Greenbelt Homes, Inc. Pilot Program

Energy and Environmental Monitoring – June 2013

2010/2011, 2011/2012, and 2012/2013 Heating Seasons

Prepared for
Greenbelt Homes Inc. (GHI)

Greenbelt Homes Inc.
A COMMUNITY FOR PEOPLE WHO VALUE COMMUNITY

Prepared by
Home Innovation Research Labs
(Formerly NAHB Research Center)
400 Prince Georges Boulevard
Upper Marlboro, MD 20774-8731

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Pilot Project

Greenbelt Homes, Inc. (GHI) has established a pilot project that to serve as a basis for decisions concerning energy efficiency features that can be cost-effectively incorporated into community-wide upgrades scheduled for implementation over the coming decade. (The upgrades consist of new windows, cladding, heat and hot water systems, and some service utility pipes.)

The pilot project takes a three-phased approach. In phase 1, evaluation of the current operation, use, environmental conditions, and energy costs for a representative set of 28 homes (7 buildings) was analyzed. Project volunteers were sought and selected and have patiently provided access to their homes several times over nearly three years; for condition assessment, air tightness testing, equipment installation and battery replacement, etc. Based on the facts derived from field audits, improvements to the pilot buildings were proposed in an April 2011 report (Phase 1, Report 1). This report covers the energy usage and environmental conditions within the pilot homes for the baseline and two subsequent heating seasons.

Phase 2 of the Pilot Project is divided into smaller phases. Phase 2a in the Fall of 2011 resulted in upgrades to the crawlspaces of all of the pilot homes. Phase 2b in the Fall of 2012 resulted in upgrades to the attics of the frame brick and frame vinyl homes. Phase 2c planned for the Fall of 2013 will consist of window and/or wall upgrades to the units.

Summary of Pilot Project Activities

The following activities in service of the pilot project have been performed through a collaborative effort between GHI Pilot Project homeowners, GHI staff, Home Innovation staff, and staff from the federal National Renewable Energy Laboratory (NREL).

November 2010

- All 28 pilot homes were evaluated for the existing conditions related to energy use and moisture performance. Physical inspection of construction features and appliance type, efficiency and age, building tightness testing, water flow rates, and homeowner's observations were performed and recorded.

December 2010/January 2011

- Three buildings (one of each type) were outfitted with remote environmental condition recording sensors and energy transducers with Home Innovation staff being assisted by NREL staff. The timing of the installations was based on receipt of the equipment.

April 2011

- Report 1 Phase 1 draft report was published by Home Innovation for GHI. The report covered, in detail, the existing condition of the homes and projected energy savings based on stated approaches and projected costs.

- After an open bid solicitation for an Architectural & Engineering firm to supply the plans and details for the Pilot Project envelope upgrade work, GHI hired Falcon Engineering.

May 2011

- Four additional buildings were outfitted with the energy transducers. Again, the timing of the installations required receipt of the equipment.

Summer/Fall 2011

- Report 2 Phase 1 report published by Home Innovation for GHI. The report covered in detail the results of energy usage for the 2010/2011 heating season.

- GHI requested bids for the Pilot Project work. The bids that were received were higher-priced than estimates had been, and GHI made the decision to proceed with the crawlspace retrofit portion of the Pilot Project work, Phase 2a. A revised request for proposal was issued for the crawlspace upgrades and a contract awarded.

November 2011

- All seven crawlspaces of the pilot home buildings were retrofitted with new ground vapor barriers. As needed, the brick and block buildings received continuous foundation wall and slab insulation (where slabs were exposed to ambient conditions). The frame vinyl-sided buildings received new ground vapor barriers and floor insulation was replaced with approximately 3" of closed cell spray polyurethane foam (SPF).

December 2011

- Due to significant datalogger hardware problems, environmental monitoring sensors were reset in each of the 28 pilot homes. In addition, several redundant sensors were installed in each building in an effort to obtain a higher degree of data integrity.

January 2012

- The frame vinyl-sided buildings were re-tested for air infiltration after the floors were sealed with the SPF insulation. The test data is reported in this report.

Spring 2012

- Home Innovation in conjunction with NREL began processing of the available winter 2011/2012 data which is included in this report.

- GHI staff requested bids for Phase 2b of the envelope retrofit upgrades; windows, doors, exterior and attic insulation (as applicable to the building type). A revised set of specifications were developed for the bid process.

Fall 2012

- Four of the seven buildings of the pilot project were retrofitted with additional attic insulation. Both board insulation (used to preserve storage space), and blown cellulose insulation was installed. Air sealing at the accessible exterior wall plates was accomplished using spray foam insulation. (The block buildings have flat roofs with rigid insulation beneath the EPDM roofing and no modifications were made.)

Spring 2013

- GHI staff requested bids for Phase 2c of the envelope retrofit upgrades; windows, doors, siding, and exterior insulation (as applicable to the building type). A revised set of specifications were developed for the bid process.

Crawlspace Improvements

In the Fall of 2011, the crawlspaces of all of the pilot homes were improved as Phase 2a of the Pilot Program. Improvements consisted of insulation repair in the block and brick homes and complete replacement of the floor insulation in the frame vinyl-sided homes. Consistent with the existing design of the crawlspaces, the foundations of the brick and block homes will continue to be semi-conditioned and the crawlspace foundations of the frame homes will be unconditioned.

The insulation was installed primarily to mitigate conductive heat losses from the house to the crawl space foundation (frame vinyl homes) or the outside (frame brick and block houses). Heat loss to the crawlspace is a smaller portion of the energy loss since the earth temperature mitigates some of the cold exterior temperatures at this portion of the building envelope. One aspect of heat loss however, that of air leakage, can represent a large portion of the foundation heat loss. The infiltration loss from the house to the crawlspace in the block and brick foundations is not significant since the monolithic concrete slab and foundation walls do not allow high levels of air leakage from the house to the crawlspace. For the frame homes however, the air leakage through the frame floor to the crawlspace can often be significant. Therefore, when the crawlspace insulation was replaced in the frame homes, an insulation product was used that air-seals as well as insulates.

At the same time of the insulation upgrades, the ground vapor barriers in all of the crawlspaces were replaced and sealed at the seams and against the foundation. This upgrade is not for energy savings but rather is to control moisture migration from the ground into the crawlspace. This upgrade feature is designed to limit moisture problems in the home and crawlspace.

Attic Insulation and Air Sealing Improvements

In the Fall of 2012, the attic spaces of the frame and brick pilot homes were improved as Phase 2b of the Pilot Program. The attic improvements included:

- Air sealing of the wall top plates,
- Construction of a 192 square foot storage platform using insulation board,

- Addition of insulation in the areas outside of the storage platform, and
- Air sealing of the attic hatch/access door.

The attic insulation and air sealing upgrades were made to increase the attic insulation level from a nominal R19 in the existing home to a minimum of R30 for the storage areas, and to between R38 and R49 in the remaining areas of the attic. In addition to the insulation, spray foam was applied to the exterior wall top plates where accessible, and including the top of the wall framing for walls adjoining units.

To complete the attic upgrades, the attic hatch was air sealed using weather stripping material. Where the attic access was provided by means of a pull-down stair, an insulated box was constructed to fit over the stairs. In the brick homes where access to the attic is by means of permanent stairs, the attic doors were insulated using rigid insulation and weather stripping.

Air Infiltration Testing

To quantify the convective losses due to building leakage, all homes were blower door tested in the original assessment of each home. Results of a blower door test indicate the volume of air leakage to the outside (or adjacent units) when the home is depressurized with a fan. Results can then be calculated as leakage under normal or natural conditions. The air leakage under natural conditions is referred to as Air Changes per Hour natural (ACHn) and indicates the percentage of the air volume within a home that leaks in or out of the home every hour under assumed conditions. The estimate is based on a standard pressure difference between the interior and exterior of the home. The leakage of heated air out of the home also brings cold, fresh air in (which must be heated). An appropriate amount of fresh air is desirable for good indoor air quality, but excessive air leakage simply wastes energy.

Largely due to the method and material of construction, the CMU block buildings were the most air tight, as a group, and require very little air sealing beyond the best practice details associated with installing new windows, doors, and fans. The frame walls of the frame brick and frame vinyl buildings allow air leakage between the house and the attic due to wiring holes through wall top plates and continuous balloon-framing. In balloon-framed construction the exterior wall studs extend from first floor to second level ceiling as one length. The sheathing on these homes is usually 1"x 6", or 8" boards which allow air leakage where boards meet. In the frame vinyl homes there was also air leakage from the homes to the crawlspace via abandoned wiring holes and gaps in the wood floor tongue and groove joints. The closed cell spray polyurethane foam (SPF) installed at the crawlspace ceiling in November 2011 should have sealed air leakage through the floor. In fact, the frame homes showed an average 15% improvement in air sealing after the crawlspace insulation was installed.

Table 1 summarizes the results of all blower door tests conducted on the homes following the upgraded floor insulation (November 2011) in the frame homes and the attic insulation upgrades (November 2012) in the frame brick and frame vinyl homes. Note that a lower ACH50 number indicates less air leakage out/into the home. Also note that the ACH_n numbers (5^{th}, 7^{th}, and 9^{th} columns from the left) indicate the percentage of the home's total air volume that is exchanged with outdoor air in one hour under natural conditions. (Conversely, the inverse of the ACH_n, or 1.00 divided by the $ACH_{n,}$, equals the number of hours required to completely replace heated air with outside air via air leakage pathways in the building.)

After the floor was insulated in the frame vinyl buildings, the average reduction in air infiltration rates was about 15% across all eight frame vinyl homes. Following the crawlspace air sealing, the range of reduction was quite large (one home saw a small increase in infiltration rate), a few homes saw little change, and one home retested with a large decrease in infiltration. Following the attic simulation upgrades, however, all of the frame vinyl homes resulted in a decrease in the infiltration rate over the original tests with the overall average reduction of 26%. For the frame brick homes, the average reduction in the infiltration rate was 10%. All but one of the frame brick and frame vinyl homes has infiltration rates that remain somewhat higher than desired and therefore will benefit from window or window/wall upgrades in the next phase of the pilot program.

Table 1. Results of Blower Door Testing – Net Convective Leakage to the Outside

			PRE-RETROFIT BLOWER DOOR RESULTS		POST-CRAWL SPACE RETROFIT BLOWER DOOR RESULTS[1]		POST-ATTIC RETROFIT BLOWER DOOR RESULTS	
Building	Unit	Volume	Net Leakage to Outside (ACH50)	Natural Air Changes per Hour (ACH_n)	Net Leakage to Outside (ACH50)	Natural Air Changes per Hour (ACH_n)	Net Leakage to Outside (ACH50)	Natural Air Changes per Hour (ACH_n)
Block	B1- end	9,344	4.7	0.29				
	B2- interior	6,752	3.3	0.21				
	B3- interior	6,752	2.4	0.15				
	B4- end	9,960	4.8	0.30				
	B5- interior	6,752	4.3	0.27				
	B6- interior	7,368	8.4	0.53				
Block w/Vinyl	BV1- end	12,224	7.2	0.45				
	BV2- end	9,960	4.8	0.30				
	BV3- end	8,896	7.5	0.47				
	BV4- interior	8,640	3.5	0.22				
	BV5- interior	12,768	4.3	0.27				
	BV6- end	12,768	4.0	0.25				
Frame Brick	FB1- end	8,640	10.4	0.65			8.8	0.55
	FB2- interior	8,640	6.8	0.43			6.4	0.40
	FB3 - interior	8,640	7.4	0.46			6.4	0.40
	FB4- end	8,640	8.0	0.50			7.7	0.48
	FB5- end	8,640	6.1	0.38			5.9	0.37
	FB6- interior	9,088	8.8	0.55			7.4	0.46
	FB7- interior	7,288	11.9	0.74			10.2	0.64
	FB8- end	9,384	5.5	0.34			5.4	0.34
Frame Vinyl	FV1- end	7,488	9.7	0.61	9.6	0.60	8.6	0.54
	FV2- interior	6,256	13.1	0.82	10.7	0.67	8.4	0.53
	FV3- interior	6,256	9.3	0.58	9.7	0.60	8.4	0.52
	FV4- end	6,960	14.1	0.88	10.6	0.66	10.5	0.66
	FV5- end	9,360	14.0	0.87	13.3	0.83	11.4	0.71
	FV6- interior	6,336	14.8	0.92	8.3	0.52	7.0	0.44
	FV7- interior	8,448	10.1	0.63	9.2	0.57	7.9	0.49
	FV8- end	8,448	11.2	0.70	10.4	0.65	9.5	0.60

[1]Note that only the Frame Vinyl homes w ere tested after the craw l space retrofit. FB, B, and BV homes did exhibit much leakage into the craw l space at pre-retrofit.

Quantifying the Severity of a Heating Season

Comparing data gathered over multiple heating seasons requires an analysis of the severity of the heating season during which the data is gathered. Reviewing average temperature data over a span of three winter periods, it is apparent that not all heating seasons are alike. The variation between winter seasons as shown in Figure 1 (2010-2011), Figure 2 2011-2012) and Figure 3 (2012-2013), ranges from below normal temperatures to much above normal the next winter season and back to above normal temperatures during the most recent winter period.[1]

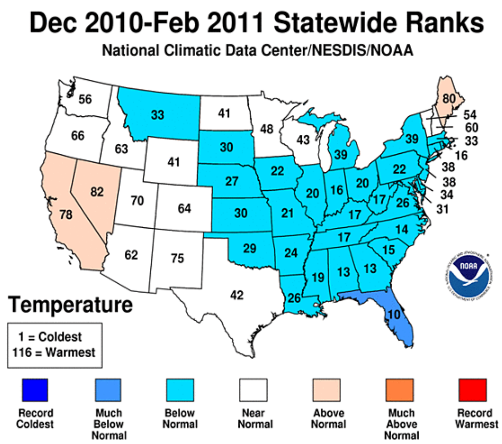

Figure 1. NOAA National Heating Ranks – 2010-2011

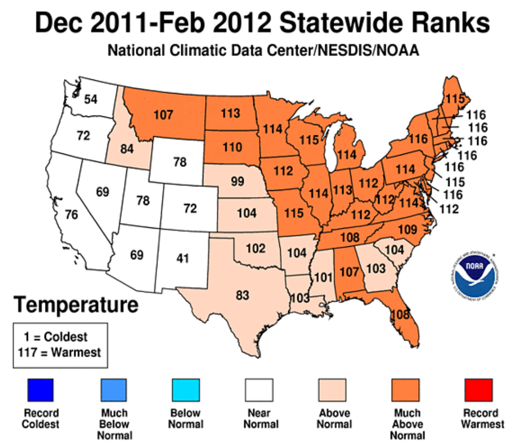

Figure 2. NOAA Nation Heating Ranks – 2011-2012

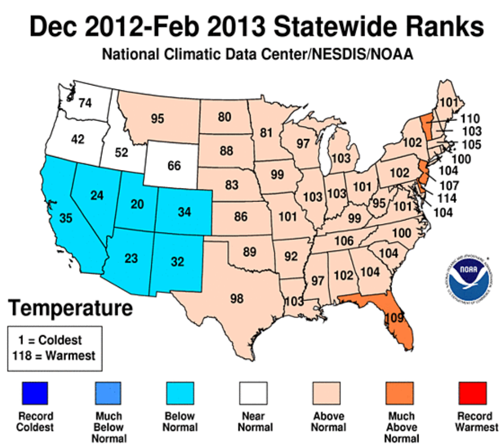

Figure 3. NOAA Nation Heating Ranks – 2012-2013

Over the past three years of the Pilot Program, GHI members experienced significantly different heating seasons during which the expected energy usage for heating an occupied home is also expected to vary considerably. Therefore, it is common to report temperature severity in context with energy use for heating. Measuring heating degree-days (HDD), a formula whereby the average of the daily maximum and daily minimum temperature is subtracted from 65°F and the difference is aggregated throughout the heating season, is a common method used to establish a perspective for gauging energy usage for

[1] National Oceanic and Atmospheric Administration, http://www.ncdc.noaa.gov/temp-and-precip/maps.php?ts=3&year=2012&month=2&imgs%5B%5D=Statewidetrank&submitted=Submit

heating a home. The higher the number of HDD in a season, the colder the temperatures are on a daily average basis. The baseline, 65°F, is a moderate temperature thought to require neither supplemental heating nor cooling.

The weather data for this report was obtained from a National Weather Service station located at College Park Airport, within five miles of the Greenbelt Homes, Inc. project center (station KCGS[2]) and verified to the data from measurements made near the GHI main office. Table 2 and Figure 4 show the weather summary data for each of the three heating seasons that were monitored thus far.

Table 2. Ambient Temperature and Heating Degree-Days for 3 Heating Seasons

	Average Temperature °F, 2010/2011	Heating Degree Days 2010/11	Average Temperature °F, 2011/2012	Heating Degree Days 2011/12	Average Temperature °F, 2012/2013	Heating Degree Days 2012/13
October	59.8	191	56.6	264	60.0	143
November	48.6	493	51.2	413	44.3	629
December	34.8	940	43.3	676	44.7	626
January	33.1	993	39.6	787	39.4	795
February	41.3	666	41.9	671	37.6	797
March	46.5	570	55.4	314	43.4	667
April	60.2	213	55.7	304	57.6	255
Average/Total	**46.3**	**4,064**	**49.1**	**3,427**	**46.7**	**3911**
Heating Period 11/1 - 4/15		**3,818**		**3,027**		**3,651**

For the heating period analyzed, the second winter season had about 20% fewer heating degree days than the first season while the third heating season had about 4% fewer heating degree-days than the first season.

[2] The station was selected for the accuracy of its data and may be referenced at http://www.wunderground.com

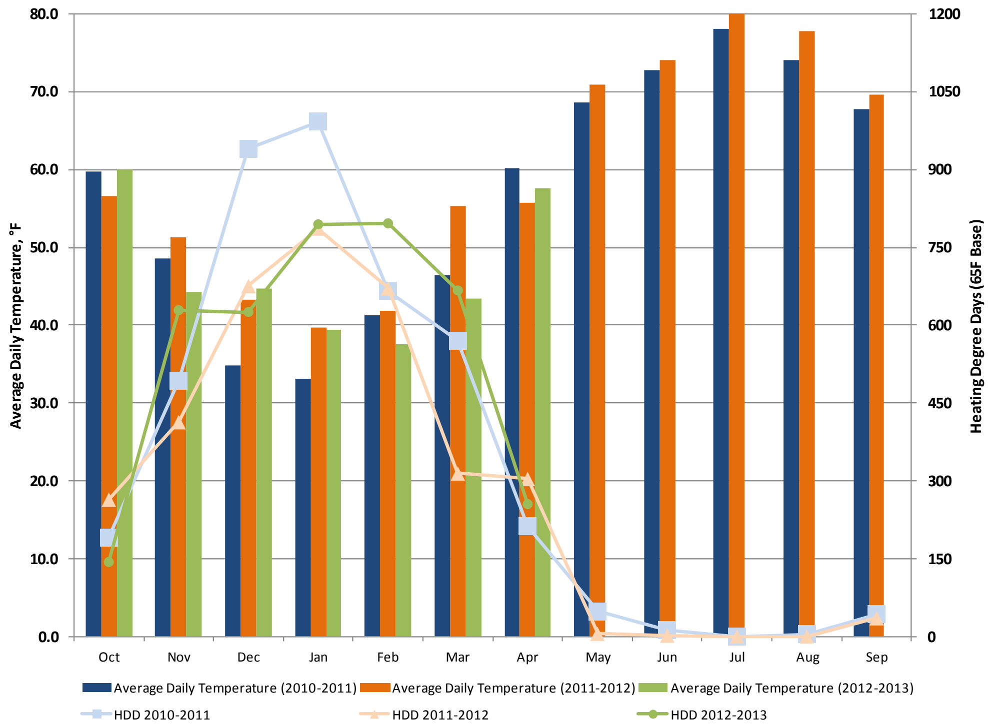

Figure 4. Graphical Comparison of Ambient Weather Factors

The data in Table 2 coincides with the weather trends reported in the NOAA maps (Figure 1 to Figure 3) however, the temperature range between the seasons is smaller than that reported on the maps when the regional temperatures are recorded, as by the graph in Figure 4. Nonetheless, October and February were the only months in all heating seasons that indicate a general similarity in temperatures. This information will be useful in evaluating the indoor temperatures and energy use which were recorded during these seasons.

Heating Season Comparison – Temperature and Relative Humidity

The indoor temperature monitoring period for the 2010/2011 heating season started in early December for some homes and late January for the remaining homes and extended through April 2011. In December 2012, the temperature and humidity sensors were restarted and batteries replaced in all units. In addition, a secondary sensor technology to record temperature and humidity was installed in each home. This data was used as backup data when the original sensors did not provide reliable readings. An overall summary of the indoor temperatures for a portion of the 2010/2011 heating season compared to the next two heating seasons is shown for each building type and unit in Table 3. The table data covers the house average air temperature, the average relative humidity, and the average dew-point temperature for the period.

Table 3. Indoor Environmental Conditions for Three Heating Seasons

Pilot Home Unit I.D.	Heating Season Average Daily Temperatures and Relative Humidity								
	Indoor Air Average of 1st and 2nd Floor, °F			Indoor Relative Humidity, %			Indoor Dewpoint Temperature, °F		
	2010-2011	2011-2012	2012-2013	2010-2011	2011-2012	2012-2013	2010-2011	2011-2012	2012-2013
B-1	69.8	68.7	69.8	n/a	44.4	42.3	n/a	45.3	45.9
B-2	68.9	68.4	68.5	n/a	44.1	44.6	n/a	n/a	n/a
B-3	61.1	64.4	65.4	67.1	65.2	67.7	50.1	52.5	54.5
B-4	72.1	71.4	71.8	35.1	45.7	43.7	42.4	49.2	47.7
B1/4 Crawl	61.6	64.8	63.7	66.8	66.4	61.1	48.1	51.5	48.3
BV-1	66.6	66.3	67.2	51.0	52.8	50.7	48.9	49.9	48.5
B-5	58.3	59.8	62.0	63.1	61.8	60.0	45.5	46.7	47.6
B-6	61.3	66.0	62.9	53.3	49.5	45.7	43.0	45.1	41.7
BV-2	64.3	69.5	70.9	37.8	47.1	42.1	37.6	46.8	45.8
BV1/2 Crawl	57.5	62.9	62.3	n/a	53.9	51.4	n/a	41.1	40.8
BV-3	69.2	69.3	69.6	44.1	48.8	41.9	46.6	49.4	46.1
BV-4	63.4	65.5	64.3	56.1	54.2	53.2	48.2	48.6	47.2
BV-5	69.4	70.3	69.5	31.1	44.2	43.5	42.4	48.7	48.8
BV-6	66.6	68.3	67.2	43.5	47.6	44.9	43.6	47.7	44.4
BV3/6 Crawl	56.5	61.3	60.4	85.1	66.1	59.4	52.4	49.8	46.2
FB-1	70.2	71.2	70.1	28.4	32.0	34.0	35.8	39.9	40.7
FB-2	65.2	67.3	69.0	34.2	36.1	30.7	36.6	39.3	35.7
FB-3	66.5	69.0	69.0	42.7	48.7	40.9	42.0	47.5	43.5
FB-4	57.4	59.1	58.2	45.9	47.8	47.8	36.0	38.7	38.6
FB1/4 Crawl	57.3	60.9	61.5	68.2	48.6	41.2	46.7	41.0	37.0
FB-5	66.2	67.5	67.6	37.5	45.8	43.4	40.1	46.3	44.2
FB-6	65.2	66.6	65.9	40.9	49.7	48.2	40.3	46.2	44.6
FB-7	55.0	58.6	57.2	38.4	46.7	42.9	29.9	38.0	35.0
FB-8	65.6	65.3	64.9	41.8	49.5	47.4	38.2	42.4	40.4
FB5/8 Crawl	55.3	61.3	59.9	64.6	53.3	49.9	43.0	42.6	40.2
FV-1	61.1	63.2	66.3	45.9	45.7	40.5	40.8	43.2	42.7
FV-2	69.0	69.5	69.7	35.3	36.0	37.4	40.3	41.5	42.3
FV-3	68.5	67.3	65.5	38.8	42.8	46.7	42.4	43.9	43.5
FV-4	67.8	67.4	67.4	38.5	42.8	42.5	40.7	43.7	42.7
FV1/4 Crawl	52.1	57.6	55.6	76.9	72.1	73.6	43.0	45.3	45.5
FV-5	68.4	69.3	68.4	31.4	38.0	36.8	35.9	41.5	39.4
FV-6	64.6	64.5	60.8	38.4	41.1	47.0	38.2	39.8	40.1
FV-7	66.8	69.3	68.2	38.7	44.9	38.9	41.2	47.8	42.6
FV-8	63.6	64.8	63.0	37.4	47.9	50.1	37.9	45.3	44.3
FV5/8 Crawl	52.5	54.9	52.9	n/a	54.1	52.9	n/a	38.6	37.7

BV5 & BV6 average includes Basement; n/a = data not available; Days in Period, add 1 for 2011-2012.
B≡Block Buildings; BV≡Block Vinyl Buildings; FB≡Frame Brick Buildings; FV≡Frame Vinyl Buildings
2010-2011 Heating Season truncated based on available data, subsequent heating seasons from Nov. 1 - Apr 15.

The average temperatures for individual homes and buildings range widely. Whether due to individual behavior or the difference in ambient conditions, most homes exhibited a change in the average indoor conditions between the comparative heating periods. In general, the average indoor temperature increased by about 1 to 2 degrees for each building type in the warmest heating season (2011/2012).

The average indoor temperature for all buildings was about 66°F for the most recent heating season (2012/2013), 67°F for the 2011/2012 heating season, and 65°F for the first heating season 2010/2011.

Indoor humidity measurements, likewise, show a slightly higher average for the warmest heating season (2011/2012) while the colder winter seasons show a lower humidity level by about 2%. The frame homes in particular, showed an increase in indoor humidity over the latest heating season (2012/2013), perhaps a result of the lower infiltration rate from the crawlspace and attic improvements. Humidity levels in the block homes remain the highest of the pilot project's building types. The dewpoint temperature average for the period was also higher for the most recent heating period although still remaining 19 to 25° F below the average indoor temperature indicating that the condensation potential is unlikely on an average basis.

Heating Season Comparison – Energy Use Data for the Period 11/1 – 3/21

The energy use in the Pilot Project homes was developed from a combination of utility meter readings (bi-weekly) and the energy transducers installed in the homes. Table 4 summarizes the heat season aggregated electrical usage by building type (using the heat season periods defined in Table 3).

The Heating Degree-Days (HDD) for the 2010/2011 heating period were 3,445 vs. 2,766 HDD for the 2011/2012 season. This indicates a 20% difference in HDD between the two seasons with the 2011/2012 heat season being milder than the previous. During the same period of the third heat season that was monitored (2012/2013), there were 3,282 HDD, about 5% fewer than the first season and about 19% more than the previous season.

Table 4. Energy Use Summary by Building and Building Type

	All Homes	Block and Block/Vinyl	Frame Brick	Frame Vinyl
Total Energy Use, Season 1, kWh	197,393	98,376	50,326	48,691
Total Energy Use, Season 2, kWh	158,086	80,476	40,350	37,260
Total Energy Use, Season 3, kWh	180,490	94,342	44,968	41,181
Percent Change Season 1 to Season 3	**-8.6%**	**-4.1%**	**-10.6%**	**-15.4%**
Heating Energy Use, Season 1, kWh	127,265	67,405	30,928	28,932
Heating Energy Use, Season 2, kWh	101,078	53,649	24,627	22,803
Heating Energy Use, Season 3, kWh	115,022	62,947	28,426	23,649
Percent Change Season 1 to Season 2	**-9.6%**	**-6.6%**	**-8.1%**	**-18.3%**
Average Indoor Temperature Change from Season 1 to Season 3	0.9 °F	1.5 °F	1.3 °F	0.0 °F
Average Total Use per Home Season 1, kWh	7,050	8,198	6,291	6,086
Average Total Use per Home Season 2, kWh	5,646	6,706	5,044	4,658
Average Total Use per Home Season 3, kWh	6,446	7,862	5,621	5,148
Of 28 Pilot Homes, B/BV - 12 Homes, FB – 8 homes, FV – 8 Homes				

The overall energy use summary provided in Table 4 shows a 10% decrease in energy consumption for the Brick and Frame/vinyl house types and a 4% decrease in the Block and Block/vinyl units' energy usage from Season 1 to Season 3. This is expected since over the past seasons there were more energy efficiency improvements made to the Brick and Frame/vinyl units. The energy savings was higher, at 15%, in the Frame/vinyl units, again an expected outcome since these units had the most significant improvements to the building envelope of all of the pilot homes.

Table 5 provides the Table 4 energy data by individual home. The energy data is summarized for each of the three heating seasons based on:

- The household total energy use for the same period for each heating season;
- The household heating energy use for the same period for each heating season; and
- The heating degree-day normalized energy use,

The major heating energy use driver, the outdoor temperature, represents the largest influence over the consumption of heating energy. This influence however is moderated by the occupant's control of the temperature setting in the home (or rooms within the home). The data summarized in Table 5 and 6 reflect the outdoor temperature and indoor temperature setting as drivers of energy use. Additional whole house energy use drivers that have not been investigated may include changes in occupancy or a significant change in the non-heating energy use in the home.

In general, a decrease in the normalized energy use (kWh/HDD) represents efficiency improvements that lower the cost of heating the homes. Small changes in the normalized energy use translate into significant annual energy cost savings.

Table 5. Pilot Home Energy Use Summary by Unit

Unit	Total Energy Use for Winter Period			Heating Energy Use for Winter Period			Heating Energy Use Intensity, kWh/HDD		
	Nov 2010 to 3/22/2011 kWh	Nov 2011 to 3/21/2012 kWh	Nov 2012 to 3/21/2013 kWh	Nov 2010 to 3/22/2011 kWh	Nov 2011 to 3/21/2012 kWh	Nov 2012 to 3/21/2013 kWh	Nov 2010 to 3/22/2011 kWh/HDD	Nov 2011 to 3/21/2012 kWh/HDD	Nov 2012 to 3/21/2013 kWh/HDD
B-1	11,210	7,570	10,093	*8,844*	4,891	7,418	2.6	1.8	2.3
B-2	7,090	5,190	6,167	*5,018*	3,860	4,555	1.5	1.4	1.4
B-3	1,990	2,150	2,345	*884*	712	1,401	0.3	0.3	0.4
B-4	14,510	11,550	9,923	*11,032*	8,829	6,640	3.2	3.2	2.0
BV-1	10,560	8,140	11,796	*7,899*	6,665	8,625	2.3	2.4	2.6
B-5	3,480	3,660	5,397	*2,221*	2,336	1,675	0.6	0.8	0.5
B-6	6,156	5,526	4,913	*3,826*	*3,432*	3,498	1.1	1.2	1.1
BV-2	8,160	8,480	10,549	*5,449*	*6,114*	7,638	1.6	2.2	2.3
BV-3	9,600	7,540	9,443	*6,398*	*5,456*	6,480	1.9	2.0	2.0
BV-4	4,925	3,740	4,434	*2,891*	*2,304*	2,290	0.8	0.8	0.7
BV-5	11,545	8,120	8,664	*7,822*	*4,250*	6,589	2.3	1.5	2.0
BV-6	9,150	8,810	10,621	*5,120*	*4,799*	6,138	1.5	1.7	1.9
FB-1	8,680	7,370	6,545	*6,190*	*4,545*	4,680	1.8	1.6	1.4
FB-2	5,200	4,010	6,065	*3,923*	2,733	4,414	1.1	1.0	1.3
FB-3	6,893	5,765	6,460	*4,893*	3,734	4,232	1.4	1.4	1.3
FB-4	3,330	2,260	3,034	*2,138*	1,495	1,738	0.6	0.5	0.5
FB-5	7,490	6,430	6,937	*4,489*	4,427	4,229	1.3	1.6	1.3
FB-6	8,928	6,972	7,379	*3,765*	2,973	3,360	1.1	1.1	1.0
FB-7	1,445	1,353	1,666	*466*	765	1,195	0.1	0.3	0.4
FB-8	8,360	6,190	6,884	*5,063*	3,955	4,580	1.5	1.4	1.4
FV-1	5,015	4,110	6,019	*2,773*	2,600	4,060	0.8	0.9	1.2
FV-2	5,666	4,690	5,069	*3,400*	2,763	2,402	1.0	1.0	0.7
FV-3	5,170	3,690	3,781	*3,465*	2,199	1,974	1.0	0.8	0.6
FV-4	6,940	5,660	5,902	*4,768*	3,844	3,420	1.4	1.4	1.0
FV-5	7,185	5,760	5,556	*4,557*	3,937	3,145	1.3	1.4	1.0
FV-6	4,875	2,590	2,906	*1,309*	2,504	1,269	0.4	0.9	0.4
FV-7	7,970	6,300	7,196	*4,485*	2,064	4,242	1.3	0.7	1.3
FV-8	5,870	4,460	4,755	*4,175*	2,891	3,136	1.2	1.0	1.0

Heating Energy data in Itallics based on utility meter estimate (B-5 uses measured heating percentage)
Note - November 2012 - April 21, 2013 adjusted from April 28, 2013 meter reading

The heating season comparison summary results shown in Table 5 illustrate the change in energy use between the three heating periods. Though somewhat subjective, the indoor temperature measurements shown in Table 3 do provide some perspective on the interior conditions, especially for periods when the average outdoor temperatures were similar. Figure 5 is a graphical representation of the same temperature data. It is helpful to compare season 1 with season 3 since the HDD for both winters were somewhat similar and the average temperature for these winter seasons was within one degree. Many homes had modest changes in interior temperature either higher or lower from the first heat season (2010/2011) to the third heating season (2012/2013). In only two instances did the average temperature decrease by more than 3 degrees and most homes were warmer on average. Given the similarity in the heating severity, one conclusion is that while there may be some lifestyle changes that cause a change in the thermostat setting, most homes were generally the same or warmer when comparing the winter seasons. It is expected that some behavioral factors play a role in the temperature setting—such as lower energy costs for the season that enable a more comfortable thermostat setting, however, since the energy decreases were significant, it is assumed that the energy efficiency upgrades played some role in both enabling warmer interior temperatures with lower utility costs.

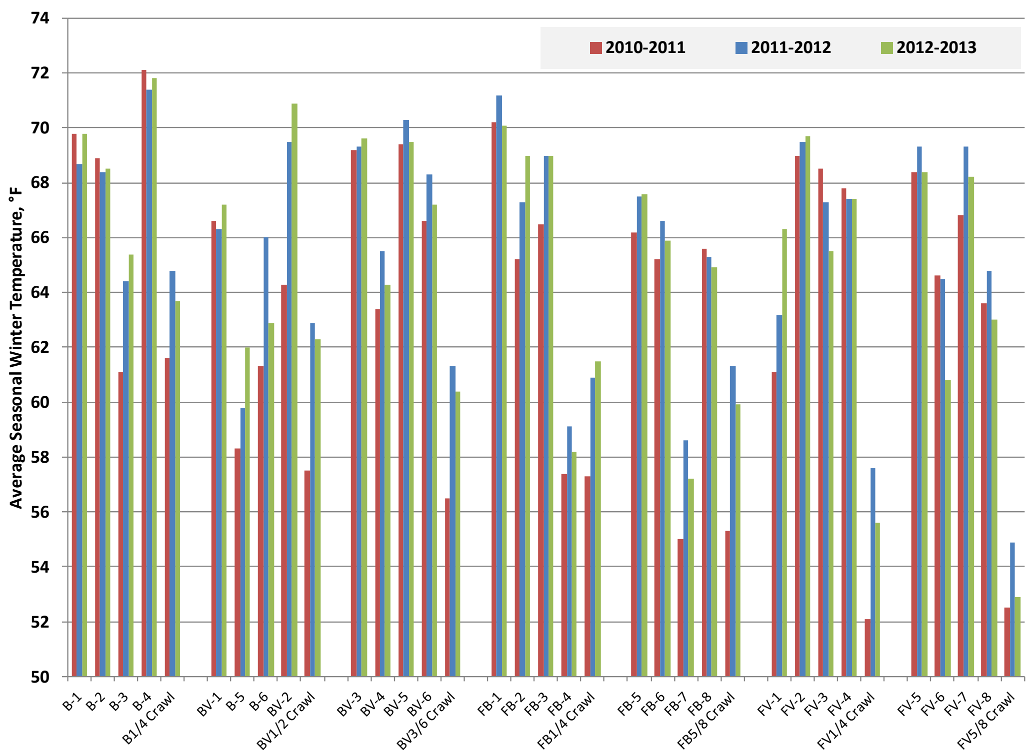

Figure 5. Average Winter Temperature by Pilot Home

Summary

Ongoing energy usage in the Pilot Program homes has been monitored during three heating seasons. The energy usage and indoor environmental data was collected over the winter seasons including 2010/2011, 2011/2012, and 2012/2013 periods. The 2010/2011 heating period is used to develop each home's baseline energy use, the next season 2011/2012 followed crawlspace upgrades in all of the pilot homes, and 2012/2013 followed the attic upgrades in the frame brick and frame vinyl pilot homes. Following the crawlspace upgrades in the frame vinyl homes, new air infiltration tests were performed and determined an average 15% reduction in the infiltration rate for these homes over the original tests. Following the attic upgrades, the frame vinyl and frame brick homes were retested for air infiltration leakage. The frame vinyl homes measured a reduced infiltration rate of 26% on average over the original tests, and the brick units saw on average a 10% reduction. Further reductions in air infiltration leakage are expected following window and wall upgrades.

In comparing the first (baseline) heating season (2010/2011) with the most recent heating season (2012/2013), the heating-degree days were fairly similar and thus the two seasons provide a a good basis for comparison of energy use.

The measured data indicates that in most cases the homes were slightly warmer in this latest winter period. While imprecise as to the effect on energy use, the homes were not operated at a lower temperature merely to conserve energy and affect the outcome. Therefore energy use in the first heating season and the third heating season may be fairly compared.

Given these assumptions the heating energy use in the 28 pilot homes reduced on average 9% or nearly 17,000 kWh between the first and third seasons. At a utility rate of $0.15 per kWh, this represents a reduction of $2,550 across the homes or an average of $90 per home over the heating period. As a building type, since the block homes had the fewer upgrades, the savings averaged about 4%, the frame/Brick about 11% and the frame/Vinyl, which received the greatest amount of energy upgrades, and showed 15% energy efficiency improvement.

The energy upgrades for the envelope planned for the fall of 2013 are expected to provide further significant energy reductions particularly for the block homes. These planned upgrades will not only improve the insulation level of the largest area of the home (the walls) but will add features to improve comfort such as tighter fitting doors and windows.

Monitoring of the homes will continue through the next heating season.