.2
10	8/2/2012	9/6/2012	35	Actual	823	$124.00	23.5
11	9/6/2012	10/2/2012	26	Actual	515	$72.22	19.8
12	10/2/2012	11/2/2012	31	Actual	574	$76.97	18.5
1-12			**368**		**7,680**	**$1,082.39**	

Measured Performance Data

Battery powered data loggers were used to measure total house energy and heat pump energy consumption at hourly intervals for the period of January 2011 to July 2012 (Table 2).

A one-time power reading of 16-17 Amps (1.8 – 2 kW) was observed on the breaker feeding the heat pumps with both operating.

Table 2. Monitored Points Measured at Wedlick

Logger	Description	Sensor
1-1	Total house energy (kWh)	Wattnode Power Meter 3Y-208
1-2	Energy on both heat pumps (kWh)	Ohio SHW 2100

Data was collected from January 1, 2011 to July 17, 2012 (the house was unoccupied until the middle of October 2011). Total house energy use was monitored from both the utility bills and the installed data logger. However, the data logger stopped recording in July 2012, so the utility bills are used for total house energy use in this analysis. Utility bills and total house power as recorded by the data logger varied by an average of 5% over the period when the data logger was operating. Part of this variance was likely due to discrepancies in the start and end points of the billing periods. It is assumed that heat pump energy between May 1 and August 31 was devoted solely to cooling, with the remainder used for heating. Cooling energy use estimates after July 17, 2012 are extrapolated based on the number of cooling degree days (CDD) that occurred from May 1 to July 17, 2012 compared to the number of CDDs that occurred in the remainder of the season (see Table 3 and Figure 2 for a summary of these data).

Table 3 Summary of Electric Use

	Period	Total Energy (kWh)	Heat Pump Energy (kWh)	Other Energy (kWh)	Heating Energy (kWh)	Cooling Energy (kWh)	Extrapolated Cooling Energy (kWh)
UNOCCUPIED	Jan-11	1,213	293	920	-	-	-
	Feb-11	329	204	126	-	-	-
	Mar-11	281	176	105	-	-	-
	Apr-11	168	79	90	-	-	-
	May-11	138	31	107	-	-	-
	Jun-11	250	121	129	-	-	-
	Jul-11	245	165	80	-	-	-
	Aug-11	270	143	127	-	-	-
	Sep-11	233	136	97	-	-	-
	Oct-11	445	117	328	-	-	-
OCCUPIED	Nov-11	625	20	605	20	0	-
	Dec-11	571	10	561	10	0	-
	Jan-12	767	35	732	35	0	-
	Feb-12	607	16	591	16	0	-
	Mar-12	613	11	602	11	0	-
	Apr-12	617	14	603	14	0	-
	May-12	607	52	555	0	52	-
	Jun-12	563	82	481	0	82	-
	Jul-12	798	14	740	0	14	44
	Aug-12	823	0	737	0	-	86
	Sep-12	515	0	511	0	-	4
	Oct-12	574	0	567	0	-	7
Occupied Totals (Nov'11 – Oct'12)		**7,680**	**254**	**7,285**	**106**	**148**	**141**

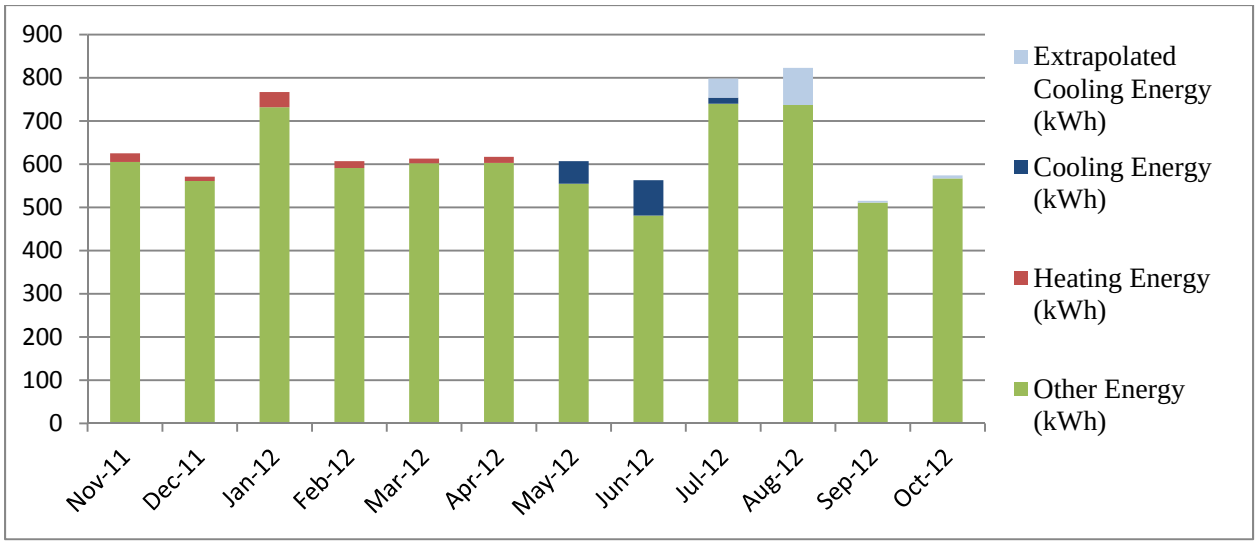

Figure 2. Summary of Electric Use

For most of 2011 the house was complete but unoccupied. The heat pump ran at a set point of approximately 60°F to provide heating and cooling while the house was on the market. Some resistance space heating (possibly construction-related) or DHW heat was also used in January 2011 (Figure 3).

In mid-October 2011 the home was occupied. Total consumption showed the expected increase when the house was being used (Figure 3). A portion of the other use is due to the electric instantaneous water heater, as shown by the demand spikes in Figure 3 and Figure 4.

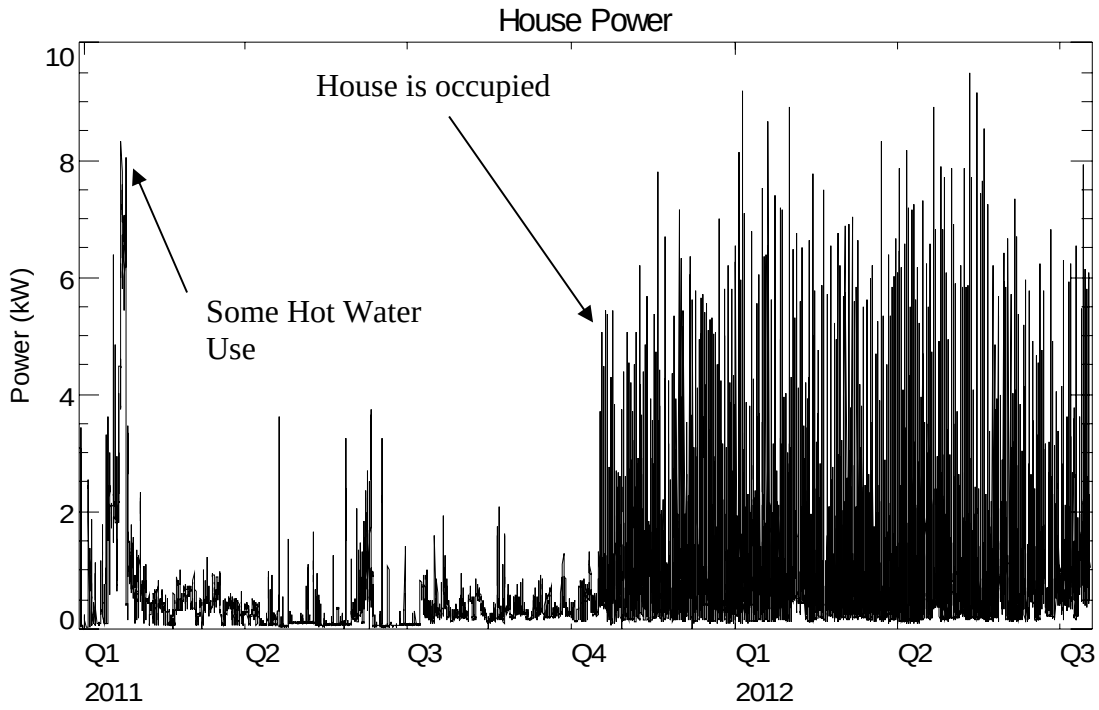

Figure 3. Total House Power

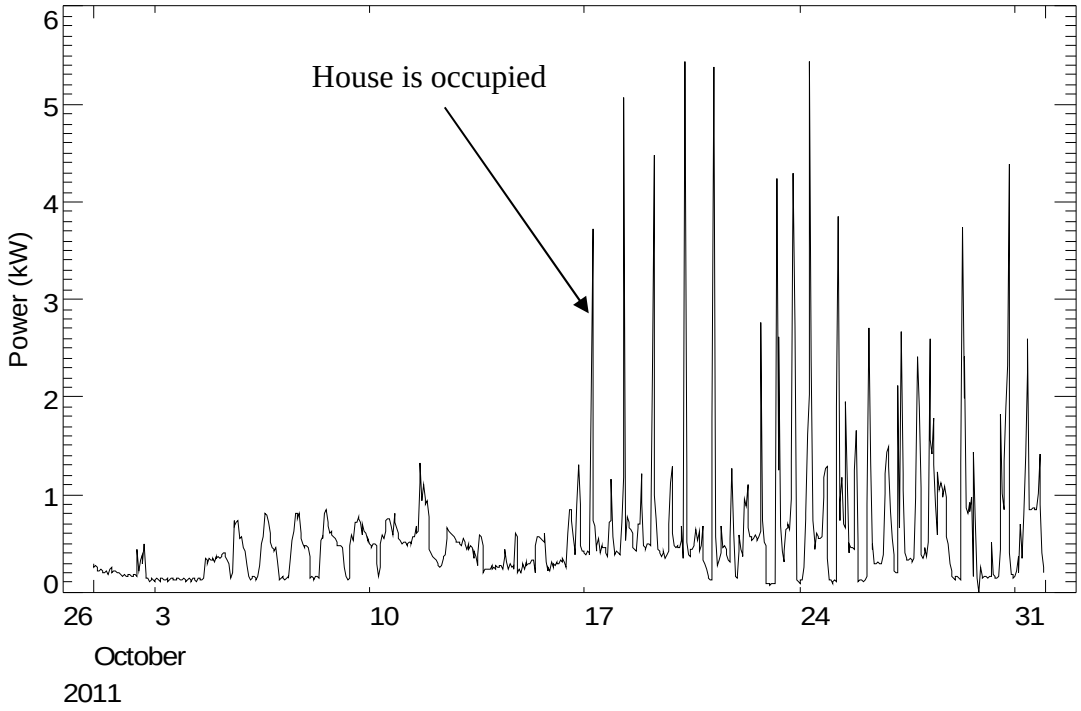

Figure 4. Total House Power Use for October 2011

The power use of the heat pumps was a significant part of total hose use before occupancy. However, once the house was occupied there was almost no need for heat pump operation over the 2011-2012 heating season (Figure 5 and Figure 6). Internal loads from the occupants helped meet the heating demand. Heat pump energy use over the heating season totaled 106 kWh (2% of total energy use) and cooling energy use in the summer of 2011 totaled 289 kWh (4% of total energy use).

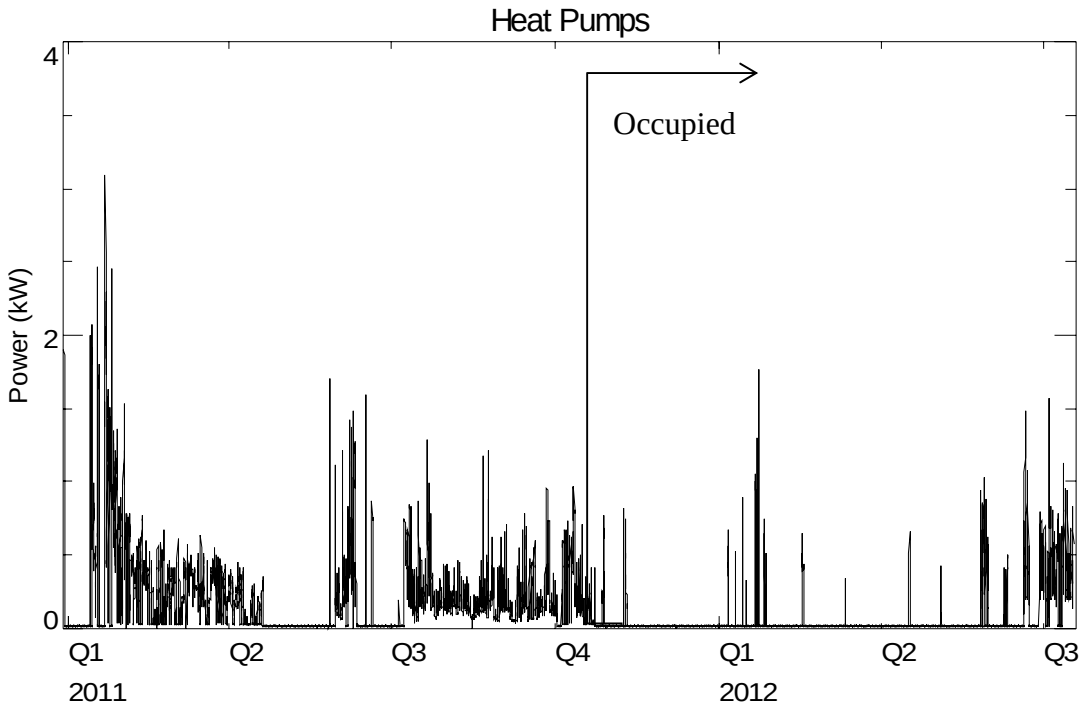

Figure 5. Heat pump power

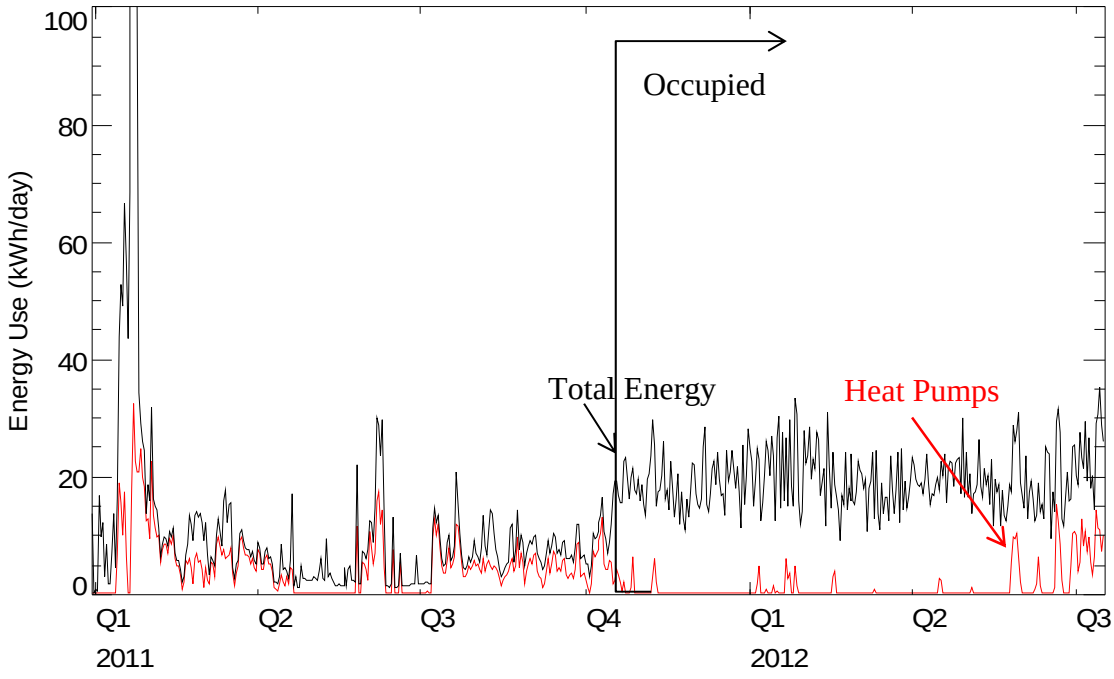

Figure 6. Breakdown of Daily Energy Use

The shade plot in Figure 7 confirms that the 6-8 kW power spikes during the occupied period correspond to hot water use with the instantaneous water heater. Usage is predominately in the morning and evening.

Total House

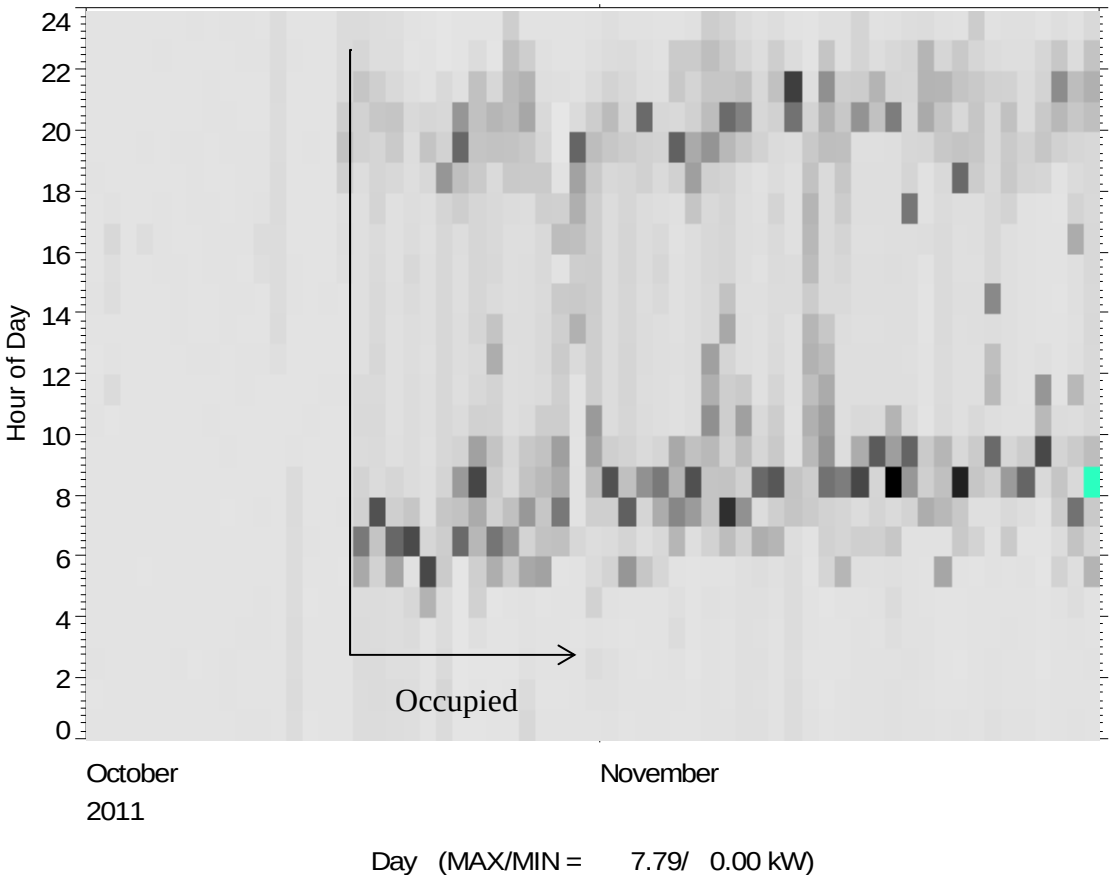

Figure 7. Shade Plot of Other Energy use for October and November 2011

Comparison of Modeled vs. Actual Energy Use

REM/Rate's energy modeling uses 30-year average weather data from the nearest weather station in Albany, NY (Architectual Energy Corporation, 2011). The actual energy consumption was weather normalized to the REM/Rate model (Table 4 and Figure 8) by the fraction of heating degree days (HDD) and CDDs experienced during the monitoring period versus the 30-year average. There were 10% less HDDs and 48% more CDDs in the monitoring period than the 30-year average (New York State Energy Research & Development Authority, 2012).

Table 4 Actual, REM/Rate predicted, and weather normalized energy consumption

		Utility Bills	Weather Normalized Utility Bills	REM/Rate Analysis	Weather Normalized Utility Bills versus REM/Rate
Units		(kWh)	(kWh)	(kWh)	
Heating		106	116	1,871	-94%
Cooling		289[i]	150	978	-85%
Baseline	DHW	-	-	3,429	-
	Other	-	-	5,906	-
	Subtotal	7,285	7,285	9,335	-22%
Total		**7,680**	**7,551**	**12,184**	**-38%**

[i] Including extrapolated cooling

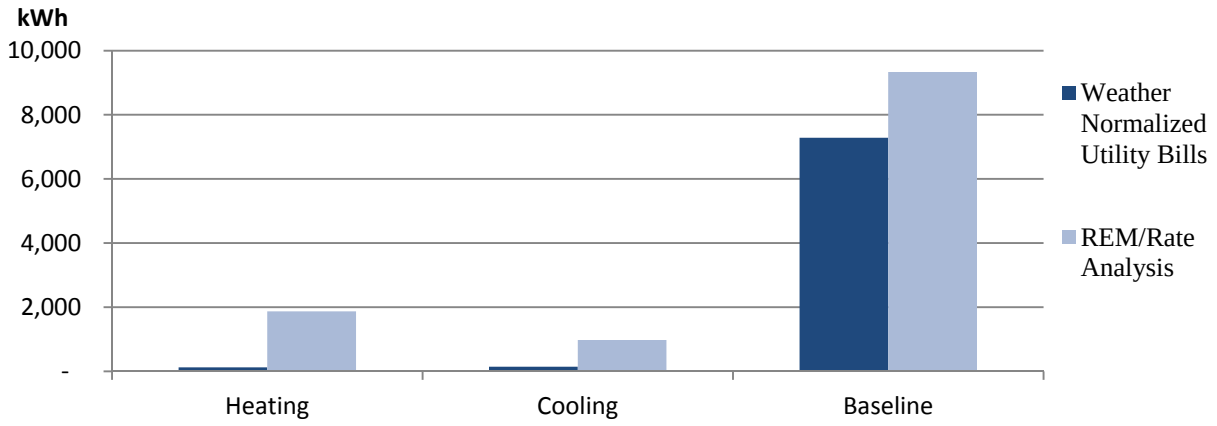

Figure 8 Actual, REM/Rate predicted, and REM/Rate weather normalized energy consumption

The weather normalized utility bill consumption is significantly lower than the REM/Rate predicted analysis (38% less, Table 4), indicating that the house performed better than anticipated by REM/Rate. Furthermore, heating and cooling energy consumption was minimal; dramatically over-predicted by REM/Rate. This is one indication (corroborated by the homeowner interview) that solar gain through the high SHGC south facing windows did not create a significant overheating problem during the summer months, despite the year being 48% warmer (by CDD) than normal (the 30-year average). Figure 9 shows the actual, normalized and REM/Rate predicted energy consumption by major end use. Only 5% of energy was used for space conditioning.

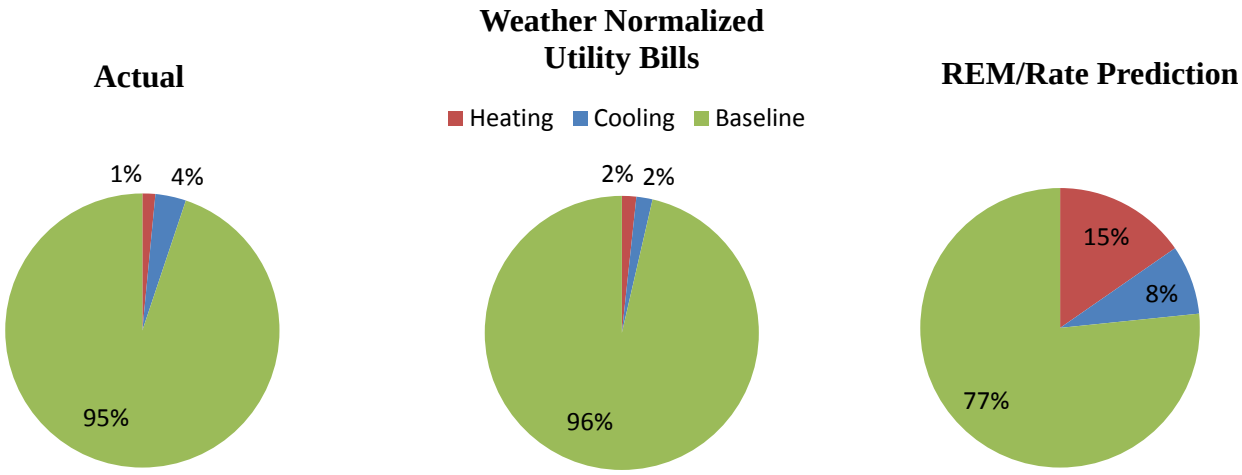

Figure 9 Proportions of actual, weather normalized utility bills, and REM/Rate predicted energy consumption

Because this house was certified as a Passive House, the Passive House Planning Package (PHPP) software was also used for modeling. The two main outputs of the PHPP software are the specific space heating demand per square meter per year (kWh/m^2-a) and the total house primary energy demand per year (kWh/m^2-a). Table 5 compares the actual usage to PHPP predicted energy usage (this comparison in not weather normalized).

Table 5 Comparison of home performance compared to Passive House Planning Package

	Actual Consumption		PHPP Predicted	Performance compared to PHPP
Units	(kWh/yr)	(kWh/m^2-yr)	(kWh/m^2-yr)	
Heating energy	106	0.7	12	-94%
Total site energy	7,680	52.7	40	+31%

Occupant Survey

An occupant survey was conducted. Results are shown below with the responses by the homeowner in italics.

NYSERDA Challenge: Hudson Passive Project Survey Responses
Interviewee: Bill Stratton
Home address: 347 Millbrook Rd, Claverack, NY
Interviewer: Jordan Dentz, The Levy Partnership, Inc.
Date: 12/12/12

1. How many homes have you owned before purchasing your current home?

Three

2. Compared to previous homes that you have owned or lived in, please rate the overall performance of your current home including comfort, energy efficiency, and quality of construction:
   (1= much lower performance; 2 = same performance; 3 = much better performance)

   1 2 3

3. Which aspect of your home have you been most pleased with?
   - o Low utility bills
   - o Good indoor air quality
   - o Very durable

A few questions about comfort and energy efficiency:

4. Compared to previous homes that you have owned or lived in, please rate the comfort level provided by the heating system in your home:
   (1= not comfortable at all; 2 = reasonably comfortable, 3= very comfortable)

   1 2 3

It's quiet, reacts fast and fulfills the heating need, but I loved the radiant floor heat I had in a previous house.

5. Compared to previous homes that you have owned or lived in, please rate the comfort level provided by the cooling system of your home (if applicable):
   (1= not comfortable at all; 2 = reasonably comfortable, 3= very comfortable)

   1 2 3

Worked well; we left air conditioning on for our two large dogs. Did not open the roof windows – they may have provided more natural cooling. Nor did we install the trellis to shade the lower front window.

6. Compared to previous homes that you have owned or lived in, please rate your satisfaction with the hot water system in your home:

(1= not satisfied at all; 2= reasonably satisfied; 3= completely satisfied)

1 2 3

Great hot water system. Gets hot instantly and never runs out. Takes longer to fill the tub but that does not bother us.

7. Compared to previous homes that you have owned or lived in, please rate your satisfaction with the your home's lighting system:
(1= not satisfied at all; 2= reasonably satisfied; 3= completely satisfied)

1 2 3

Not satisfied with the lighting – need more and better location of fixtures.

8. Compared to previous homes that you have owned or lived in, please rate your satisfaction with the home's ability to provide a quiet indoor environment:
(1= not satisfied at all; 2= reasonably satisfied; 3= completely satisfied)

1 2 3

Unbelievably quiet. Even the dogs can't hear us coming up to the house when they are inside.

9. Compared to previous homes that you have owned or lived in, please rate your satisfaction with the home's draftiness:
(1= not satisfied at all – the home is drafty; 2 = reasonably satisfied, 3 = completely satisfied – no drafts)

1 2 3

No drafts.

10. How do your actual utility bills compare with your expectations when you bought this home?
(1=Much higher than expected; 2= as much as expected; 3=much lower than expected)

1 2 3

11. How well informed about the energy efficiency features of your home did you feel upon purchase of the home? (1=not informed at all; 2=reasonably informed, 3=well informed)

1 2 3

12. What are your favorite technologies or systems in this home? This could include windows, ventilation, heating/cooling, lighting, hot water, appliances, etc.

    1. *The HRV – air quality is great*
    2. *The hot water system*

3. *Induction cooktop*

13. Have you had any problems or disappointments with any of the energy-related systems in the home?

The lighting.

Please indicate if you agree, disagree, or are "not sure" about the following statements:

14. Increased energy efficiency in a new home makes sense if the energy cost savings can pay for the added up-front costs on a monthly basis.
    - o Agree
    - o Disagree
    - o Not sure
15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.
    - o Agree
    - o Disagree
    - o Not sure
16. Increasing energy efficiency, even beyond the point where it pays for itself on a monthly basis, makes sense because of other benefits like indoor air quality and durability.
    - o Agree
    - o Disagree
    - o Not sure
17. If I were to purchase another new home in the future, I would make the energy features of the home a high priority in the purchasing decision.
    - o Agree
    - o Disagree
    - o Not sure

A few questions about occupancy:

18. When did you occupy the house during the term that we are speaking of? Which months? Full time or only weekends and/or holidays?

Occupied full time since mid-October 2011 without any vacant periods.

19. How many people on average occupied the house?

Two adults and two large, active dogs.

20. When the house was vacant (in the heating season), what did you set the thermostat to?

58-60° F

21. What thermostat settings did you typically set when the house was occupied (for heating and cooling)?

70° F.

22. Other remarks:

The thermostat was set at about 60° F during the period between completion of the house and occupancy.

We did not have any overheating problems in the shoulder seasons or otherwise.

Temperature distribution in the house was pretty even; slightly warmer upstairs and ion the bathrooms.

HRV was used 100% of the time. We used the setting adjustments from 1 (typical) to 3 (cooking) as needed. You can hear it slightly when on speed 3.

IAQ was excellent.

Did not install the electric resistance heater in the main room.

Did install one electric baseboard heater in the bedroom but never turned it on except once the dogs activated it by accident.

The condensation clothes dryer works but is about 30% slower than an exhaust dryer.

References

Architectual Energy Corporation. (2011). Utility Bill Disaggregation | REM help file. (REM/Rate Version 12.96).

New York State Energy Research & Development Authority. (2012, 02 08). *Monthly Cooling and Heating Degree Day Data*. Retrieved 02 13, 2012, from NYSERDA: http://www.nyserda.ny.gov/en/Page-Sections/Energy-Prices-Supplies-and-Weather-Data/Weather-Data/Monthly-Cooling-and-Heating-Degree-Day-Data.aspx?sc_database=web

Appendix A – Weather data and calculations

Table 6. Daily average temperature during monitoring period (°F)

Day	Nov '11	Dec '11	Jan '12	Feb '12	Mar '12	Apr '12	May '12	Jun '12	Jul '12	Aug '12	Sep '12	Oct '12
1	42	36	40	50	33	43	51	62	77	75	74	58
2	43	34	35	33	33	46	54	58	74	77	68	56
3	46	33	16	29	43	44	56	61	74	80	68	64
4	41	42	13	31	32	47	66	56	79	81	74	60
5	38	46	29	26	23	41	57	57	75	80	69	64
6	38	48	37	35	25	42	56	59	77	70	70	57
7	43	36	37	33	47	45	59	60	76	69	76	49
8	54	34	31	24	53	47	54	66	75	76	72	47
9	54	34	28	33	36	46	63	64	71	80	63	49
10	53	31	36	30	31	48	52	71	70	72	58	51
11	40	26	33	27	43	42	54	72	73	74	57	48
12	42	31	35	16	51	48	58	66	80	74	63	42
13	49	32	32	29	58	47	66	69	79	72	68	39
14	54	41	19	29	50	52	65	66	78	69	70	56
15	51	46	7	37	46	62	63	66	76	72	61	59
16	46	44	16	30	47	72	65	69	78	74	58	44
17	40	28	36	39	54	58	56	70	84	72	62	46
18	36	19	30	35	57	46	57	65	77	68	66	52
19	40	31	18	33	63	52	65	70	73	63	56	59
20	57	34	21	31	65	65	69	82	68	66	55	58
21	38	41	14	28	66	59	64	82	71	69	61	51
22	32	47	14	46	65	41	68	79	75	68	64	54
23	35	34	38	38	64	49	71	72	77	73	55	49
24	38	21	41	34	49	47	72	69	75	72	52	51
25	40	27	33	34	47	44	71	64	71	74	58	56
26	46	32	29	27	41	44	73	62	75	76	63	60
27	45	33	38	34	35	42	71	68	75	75	58	57
28	54	34	37	35	48	42	73	73	71	73	51	55
29	55	22	34	31	44	45	79	80	73	65	57	59
30	49	28	28		41	45	71	78	73	65	57	58
31		37	39		41		64		75	72		58

Table 7. Weather calculations

	Nov '11	Dec '11	Jan '12	Feb '12	Mar '12	Apr '12	May '12	Jun '12	Jul '12	Aug '12	Sep '12	Oct '12
Monthly HDDs base 65°F	676	953	1121	1078	585	571	122	112	0	2	191	349
Monthly CDDs base 65° F	0	0	0	0	1	7	70	133	310	233	60	0
Fraction HDDs	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	100%	100%
Fraction CDDs	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	0%	0%
Heat Pump energy (kWh)	19.8	10.1	35.2	15.9	10.9	14.2	52.2	82.0	14.0	-	-	-
CDDs in monitoring period (through 7/17)	0	0	0	0	1	7	70	133	191	-	-	-
CDDs in unmonitored period	-	-	-	-	-	-	-	-	119	233	60	0
Cooling energy (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	52.2	82.0	14.0	-	-	-
Extrapolated Cooling Energy (kWh)[i]	-	-	-	-	-	-	-	-	43.9	85.9	0.0	0.0
HDDs in monitoring period	676	953	1121	1078	585	571	122	112	0	-	-	-
Heating Energy (kWh)	19.8	10.1	35.2	15.9	10.9	14.2	0.0	0.0	0.0	-	-	-
Extrapolated Heating Energy (kWh)[ii]	-	-	-	-	-	-	-	-	-	0.0	3.9	7.1

[i] Based on a total average (total CDDs /Cooling kWh in the monitoring period) of 0.37 kWh/CDD
[ii] Based on a total average (total HDDs /Cooling kWh in the monitoring period) of 0.02 kWh/HDD