# High Performance Residential Design Challenge

## *Final Report*

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# Abstract

Six new home building projects were developed with the support of the NYSERDA High Performance Development Challenge. In exchange for technical and other support, the homes were constructed to be highly energy efficient. The Levy Partnership provided technical support to the builders, inspected and documented the construction process, conducted a series of tests on each home, tracked costs required to upgrade the homes to their increased efficiency levels, and collected utility bill and other data of the homes once occupied.

# Keywords

High performance homes, low energy homes, energy efficient construction, insulation, heat recovery ventilator, energy modeling, utility bill analysis

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# Acronyms and Abbreviations List

| | |
|---|---|
| ACH | Air Changes per Hour |
| AFUE | Annual Fuel Utilization Efficiency |
| AC | Air Conditioner |
| Approx. | Approximately |
| btu | British thermal unit |
| CDD | Cooling Degree Day |
| CFL | Compact Fluorescent Lamp |
| CFM | Cubic Feet per Minute |
| DHW | Domestic Hot Water |
| EER | Energy Efficiency Ratio |
| EF | Energy Factor |
| EPS | Expanded Polystyrene |
| FG | Fiber Glass |
| HDD | Heating Degree Day |
| HERS | Home Energy Rating System |
| hrs | Hours |
| HRV | Heat Recovery Ventilator |
| HSPF | Heating Season Performance Factor |
| HVAC | Heating, Ventilation, and Air Conditioning |
| kBtu | thousand British thermal units |
| kWh | killowat hour |
| m/s | meter per second |
| MMBtu | Million British thermal units |
| N/A | Not Applicable |
| NYSERDA | New York State Energy Research and Development Authority |
| SEER | Seasonal Energy Efficiency Ratio |
| sf | Square footage |
| SHGC | Solar Heat Gain Coefficient |
| SIPs | Structural Insulated Panels |
| TLP | The Levy Partnership |
| XPS | Extruded Polystyrene |

# 1 Introduction

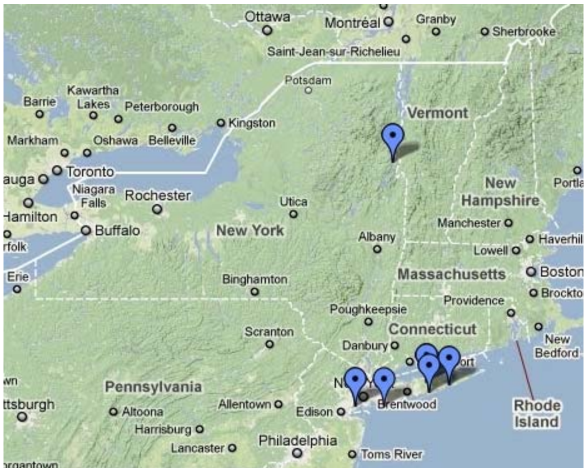
In 2010 the New York State Energy Research and Development Authority (NYSERDA) initiated a program called the High Performance Residential Development Challenge, partnering with leading building science firms and home builders in New York State to develop a series of high-performance case study homes. The Levy Partnership, Inc. (TLP) was one of the building science teams responsible for eight of the demonstration projects. This report summarizes the results of six projects developed with TLP. The goals of the challenge were to demonstrate high performance construction and evaluate incremental costs and performance, as well as monitor key energy markers during each home's first year of occupancy. The Challenge focused on low-rise residential construction, both new or gut rehab. Special emphasis was placed on the envelope of the home, with a targeted New York Home Energy Rating System (HERS) Score of 91 (HERS Index 45).

The Challenge demonstrated that all of the tools are available for a builder to deliver highly efficient homes. TLP worked with builders to redesign existing, popular models. Starting with a familiar design provided a useful benchmark for identifying material changes required to hit the new efficiency mark, the associated costs, required skills and other impacts. The results were documented and performance monitored for one year following occupancy. Table 1 and Figure 1 summarize the six projects.

**Table 1. Summary of the six Challenge projects in New York State**

| Project | Location | Conditioned space | Type | HERS Score |
|---|---|---|---|---|
| **Deerfield** | Ridge | 2,627 | Single family detached new construction | 91 |
| **Canoe Place** | Hampton Bays | 1,955 including finished basement | Townhome new construction | 89.8 |
| **Lake Haven** | Staten Island | 3,181 | Two-family new construction | 91 (owners residence), 89.2 (rental apartment) |
| **Nuvision** | Mastic Beach | 2,038 including conditioned basement | Single family detached new construction | 91.2 |
| **Stephens** | Hague | 2,411 (3,982 with conditioned basement) | Single family detached new construction | 91.6 |
| **United Way** | Long Beach | 2,211 | Two-family gut rehab | 91.4 (modeled as one home) |

**Figure 1: Project locations in New York State**



Following are profiles and descriptions of each project, along with a summary of specifications, costs, notable efficiency strategies and challenges encountered. Appendices contain more detailed long-term monitoring results, additional short-term testing results in two cases and results of occupant interviews.

# 2 Deerfield Builders

This home, constructed by Deerfield Builders, is a four-bedroom single-family detached home in Ridge, NY (Figure 2). The above-grade living portion of the home is 2,627 sf.

**Figure 2. The Deerfield House**

Many improvements were made in the course of upgrading the planned design, including boosting wall cavity insulation quality, adding exterior rigid insulation, upgrading windows, using more efficient heating and cooling equipment, bringing most equipment and ducts into the conditioned space, using balanced heat recovery ventilation instead of exhaust ventilation, and increasing the air tightness of the home. The original planned and upgraded energy-related specifications are shown in Table **2**.

**Table 2. Deerfield energy-related specifications**

| Component | Original specification/assumption | Upgrade specification/test result |
|---|---|---|
| **Foundation type** | Unconditioned full basement | Unconditioned full basement with insulated mechanical room |
| **Foundation wall** | Uninsulated 8" thick concrete block wall | 10" thick concrete block wall, uninsulated except at mechanical room which has 2" rigid polyisocyanurate board on walls (R-13) |
| **Mechanical room partition** | N/A | R-13 fiberglass batt plus 2" rigid polyisocyanurate board |
| **Slab insulation** | None | Slab under mechanical room insulated with 2" rigid foam at slab edge (R-10) and 2" rigid foam under slab (R-10) |
| **Frame floor** | 1st floor R-19 fiberglass batt; garage and cantilever R-30 fiberglass batt | First floor, garage and cantilever insulated with R-38 fiberglass batt |
| **Above grade walls** | 1st floor, 2nd floor, garage: R-19 fiberglass batt; 2nd floor knee wall and basement stairwell: R-13 fiberglass batt | 1st floor, 2nd floor, garage: 5.5" spray-applied rock wool plus 1" rigid polyisocyanurate on exterior (R-30). 2nd floor knee wall: 3.5" spray-applied rock wool plus 1" rigid polyisocyanurate on exterior (R-21.5) |
| **Windows and glass doors** | All windows: U=0.35, SHGC=0.30 | U=0.31, SHGC=0.30, except for master bath windows, fixed arches and transom: U=0.33, SHGC=0.30 |
| **Exterior doors** | Four doors (main entry, garage, mud room, basement) Steel with urethane foam | Five doors (main entry, garage, mud room, basement, mechanical room): steel with urethane foam |
| **Ceiling (roof)** | Flat ceiling: R-38 fiberglass batt; sloped ceiling R-30 fiberglass batt; attic hatch insulated with 4" foam board (R-20) | Flat ceiling 17" spray-applied rock wool (R-57.5); sloped ceiling 9.3" low density spray foam (R-34); attic hatch insulated with 12" foam board (R-60) |
| **Skylights** | One unit in master bath: U=0.55, SHGC=0.33 | One unit in master bath: U=0.55, SHGC=0.33 |
| **Heating** | Natural gas boiler 92% AFUE (Slant Fin Bobcat), 66kbtu | Natural gas boiler 95% AFUE (Slant Fin Lynx), |
| **Cooling** | 14.5 SEER 60 kBtu/hr; air handler in unconditioned attic | 16 SEER 48 kBtu/hr; air handler in conditioned space |

| Component | Original specification/assumption | Upgrade specification/test result |
|---|---|---|
| **Domestic hot water** | Natural gas, indirect, 38 gallon tank, 0.85 EF | Natural gas, indirect, 38 gallon tank, 0.875 EF |
| **Ventilation** | Exhaust only, 135 cfm, 22 watts, 11.5 hrs per day required | Balanced heat recovery ventilation, 62% heat recovery efficiency, 117 cfm, 154 watts, 16 hours per day required |
| **Ducts** | Estimated typical leakage of 154 cfm @ 25 pascals in attic partially under insulation, with R-8 insulation wrap | Measured leakage of 30 cfm @ 25 pascals in attic, under insulation with R-11 insulation wrap |
| **Infiltration** | Target 5 ACH @ 50 pascals | Measured 2.7 ACH @ 50 pascals |
| **Appliances** | Refrigerator 775 kWh/yr<br>Dishwasher 0.46 EF | Refrigerator 550kWh/yr<br>Dishwasher 0.68 EF |

## 2.1 Discussion

Exterior foundation insulation with a conditioned basement was explored as an alternative to insulating the first floor with an unconditioned basement. Exterior foundation insulation provides superior moisture and thermal protection, however it was cost prohibitive and the builder elected to maintain the thermal envelope at the floor line with the exception of at the small basement boiler room.

A number of cavity insulation options were considered, including spray foam, cellulose and blown-in fiberglass. Rock wool was selected because of its moisture resistance compared to cellulose, higher density and resistance to settling compared to fiberglass and cellulose, and lower cost compared to spray foams. It was used in walls and some ceilings. The resulting installation (Figure 3) was highly consistent and provided excellent sound transmission resistance.

**Figure 3. Rock wool insulation**

One goal of the design was to locate heating and cooling equipment within the home's conditioned enclosure. The home was to have space and water heating equipment in the basement and cooling, ventilation and air handling equipment in the attic. Bringing these entire spaces within the conditioned enclosure by insulating the roof plane and the basement would have added greatly to the conditioned volume and been cost prohibitive. The strategy pursued was to enclose small portions of the attic and basement to house the equipment. In the attic, a recessed area above the second floor hall provided an ideal location with minimal added cost. In the basement, a small insulated room (Figure 4) was created and sealed off with an insulated door.

**Figure 4. Basement mechanical room framing – the framed and concrete walls were later insulated**

## 2.1 Costs

Table 3 lists the costs of each major energy efficiency measure. The “Item” column in the table explains the difference between the base and upgrade specification (i.e. “None to two inches under and two inches at edge” indicates that the base specification had no slab insulation and the upgrade specification called for two inches under and two inches at the edge).

**Table 3. Cost of each upgrade feature and total incremental cost of energy-related features**

| Item | Base cost | Upgrade cost | Incremental cost |
|---|---|---|---|
| Slab insulation: None to two inches under and two inches at edge | n/a | $974 | $974 |
| Mechanical room: None to interior wall framing and FG cavity insulation | n/a | $380 | $380 |
| Mechanical room rigid insulation: None to two inch Thermax all walls | n/a | $900 | $900 |
| Exterior insulation materials for conditioned space: None to 1 inch Tuff-R under vinyl | n/a | $2,452 | $2,452 |
| Exterior insulation labor for installation | n/a | $1,530 | $1,530 |
| Exterior insulation over unconditioned space (gable ends): None to Shelter Wrap | n/a | $205 | $205 |
| Air Sealing: Standard Energy Star to enhanced air sealing target of 2.4 ACH | $1,288 | $1,530 | $242 |
| **Item** | **Base cost** | **Upgrade cost** | **Incremental cost** |
| Above grade wall cavity insulation: Fiberglass to rock wool | $3,980 | $4,350 | $9,437 |
| Flat ceiling insulation: Fiberglass to rock wool | | $3,600 | |
| Sloped ceiling insulation: Fiberglass to spray foam | | $3,817 | |
| First floor insulation: R-19 to R-38 FG | | $1,650 | |
| Thermal load calculations: New calculations to account for upgraded envelope | n/a | $675 | $675 |
| AC system size: 5 ton to 4 ton | $9,980 | $9,490 | $(490) |
| Heat recovery ventilation and cooling system: None to HRV; 14.5 SEER AC to 16 SEER AC | n/a | $3,650 | $3,650 |
| Duct insulation in unconditioned spaces: R-8 to R-11 | - | $90 | $90 |
| Windows: Air filled to argon filled | 7,587 | $7,995 | $408 |
| Mechanical room door: None to exterior door | n/a | $300 | $300 |
| Boiler: Slant Fin Bobcat B-120 AFUE 92% to Slant Fin Lynx 95% AFUE | $3,509 | $2,237 | $(1,272) |
| Total incremental costs | - | - | $19,482 |

## 2.2 Energy performance

Actual energy consumption for the first year of occupancy compared to modeled estimated energy expenditure for both the original and upgraded home design is summarized in Table 4.

**Table 4. Actual versus predicted energy consumption (MMBtu)**

| | Actual | Upgraded design REM/Rate model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 63.6 | 43.5 | 77.8 |
| **Cooling** | 10.6 | 3.5 | 3.5 |
| **Baseload** | 56.3 | 42.4 | 42.2 |
| **Total** | 130.5 | 89.4 | 123.4 |

Actual energy consumption was significantly higher than predicted for heating, cooling and baseload for this house. Some of this discrepancy may be attributed to behavioral and operational factor+s or weather (the comparison is not weather normalized). Data loggers were used to record equipment power and indoor conditions at hourly intervals at the Deerfield house. An analysis of this data is provided in the appendix.

# 3 Canoe Place Townhome

The participating home is a new two-story (plus basement) end-unit townhouse unit in Hampton Bays, NY (Figure 5). The living portion of the home is 1,955 sf including the conditioned basement. shows the original planned specifications and the upgrade specifications.

**Figure 5. Canoe Place Townhome**

**Table 5. Canoe Place energy-related specifications**

| Component | Original specifications/assumptions | Proposed upgrade specifications |
|---|---|---|
| **Foundation type** | Unconditioned basement | Conditioned basement |
| **Foundation wall** | Uninsulated concrete | 4” rigid polyisocyanurate board insulation (R-26) over concrete |
| **Slab floor insulation** | N/A | 2” rigid foam at edge (R-10)<br>4” rigid foam under entire slab (R-20) |
| **Frame floor** | R-19 fiberglass batt | No insulation |
| **Above grade walls** | R-15 fiberglass batt | 3.5” closed-cell spray-foam (R-21.7)<br>3/4” rigid insulation (R-4.8) |
| **Windows and glass doors** | Low-E with argon fill<br>Double hung: U=0.31, SHGC=0.27<br>Awning: U=0.28, SHGC=0.24<br>Casement: U=0.28, SHGC=0.24 | Low-E with argon fill<br>Double hung: U=0.31, SHGC=0.28<br>Casement: U=0.28, SHGC=0.24<br>Fixed (Semi-circular): U=0.30, SHGC=0.30<br>Basement slider: U=0.26, SHGC=0.19<br>Basement awning window: U=0.46, SHGC=0.57 |
| **Exterior door type** | Front door: R=3.85<br>Rear door: R=3.22<br>Basement door: R=1.3 | Front door: R=3.85<br>Rear door: R=3.22 |
| **Ceiling (roof)** | R-38 fiberglass batt | Attic: R-38 blown in fiberglass over R-38 fiberglass batt (R-76) |
| **Heating** | Gas furnace, 89% AFUE | Gas furnace, 94.1% AFUE |
| **Cooling** | 13 SEER | 16 SEER |
| **Domestic hot water** | Gas, 40 gallons storage, 64% Eff. | Gas, Instantaneous EF 0.92 |
| **Ventilation** | Exhaust, 67 cfm, 25 watts, 24 hrs per day | Energy Recovery Ventilation<br>81% Eff, 53 cfm, 63 watts, 19 hours per day located in basement |
| **Ducts** | 88 cfm @ 25 pascals | 10 cfm @ 25 pascals / 50% Conditioned basement, 50% Attic under insulation |
| **Infiltration** | 5 ACH @ 50 pascals | 1.5 ACH @ 50 pascals |
| **Lighting and Appliances** | Lighting: 20% pin-based, 0% CFL<br>Refrigerator: 775 kWh/yr<br>Dishwasher: 0.46 EF | Lighting: 20% pin-based, 80% CFL<br>Refrigerator: 350 kWh/yr maximum<br>Dishwasher: 0.75 minimum EF |

## 3.1 Discussion

Construction modifications necessary for the upgraded design included building out widows to accommodate exterior foam insulation (Figure 6) and some advanced framing to minimize thermal bridging (Figure 7).

**Figure 6. Windows are built out to accommodate the exterior rigid foam insulation**

**Figure 7. Some advanced framing techniques were used such as at this 2-stud corner**

The walk-out basement (Figure 8) was converted into conditioned space by insulating the slab and basement walls. This had the additional benefit of brining all the mechanical equipment into the thermal envelope. Some portions of the basement wall, however, were uninsulated because of equipment or pipes adjacent or mounted to the wall (Figure 9).

**Figure 8. Walk out basement**

**Figure 9. The tankless water heater on the basement wall**

In an adjacent unit where closed cell spray foam was also used, the foam did not cure properly, resulting in a strong unpleasant odor. The foam had to be removed and re-installed. This highlights the sensitivity of this product to improper installation and the need to ensure qualified applicators following manufacturer's instructions are on the job.

## 3.2 Costs

Table 6 lists the cost implications for each major energy efficiency measure.

**Table 6. Cost of each upgrade feature and total incremental cost of energy-related features**

| Item | Base | Upgrade | Increment |
|---|---|---|---|
| Wall cavity insulation (R-15 to R-21.7) and ceiling insulation (R-38 to R-76) | $2,600 | $9,475 | $6,875 |
| Exterior rigid insulation: None to 3/4” XPS (R-4.8) | | | |
| Labor | $0 | $1,260 | $1,260 |
| Material | $0 | $1,477 | $1,477 |
| Whole house ventilation: None to heat recovery ventilation | $0 | $2,500 | $2,500 |
| Cooling: 13 SEER to 16 SEER | - | $1,250 | $1,250 |
| Furnace: 89% AFUE to 94% AFUE | - | $1,250 | $1,250 |
| Water heater: Storage tank 0.64 EF to instantaneous 0.92 EF | $1,540 | $3,045 | $1,505 |
| Basement wall insulation: None to 4” rigid board insulation (R-20) | $0 | $3,360 | $3,360 |
| Basement slab insulation: None to 2” rigid foam at edge (R-10) and 4” rigid foam under entire slab (R-20) | $0 | $1,600 | $1,600 |
| Total incremental upgrade costs | N/A | N/A | $21,077 |

## 3.3 Energy performance

Actual energy consumption for the first year of occupancy compared to modeled estimated energy expenditure for both the original and upgraded home design is summarized in Table 7.

**Table 7. Actual versus predicted energy consumption (MMBtu)**

| | Actual | Upgraded design REM/Rate model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 40.2 | 36.3 | 42 |
| **Cooling** | 0.9 | 2.5 | 1.7 |
| **Baseload** | 15 | 31.6 | 25.9 |
| **Total** | 56.1 | 70.4 | 69.6 |

The upgraded REM/Rate model predictions are similar to the original design predictions due to the incorporation of the basement into the conditioned space. This adds to envelope heat loss and affects the baseload modeling assumptions, which are predicated in part on conditioned floor area.

The bill analysis heating gas consumption was 11% higher compared to the model, despite there being 3% fewer heating degree days in the monitored winter compared to the 30 year average used by REM/Rate (the data is not weather normalized) and despite the lower average winter set point used by the occupant as recorded by the space temperature logger. Gas use was substantially lower than the model, due at least in part to the lower actual occupancy (one verses the three people assumed by REM/Rate).

The actual cooling energy use was more than 60% lower than the model, likely due to the judicious use of air conditioning and frequent thermostat setbacks as reported by the owner in the Occupant Survey (see Appendix). Baseload electric was 19% lower, also affected by the lower occupancy. Overall, energy consumption was 20% lower than the REM/Rate model.

Data loggers were used to record equipment power and indoor conditions at hourly intervals at the Deerfield house. An analysis of this data is provided in the appendix.

# 4 Stephens Construction

The home built by Stephens Construction is a single family detached home in Hague, NY (Figure 10). Table 8 shows the original planned specifications and the upgrade specifications.

**Figure 10. The Stephens House**

**Table 8. Stephens Construction energy-related specifications**

| Component | Original design | Upgrade specifications |
|---|---|---|
| **Foundation type** | Conditioned basement | Conditioned basement |
| **Foundation wall** | 2” Thermax (R-13) | 2” Thermax (R-13) |
| **Slab floor** | None | None |
| **Frame floor overhang** | R-30 fiberglass batt | R-30 fiberglass batt |
| **Above grade walls** | 4” polyurethane core SIPs (R-24) | 6.5” polyurethane core SIPs (R-40) |
| **Windows and glass doors** | Low-e argon single hung U=0.29, double hung U=0.33, casements U=0.28; glass doors U=0.29 | Low-e argon single hung U=0.29, double hung U=0.31, casements U=0.28; 3 glass doors U=0.29 |
| **Doors** | Fiberglass | Fiberglass |
| **Ceiling (roof)** | Flat ceilings R-11 fiberglass plus R-30 cellulose | Flat ceilings R-11 fiberglass plus R-40 cellulose |
| **Heating** | 93% LPG furnace 60kbtu | Geothermal heat pump: 38.5 heating capacity, 3.7 COP; 48.7 cooling capacity, 18.9 EER |
| **Cooling** | SEER 13 24k | |
| **Domestic hot water** | 75 gallon LPG tank 60% EF | Tankless LPG, 87% EF (2 units) |
| **Duct leakage** | RESNET/HERS default (estimated) | 88 CFM@25 |
| **Infiltration** | 3.5 ACH50 (estimated) | 2.3 ACH50 tested |
| **Ventilation** | None | Heat recovery ventilation 168 cfm, recovery efficiency 62%, 150 watts, run time 50% |
| **Lighting** | 10% pin-based, 0% CFL | 10% pin-based, 90% CFL |

## 4.1 Discussion

The SIP wall thickness was increased from 4” to 6.5”. In addition to increased thermal insulation, the thicker panels also resulted in a quieter home; this is less of an issue in this rural location, but potentially a greater benefit in an urban setting. The thicker walls also resulted in deeper window recesses, requiring wider interior trim, and are heavier, making installation a bit more of a chore.

**Figure 11. SIPs are 6.5” thick with a polyisocyanurate core, obtaining a total R value of 40**

Ceiling insulation was increased from R-41 to R-51. The amount added here (about 4 inches) was not significant enough to make a significant difference in ceiling heat loss, but did allow the ducts in the attic to be buried deeper.

**Figure 12. Blown-in attic insulation**

The heat recovery ventilator was installed in the conditioned basement. The long duct runs from the HRV to the second floor bathrooms resulted in lower than desired airflow to those locations, requiring setting the HRV to a higher fan speed.

**Figure 13. An American Aldes HRV is installed in the insulated basement**

## 4.2 Costs

Table 9 lists the cost implications for each major energy efficiency measure.

**Table 9. Actual versus predicted energy consumption (MMBtu)**

| Item | Base | Upgrade | Increment |
|---|---|---|---|
| SIP wall panels: Upgrade from 4 inch to 6.5 inch thick cores | $12,125 | $15,850 | $3,725 |
| Ceiling insulation: Addition of blown-in fiberglass insulation to bring ceiling from R-41 to R-51. | $1,874 | $2,020 | $145 |
| Domestic water heater: Replacement of 75 gallon storage tank with two tankless propane fired units | $1,200 | $2,763 | $1,563 |
| Heat recovery ventilator: Replacement of three bath exhaust fans with ducted HRV | $525 | $1,519 | $994 |
| Sunspace SIP wall panels | $0 | $4,656 | $4,656 |
| Sunspace windows | $0 | $1,900 | $1,900 |
| Total incremental upgrade costs | | | $12,983 |

## 4.3 Energy performance

Actual energy consumption for the first year of occupancy compared to modeled estimated energy expenditure for both the original and upgraded home design is summarized in Table 10.

**Table 10. Actual versus predicted energy consumption (MMBtu)**

| | Actual | Upgraded design REM/Rate model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 9.2 | 18.6 | 62.6 |
| **Cooling** | 1.7 | 2.3 | 4.9 |
| **Baseload** | 23.1 | 52.0 | 61.2 |
| **Total** | 34.0 | 72.9 | 128.7 |

The actual energy consumption was much less than that predicted by REM/Rate in part due to the seasonal occupancy pattern of the house. The home was occupied in the summer and sporadically for the rest of the year. The thermostat was set at 60°F during heating season when the home was unoccupied. Domestic hot water was provided by a propane appliance. Irregular propane tank refills, co-mingling of propane for multiple uses (heating the guest house and cooking in addition to DHW) made it difficult to isolate fuel consumption for DHW. The dramatic reduction in predicted heating energy from original the upgrade design is partially a result of the low energy consumption assumed by REM/Rate for the ground source heat pump as compared to a propane furnace.

# 5 NuVision Builders

The NuVision house is a single family detached home in Mastic Beach, NY (Figure 14). The house was completed in October 2011. It is occupied by two adults and three children. The house is heated by dual (one for each zone) hybrid electric heat pumps with two-stage propane backup, utilizes a heat recovery ventilator and a propane-fired tankless water heater. Table 11 shows the original planned specifications and the upgrade specifications.

**Figure 14. The NuVision House**

**Table 11. NuVision energy-related specifications**

| Component | Original specifications | Upgrade specifications |
|---|---|---|
| **Foundation** | Unconditioned basement | Unconditioned basement with conditioned mechanical room |
| **Foundation wall** | Uninsulated concrete block | *Below grade:* 2” rigid foam (R- 10)<br>*Above grade knee wall*: R-15 fiberglass batt plus 2” rigid exterior insulation (R-13) |
| **Slab floor insulation** | None | 2” rigid foam at edge (R10) and under slab in mechanical room area only |
| **Frame floor** | R-30 fiberglass batt | None |
| **Above grade walls** | R-15 fiberglass batt plus 1” rigid exterior insulation (R-4) | 3.5” blown (R-15) plus 2” rigid exterior insulation (R-13); 10mm Spaceloft aerogel (R-4) insulation used to mitigate thermal bridging at window build-out |
| **Windows** | U=0.34, SHGC=0.28 | U=0.34, SHGC=0.28 |
| **Exterior door type** | *Entry door*: Fiberglass (R-5.25)<br>*Mud room door*: Steel Door with foam (R-4) | *Entry door*: Fiberglass (R-5.25)<br>*Mud room door*: Steel Door with foam (R-4) |
| **Ceiling (roof)** | *Flat ceiling:* R-38 fiberglass batt | *Flat ceiling:* 22”Blownfiber glass (R-65)<br>*Vaulted ceiling:* R-38 fiberglass batt |
| **Heating** | Oil, 85% AFUE, Hydro-air | Hybrid heat pumps (2) 9.75 HSPF, 16 SEER back-up propane 95 AFUE |
| **Cooling** | 13 SEER 24K ACC and 13 SEER 36K ACC | |
| **Domestic hot water** | Oil, 40 gallon tank, 85% efficient indirect | Instantaneous, propane, 0.82 EF |
| **Ventilation** | Exhaust fan 46 cfm, 40 watts, 12 hrs per day | Heat recovery ventilation, 62% efficiency, 117 cfm, 154 watts, 10 hours per day |
| **Ducts** | 60 cfm @ 25 pascals in unconditioned basement with R-8 insulation | No leakage to outside (all ducts in conditioned basement) |
| **Infiltration** | 5 ACH @ 50 pascals | 2.13 ACH @ 50 pascals |
| **Lighting and Appliances** | *Lighting:* 10% pin-based, 0% CFL<br>Refrigerator: 775 kWh/yr<br>Dishwasher: 0.46 EF | *Lighting:* 10% pin-based, 90% CFL<br>*Refrigerator:* 450 kWh/yr maximum<br>*Dishwasher:* 0.68 EF minimum |

## 5.1 Discussion

Originally the basement was planned to be outside of the conditioned space except for an insulated and air sealed mechanical room. However the target airtightness of the main portion of the home was not being reached due to leakage through the floor (particularly around the basement stair and along the change in level that ran the length of the house). Therefore the basement was converted to an insulated and conditioned basement (the owner planned to finish it in the future anyway).

**Figure 15. Basement walls prior to installation of interior rigid foam**

**Figure 16. Basement walls with interior rigid foam installed (2" XPS)**

Windows are built out to accommodate the two inch thick exterior rigid polyisocyanurate insulation. To reduce thermal bridging at the blocking around windows, a 10mm thick aerogel matt (white in the photo) was applied over the blocking prior to installation of the windows.

**Figure 17. Windows built-out for exterior foam insulation**

## 5.2 Costs

Table 12 lists the cost implications for each major energy efficiency measure.

**Table 12. Cost and energy savings by feature – NuVision**

| Item | Base | Upgrade materials | Upgrade labor | Increment |
|---|---|---|---|---|
| Foundation wall insulation: None to 2" Continuous XPS R-10 | $0 | $2,500 | $600 | $3,100 |
| Slab floor insulation in mech. room: None to 2" rigid foam, and 2" at edge | $0 | $210 | $19 | $229 |
| Frame floor insulation: R-30 fiberglass batt to none | $1,715 | $0 | $0 | -$1,715 |
| Above grade walls: 1" rigid EPS exterior to 2" Tuff-R exterior insulation | $1,425 | $2,796 | $0 | $1,371 |
| Above-grade walls: Wood to pack-out windows | $0 | $119 | $0 | $119 |
| Above grade walls: fiberglass batt to blown fiberglass insulation | $0 | $400 | included | $400 |
| Flat ceiling: R-38 fiberglass batt to 22" blown-in fiberglass insulation | $2,265 | $4,745 | $0 | $2,480 |

| Item | Base | Upgrade materials | Upgrade labor | Increment |
|---|---|---|---|---|
| DHW: Oil-fired tank water heater to tankless propane water heater | $1,150 | $1,025 | $0 | -$125 |
| Cooling: 13 SEER AC to two hybrid heat pumps | $2,634 | $5,808 | $0 | $774 |
| Heating: Oil-fired hydro-air system to two hybrid heat pumps | $2,400 | | | |
| Ventilation system including ductwork: Exhaust fan to HRV | $130 | $1,095 | $600 | $1,565 |
| Total incremental costs | $11,719 | $18,697 | $1,219 | $8,197 |

## 5.3 Energy consumption

REM/Rate's energy modeling uses 30-year average weather data from the nearest weather station in Riverhead, NY. Compared to the 30-year average, the actual weather over the monitoring period had 13.3% fewer HDDs and 12.2% additional CDDs. Normalized seasonal heating and cooling expenditures compared to the REM/Rate model are show in Table 13.

**Table 13. Weather normalized expenditure compared to REM/Rate's predicted expenditure (MMBtu)**

| | Weather Normalized Consumption | Upgrade REM/Rate Model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 16.6 | 21.1 | 75.3 |
| **Cooling** | 5.9 | 2.1 | 2.9 |
| **Baseload** | 44.0 | 46.8 | 40.6 |
| **Total** | 66.4 | 70.0 | 118.8 |

Overall, the total weather normalized energy consumption was very close to the REM/Rate prediction – only 5% less (Table 13). More details on the energy consumption are provided in the Appendix.

# 6 United Way

The United Way home is a two-family detached home in Long Beach, NY (Figure 18). The house is a gut rehab of a dilapidated single family home (Figure 18 inset). It is owned and operated by Catholic Charities of New York as a residence for two families. Table 14 shows the original planned specifications and the upgrade specifications.

**Figure 18. The United Way House**

**Table 14. United Way energy-related specifications**

| Component | Original design | Upgrade design |
|---|---|---|
| **First floor insulation** | R-30 fiberglass batt | 5” closed cell spray foam (R-32.5) |
| **Exterior wall cavity insulation (1st and 2nd floor)** | R-15 Fiberglass batt | 3” to 5” closed cell spray foam (R-19.5 to R-32.5) |
| **Exterior continuous insulation** | None | 1.5” exterior polyisocyanurate insulation (R-10) |
| **Attic mechanical room walls** | None | 3” to 5” closed cell spray foam (R-19.5 to R-32.5) plus 1.5” polyisocyanurate insulation (R-10) |
| **Windows** | U=0.30, SHGC=0.30 | Casement replacement windows. Low-E, Argon filled. |

| | | |
|---|---|---|
| | | U=0.29, SHGC=0.25 |
| **Main exterior entry door** | 1-3/4” solid wood door (R-2.10) | Fiberglass door (R-6.6) |
| **Ceiling above 1st and 2nd floors (attic flat)** | R-30 fiberglass batt | In original section of house: 1” closed cell foam for air sealing (R-6.5) + 18” Cellulose loose fill (R-67.5) |
| **Attic mechanical room sloped ceiling area under rafters** | None | 6” closed cell foam (R-36) |
| **Cooling** | 13 SEER AC, 24K – 2 units | 16 SEER, 24K – 1 unit, zoned control for each floor |
| **Heating** | Gas Boiler, 83% AFUE – 2 units | Gas Boiler with hydro-air coil, 95% AFUE minimum – 1 unit, zoned control for each floor |
| **Domestic hot water** | Natural gas, 40 gallons, 60% EF – 2 units | *Indirect*, 38 gallons, 87.5% EF - 1 unit |
| **Ducts** | Located in attic and conditioned space | 100% in conditioned space (in soffits as necessary) |
| **Duct leakage** | 200 cfm @ 25 pascals (2 systems)<br>System 1 location: 100% conditioned space ,<br>System 2 location: 100% Attic under insulation | 25 cfm @ 25 pascals to outside<br>Location: 100% conditioned space |
| **Infiltration rate** | 3.8 ACH @ 50 pascals | 3 ACH @ 50 pascals |
| **Ventilation** | Panasonic bath fans, each bathroom | Energy Recovery Ventilation 77% efficiency; dedicated ducts from each bathroom |
| **Lighting and appliances** | *Lighting:* 10% pin-based, 0% CFL<br>Refrigerator: 1550 kWh/yr<br>Dishwasher: 0.46 EF | *Lighting:* 10% pin-based, 90% CFL<br>*Refrigerator:* 800 kWh/yr (2 units)<br>Dishwasher: 0.68 EF |

Closed cell spray foam was used extensively to insulate and airseal existing construction. For example, one to two inches of spray foam was applied to the existing attic floor boards to air seal the third floor attic space from the living space below (Figure 19). Cellulose was blown on top of the foam. Closed cell foam was also used under the first floor in the crawlspace (Figure 20), and in the complex framing of the existing bay window on the front façade (Figure 21). Polyisocyanurate was used as the exterior insulation material (Figure 22).

**Figure 19. Spray foam on the attic floor prior to covering with cellulose**

**Figure 20. Closed cell spray foam under the first floor. The basement has been filled and topped with a concrete slab to comply with city flood zone requirements.**

**Figure 21. Spray foam under front bay window**

**Figure 22. Exterior insulation completed with seams taped**

## 6.1 Costs

Table 15 lists the cost implications for each major energy efficiency measure.

**Table 15. Cost by feature – United Way**

| Item | Base Cost | Upgrade Cost | Increment |
|---|---|---|---|
| First floor insulation: R-30 fiberglass batt to 5” closed cell spray foam (R-32.5) | $1,800 | $6,800 | $5,000 |
| Exterior wall cavity insulation: R-15 Fiberglass batt to closed cell spray foam (approx. R-25) | $3,000 | $12,000 | $9,000 |
| Exterior continuous insulation: None to 1.5” exterior polyisocyanurate (R-10) | N/A | $7,920 | $7,920 |
| Attic mechanical room wall insulation: None to closed cell spray foam (approx. R-25) | N/A | $2,000 | $2,000 |
| Main entry door: Solid wood to fiberglass | $260 | $450 | $190 |
| Ceiling (attic flat): R-30 fiberglass batt to 20” cellulose loose fill | $2,800 | $3,500 | $700 |
| Attic mechanical room sloped ceiling area under rafters: None to 5.5” deep closed cell foam | N/A | $700 | $700 |
| Cooling: 13 SEER 24kBtu/hr (2 units) to 16 SEER 24kBtu/hr (1 unit) zoned control for each floor | $7,000 | $6,500 | ($500) |
| Heating: Natural gas boiler, 83% AFUE (2 units) to gas boiler with hydro-air coil, 95% AFUE minimum (1 unit) zoned control for each floor | $7,500 | $6,000 | ($1,500) |
| Hot water: Natural gas, 40 gallons, 60% EF (2 units) to Indirect, 38 gallons, 87.5% EF – (1 unit) | $900 | $1,200 | $300 |
| Ductwork (for space conditioning and ERV): Relocate from attic to 100% in conditioned space (in soffits as necessary) | $4,000 | $7,800 | $3,800 |
| Ventilation: Bath fans, each bathroom to energy recovery ventilation plus bath fans | $300 | $1,500 | $1,200 |
| Total incremental cost | | | $28,810 |

## 6.2 Energy consumption

The comparison between the model and the data analysis show that heating gas consumption was nearly three times that of the model and DHW gas was more than double that of the model. The bill analysis cooling energy use was 21% higher than the model and the baseload electric was 76% lower than the model. Overall, energy consumption was 185% higher than the REM/Rate model. The excessive gas consumption is consistent with the very high heating season indoor temperature data (see Appendix for details) and resident reports of excessive heat. It was determined that the temperatures were high due to problems with the heating system controller. The controllers were replaced in the winter of 2013-14.

**Table 16. Actual versus predicted energy consumption (MMBtu)**

| | Actual | Upgraded design REM/Rate model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 130.2 | 41.5 | 53.7 |
| **Cooling** | 5.8 | 4.8 | 7.2 |
| **Baseload** | 25.4 | 23.3 | 55.8 |
| **Total** | 161.4 | 69.6 | 116.7 |

# 7 Lake Haven Homes

The Lake Haven home is a new two-family house in Staten Island, NY (Figure 23. The Lake Haven HouseFigure 23). The structure includes a four-bedroom owner's unit on two floors and a two-bedroom rental apartment on the ground floor for a total of 3,181 sf plus a one-car garage. Table 17shows the original planned specifications and the upgrade specifications.

**Figure 23. The Lake Haven House**

**Table 17. Lake Haven energy-related specifications**

| Component | Original specifications | Upgrade specifications |
|---|---|---|
| **Foundation type** | Conditioned basement | Conditioned basement |
| **Foundation wall** | Uninsulated | 2” closed cell spray foam (R-13) |
| **Slab insulation** | Uninsulated | 2” XPS at edge and under slab (R-10) |
| **Frame floor** | R-19 fiberglass batt | 7.3” closed cell spray foam (R-45) |
| **Above grade walls** | R-11 fiberglass batt | 3.5” to 5” open cell spray foam (R-13 to R-18.3) plus 2” rigid foam (R-10) (no XPS on walls between garage and house)<br>At attic mechanical space 7.3” open cell foam (R-27) |
| **Windows and glass doors** | Double hung low-e vinyl argon, U-value 0.31, SHGC 0.30 | Casements: U-value 0.30, SHGC 0.36<br>Double hung: U-value 0.31, SHGC 0.25<br>Sliding: U-value 0.32, SHGC 0.43<br>Fixed: U-value 0.30, SHGC 0.36,<br>U-value 0.31, SHGC 0.36 |
| **Component** | **Original specifications** | **Upgrade specifications** |
| **Ceiling (roof)** | R-19 fiberglass batt | *Flat ceiling:* 16” loose-fill cellulose (R-59)<br>*Tray ceiling:*7.3” open cell spray foam (R-27)<br>*Attic mechanical space:* 7.3” closed cell spray foam (R-43.8) |
| **Skylights** | Two | None |
| **Heating** | *Owner:* Gas boiler 90% AFUE | *Owner:* 93% AFUE gas boiler |
| | *Apt:* Gas furnace 90% AFUE | *Apt:* 95% AFUE furnace |
| **Cooling** | *Owner:* 16 SEER 2.5 ton | *Owner:* 2 units - 18 SEER 2 ton |
| | *Apt:* 16 SEER 1.5 ton | *Apt:* 18 SEER 1.5 ton |
| **Domestic hot water** | *Owner:* Gas storage tank 40 gal 56% | *Owner:* Indirect storage tank, gas, 87% EF |
| | *Apt:* Gas storage tank 40 gal 56% | *Apt:* Tankless, gas, 82% EF |
| **Ventilation** | None | Energy recovery ventilators (2), 77% efficiency, 120 cfm, 168 watts, 18 hours per day |
| **Ducts** | Assumed 100 cfm@25 pa | *Owner:* 2 systems – Total 40 CFM @ 25 pascals to outside. Location system 1: 100% Attic under insulation (R-8); location system 2: 30% conditioned space and 70% attic under insulation (R-8)<br>*Apt:* 20 CFM @ 25 pascals to outside; location 100% conditioned space |
| **Infiltration** | Assumed 4.19 ACH @ 50 pa | 2.62 ACH @ 50 pa |
| **Lighting and Appliances** | *Appliances:* Gas oven/dryer<br>*Lighting:* 0% CFL, 10% Pin-based | *Appliances:* Gas oven/dryer<br>*Lighting:* 90% CFL, 10% Pin-based<br>Refrigerator: 550 kWh/yr<br>Dishwasher: 0.68 EF |

The attic mechanical space was incorporated into the conditioned space with closed cell spray foam. Figure 24 shows the ceiling of the mechanical space and Figure 25 shows the perimeter sealing at the intersection with the third floor ceiling.

**Figure 24. Low density spray foam used to enclose a small area of the attic containing mechanical equipment**

**Figure 25. Blocking and spray foam was used to extend the thermal and air barrier through the ceiling joists under the walls enclosing the attic mechanical space**

The garage was air sealed from the living space (Figure 26). The front porch roof is built out from the front wall to permit continuous foam insulation and brick to pass behind (Figure 27) with a continuous air barrier and minimal thermal bridging.

**Figure 26. High density spray foam in the garage ceiling**

**Figure 27. Porch roof (top of photo) is built out from front wall to permit continuous foam insulation and brick to pass behind**

## 7.1 Costs

Table 18 lists the cost implications for each major energy efficiency measure.

**Table 18. Cost by feature – Lake Haven**

| Item | Base | Upgrade | Increment |
|---|---|---|---|
| Cavity insulation package, including: | $3,100 | $11,550 | $8,450 |
| Spray foam frame walls | | | |
| Spray foam floors at garage and overhang | | | |
| Attic mechanical room insulation | | | |
| Spray foam basement walls | | | |
| Ceiling insulation - blown in cellulose | | | |
| Slab insulation | $0 | $871 | $871 |
| Exterior rigid insulation | $0 | $6,805 | $6,805 |
| Boiler and DHW - owner's unit | see increment | | $2,885 |
| Furnace – rental unit | $2,000 | $3,300 | $1,300 |
| Cooling system | $11,250 | $14,000 | $2,750 |
| DHW - rental unit | see increment | | $2,400 |
| HRV- owner's unit | $0 | $2,450 | $2,450 |
| HRV- rental unit | $0 | $2,450 | $2,450 |
| Total incremental costs | | | $30,361 |

## 7.2 Energy consumption

Actual energy consumption compared to REM/Rate's estimated energy use is summarized in Table 19. While the home has four bedrooms, the number of bedrooms was reduced to one in the model to mimic the actual number of occupants (two) reported by the homeowner. REM/Rate estimates occupancy as number of bedrooms plus one. The number of occupants affects the internal heat gains, domestic hot water usage, lighting, appliance and plug load assumptions. The REM/Rate predictions for heating, cooling and baseload energy consumption were higher than actual use by 23.2%, 14.5% and 37.8% respectively. This is consistent with the behavior reported in the occupant survey (see Appendix) – in particular the high air conditioning set point and the judicious use of heating.

**Table 19. Weather normalized expenditure compared to REM/Rate's predicted expenditure (MMBtu)**

| | Weather Normalized Consumption | Upgrade REM/Rate Model | Original design REM/Rate model |
|---|---|---|---|
| **Heating** | 30.6 | 35.4 | 92.2 |
| **Cooling** | 2.97 | 5.8 | 6.5 |
| **Baseload** | 25.47 | 68.2 | 87.6 |
| **Total** | 59.04 | 113.2 | 186.2 |

# 8 Conclusion

This report documents the redesign and construction of eight high performance homes in six projects built with the assistance of NYSERDA under the High Performance Development Challenge. Project teams were tasked with improving the performance of planned projects to achieve at least a HERS score of 91 or better before the use of renewable energy. Only the Canoe Place townhome and the small rental apartment in the Lake Haven project did not achieve this goal, consistent with the difficulty of improving HERS scores in small, attached dwellings. Most of the builders involved in these homes had never before built homes to this level of energy efficiency (United Way being the exception) and so the builders and their subcontractors had to surmount significant learning curves. The homes included a wide range of types, sizes and price points typical of new construction in New York State; both single and two-family homes; detached and attached.

The energy consumption of each home was predicted before and after the design upgrades using simulation software. Actual energy consumption was tracked for one year following occupancy. In four of the six homes, monitored energy consumption was lower than predicted and in two it was higher. Discrepancies between modeled and actual energy consumption were significant in some cases and are attributed in large part to occupancy and behavioral effects.

The costs of the energy upgrades were recorded. They ranged from a low of $8,197 for the NuVision house to a high of $30,361 for the two-family Lake Haven project. Upgrade costs are highly dependent on original design specifications. In some cases (e.g. the Stephens project) the original home design exceeded code requirements and reached Energy Star levels. The average upgrade cost per housing unit (averaging over the eight living units in all projects) was $15,103 (Table 20). The total square footage of conditioned space among the six projects is approximately 16,000 square feet; the overall upgrade cost per square foot was $7.55.

**Table 20. Cost and area per house**

| Project | No. living units | Upgrade cost | Area (sf) |
|---|---|---|---|
| Deerfield | 1 | $ 19,482 | 2,627 |
| Canoe Place | 1 | $ 21,077 | 1955 |
| Lake Haven | 2 | $ 30,361 | 3,181 |
| Nuvision | 1 | $ 8,197 | 2038 |
| Stephens | 1 | $ 12,893 | 3982 |
| United Way | 2 | $ 28,810 | 2,211 |
| Total | 8 | $ 120,820 | 15,994 |
| Average |  | $ 15,103 | 1999 |

The average planned HERS score was 85.7 and the average final HERS score was 90.7. This converts to a 35% decrease in HERS index from 71.3 to 46.3. A summary of the changes in HERS index by house is provided in Table 21.

**Table 21. Change in HERS index**

| Project | Original design HERS index | Final HERS Index |
|---|---|---|
| Deerfield | 64 | 45 |
| Canoe Place | 77 | 51 |
| Lake Haven | 73 | 45 (owner residence) |
|  |  | 54 (rental apartment) |
| Nuvision | 70 | 44 |
| Stephens | 65 | 42 |
| United Way | 79 | 43 |
| Average | 71.3 | 46.3 |

In order to achieve this HERS Index reduction, a variety of energy efficiency measures were employed including upgraded insulation, heat recovery ventilators, air sealing, and equipment upgrades. Table 22 summarizes the most common upgrades used in the six projects.

**Table 22. Frequency of major energy measures**

| Strategy/material | Number of projects (total of 6) |
|---|---|
| Spray foam insulation | 4 |
| Exterior rigid wall insulation | 5 |
| Increased space conditioning equipment efficiency | 6 |
| Tankless water heater | 4 |
| Increased ceiling insulation | 6 |
| HRV/ERV added | 6 |

At the conclusion of the one-year monitoring period, an interview was conducted with a resident of each project. In most cases, the homeowner was interviewed. The complete results of each interview are included in the appendices. Some highlights of the survey findings include:

- All homeowners agreed that “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.”
- All except one homeowner agreed that “Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.”
- Three of the five1 homeowners agree that “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. “
- All homeowners agreed that “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.”

A number of lessons can be drawn and/or reinforced from the experiences with these six projects that affect the construction of high performance homes. The lessons fall into two broad categories: 1) technical lessons relating to construction, and 2) market-related lessons relating to homebuyer interest in performance and reaction to the benefits of high performing homes. Both of these types of lessons can benefit other builders as they embark on building similarly high performance homes.

Some technical lessons from the project are:

- Air sealing was the most challenging aspect of construction. Most builders did not hire a specialist air sealing contractor but rather attempted to achieve the air tightness goals with in-house staff and/or existing insulation contractors advised by TLP staff. Air sealing results were generally similar, ranging from 2 to 3

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[1] The residents of the United Way house were not owners, nor were they responsible for the utility bills.

across all projects with the exception of the townhome project with one large adiabatic wall. No correlation is observed between air sealing results and insulation type. In general the most difficult area to airseal was at the ceiling-attic interface. All projects attempted to airseal this area by caulking the top plates to the ceiling drywall (which the exception of the rehabbed portion of the United Way project), with moderately successful results. More thorough attention to this interface, perhaps with the use of targeted spray foam would achieve better results. Alternatively, a sealed attic with the air barrier at the roof plane may have been superior.

**Table 23. Air tightness results**

| Project | ACH50 | Air sealing specialist? | walls insulation | roof insulation | Note |
|---|---|---|---|---|---|
| Deerfield | 2.7 | yes | Rock wool | Rock wool | |
| Canoe Place* | 1.5 | no | spray foam | fiberglass | End unit townhome; leakage to outside only |
| Lake Haven | 2.62 | no | spray foam | fiberglass and spray foam | |
| Nuvision | 2.13 | no | Blown in fiberglass | Loose fill fiberglass | |
| Stephens | 2.3 | no | SIPs | fiberglass | |
| United Way | 3 | no | spray foam | Spray foam & fiberglass | Gut rehab |
| Average | 2.38 | | | | |

- As performance requirements increase, the importance of more precisely coordinating trades becomes greater. The builder must ensure that trades (plumbers, HVAC, electricians, painters, etc.) work together so they achieve maximum performance and do not compromise each other.
- Planning also becomes more important and an integrated design approach becomes more beneficial. The designer must consider the interactive effects of the building envelope, ventilation needs, space conditioning, solar exposure and other factors in tandem. No longer can these aspects of the home be specified in isolation.
- Occupancy and behavior effects can override the impact of a more efficient building.
- Homes can be substantially improved in energy efficiency with little or no outward change in appearance – for better or for worse.
- Improved thermal envelope did allow some reduction space conditioning equipment sizes and cost, but not significant enough to have a large cost impact. Three projects were able to reduce cooling equipment sizes by one half to one ton. Two projects were able to reduce space conditioning equipment costs to offset other

upgrades: Deerfield by $1,762 and United Way by $2,000. With greater confidence in the lower loads, builders could have gained some additional savings here.

- Home operation can unknowingly have an impact on energy and comfort and potentially durability – witness the air handlers on constant fan mode in two of the six homes. In a misguided attempt to improve comfort, or perhaps without intent, this increased energy use and humidity.

Some market-based lessons from the project are:

- Many home shoppers are not enticed by energy efficiency. This was the experience of the Lake Haven builder when trying to sell the home. Perhaps the high cost of housing in New York City makes energy costs less relevant.
- Energy performance is highly subjective; a homeowner's perception of the efficiency of their home may not match up to standard measures. This highlights the importance of benchmarking for educational purposes.
- A quiet indoor environment and fresh air were two of the biggest benefits perceived by occupants. Both of these are things that can be sensed in the home and contribute to environmental comfort.

# Appendix A

## NYSERDA High Performance Development Challenge Energy Monitoring Report – Deerfield Homes

The participating home is a single family detached home in Ridge, NY. The house was completed and occupied in April 2010. It is occupied by a couple with two young children, one a baby that was born during the course of the monitoring year.

**Figure A1: The residence in Ridge, NY**

## Energy bill analysis

The monthly energy consumption and costs are shown in the utility bills in Table A1.

**Table A1. Utility bills for electricity and natural gas**

| Month | Start | End | Days | Reading type | Electric | | Natural Gas | |
|---|---|---|---|---|---|---|---|---|
| | | | | | kWh | $ | Therms | $ |
| **1 (May-Jun'10)** | 5/19/2010 | 6/17/2010 | 30 | Est. | 562 | $120 | 38 | $75 |
| **2 (Jun-Jul'10)** | 6/18/2010 | 7/17/2010 | 30 | Actual | 1412 | $300 | 12 | $32 |
| **3 (Jul-Aug'10)** | 7/17/2010 | 8/17/2010 | 31 | Est. | 825 | $177 | 35 | $71 |
| **4 (Aug-Sep'10)** | 8/17/2010 | 9/20/2010 | 34 | Actual | 2206 | $468 | 15 | $37 |
| **5 (Sep-Oct'10)** | 9/20/2010 | 10/18/2010 | 28 | Est. | 956 | $195 | 59 | $95 |
| **6 (Oct-Nov'10)** | 10/18/2010 | 11/18/2010 | 31 | Actual | 1135 | $224 | 32 | $64 |
| **7 (Nov-Dec'10)** | 11/18/2010 | 12/16/2010 | 28 | Est. | 965 | $191 | 213 | $268 |
| **8 (Dec'10-Jan'11)** | 12/16/2010 | 1/24/2011 | 39 | Est. | 1344 | $259 | 390 | $592 |
| **9 (Jan-Feb'11)** | 1/24/2011 | 2/15/2011 | 22 | Est. | 758 | $144 | | |
| **10 (Feb-Mar'11)** | 2/15/2011 | 3/22/2011 | 35 | Actual | 611 | $123 | | |
| **11 (Mar-Apr'11)** | 3/23/2011 | 4/19/2011 | 27 | Est. | 506 | $101 | 89 | $139 |
| **12 (Apr-May'11)** | 4/18/2011 | 5/17/2011 | 29 | Actual | 711 | $137 | 45 | $93 |

Heating season, cooling season, and baseload calculations are shown in Table A2 and Table A3.

### Table A2. Heating, cooling, and baseload calculations

| Heating Energy Expenditure | | | | |
|---|---|---|---|---|
| **Normalized Baseline Energy Expenditure** | 0.801 | Therms/day | 0.080 | MMBtu/day |
| **Energy Expenditure in Heating Season** | 828 | Therms | 82.8 | MMBtu |
| **Days in Heating Season** | 239 | days | 239 | days |
| **Baseline Energy Expenditure in Heating Season** | 192 | Therms | 19.2 | MMBtu |
| **Total Heating Energy Expenditure** | 636 | Therms | 63.6 | MMBtu |
| **REM/Rate Estimated Expenditure** | | | 46.00 | MMBtu |
| **Difference from Estimated** | | | 138% | |

### Table A3. Heating, cooling, and baseload calculations

| Cooling Energy Expenditure | | | | |
|---|---|---|---|---|
| **Normalized Baseline Energy Expenditure** | 22 | kWh/day | 0.074 | MMBtu/day |
| **Energy Expenditure in Cooling Season** | 7096 | kWh | 24.22 | MMBtu |
| **Days in Cooling Season** | 184 | days | 184 | days |
| **Baseline Energy Expenditure in Cooling Season** | 3999 | kWh | 13.65 | MMBtu |
| **Total Cooling Energy Expenditure** | 3097 | kWh | 10.57 | MMBtu |
| **REM/Rate Estimated Expenditure** | | | 3.30 | MMBtu |
| **Difference from Estimated** | | | 320% | |

Actual energy consumption compared to REM/rate's estimated energy expenditure is summarized in Table A4.

### Table A4. Actual versus predicted energy consumption

| | Total Consumption | | | |
|---|---|---|---|---|
| | Actual | | REM/rate | |
| | kWh | MMBtu | kWh | MMBtu |
| **Heating** | 18,655 | 63.6 | 12,749 | 43.5 |
| **Cooling** | 3,098 | 10.6 | 1,026 | 3.5 |
| **Baseload** | 16,506 | 56.3 | 12,427 | 42.4 |
| **Total** | 38,259 | 130.5 | 26,202 | 89.4 |

Actual energy consumption was significantly higher for heating, cooling and baseload for this house. While some of the discrepancy may be attributed to behavioral and operational factors (see Measured Performance Data below), significant discrepancy must also be attributable to the REM/Rate model.

# Measured Performance Data

Battery powered data loggers were used to measure the parameters listed in Table A1 at hourly intervals. This report summarizes the data collected from April 8, 2010 to March 27, 2011. The house had a high efficiency boiler that provided heat via hot water baseboard on both floors as well as an indirect water heating tank. All three circulation pumps were monitored. Power consumption for the boiler system (with pumps), the air handler and the condensing unit for the two-stage cooling system were also measured. The power transducer for the condensing unit failed and did not provide any readings.

**Table A5. Monitored Points Measured at Deerfield**

| | | |
|---|---|---|
| **1** | 1st Floor Pump Runtime (hrs) | Veris Current Switch |
| **2** | 2nd Floor Pump Runtime (hrs) | Veris Current Switch |
| **3** | DHW Pump Runtime (hrs) | Veris Current Switch |
| **4** | Boiler System Power (kWh) | Ohio Semitronics SHW2100 |
| **5** | Air Handler Power (kWh) | Ohio Semitronics SHW2100 |
| **6** | Condensing Unit Power (kWh) | Ohio Semitronics SHW2100 (FAILED) |

The table and graphs below summarize the monthly power use and operating hours. The boiler and its pumps consume 700 Watts when everything is on and used more than 1600 kWh for the year measured. The air handler unit (AHU) fan power consumption was modest (less than 300 kWh) despite the fact that the fan operated in the continuous mode during the cooling season (low speed fan power was about 140 Watts; high speed fan power was 240 Watts). The fan ran at high speed for just over 300 hours of the 3,853 total run hours (8%). The operation of the DHW pump changed in November. The family added a new baby to the household at this time, which may have resulted in a change in DHW usage patterns.

**Table A6. Measured Electric Use and Operating Hours for HVAC Equipment**

| | **No of Hours** | **Boiler Electic (kWh)** | **AHU Electric (kWh)** | **1st Flr Heating (hours)** | **2nd Flr Heating (hours)** | **DHW Pump Runtime (hrs)** | **AHU Total Runtime (hrs)** | **AHU High Speed Runtime (hrs)** |
|---|---|---|---|---|---|---|---|---|
| Apr-10 | 533 | 39.4 | 1.2 | 11.6 | 13.3 | 28.0 | 31 | 0 |
| May-10 | 744 | 32.2 | 16.6 | - | - | 35.5 | 248 | 24 |
| Jun-10 | 720 | 27.6 | 51.9 | - | - | 27.0 | 718 | 62 |
| Jul-10 | 744 | 25.8 | 69.6 | - | - | 21.4 | 744 | 116 |
| Aug-10 | 744 | 27.6 | 58.9 | - | - | 24.3 | 744 | 78 |
| Sep-10 | 720 | 29.1 | 43.9 | - | - | 27.8 | 720 | 25 |
| Oct-10 | 744 | 38.5 | 15.9 | 13.2 | - | 29.2 | 392 | 2 |
| Nov-10 | 720 | 135.2 | 0.8 | 121.8 | 60.4 | 18.6 | 1 | 0 |
| Dec-10 | 744 | 330.6 | 0.8 | 423.4 | 122.7 | 6.7 | 0 | 0 |
| Jan-11 | 744 | 337.1 | 0.9 | 433.4 | 116.4 | 10.7 | 0 | 0 |
| Feb-11 | 672 | 327.5 | 0.5 | 480.3 | 39.0 | 8.3 | 0 | 0 |
| Mar-11 | 636 | 219.7 | 31.9 | 311.9 | 10.2 | 11.0 | 255 | 0 |
| Total | 8,465 | 1,570.3 | 292.9 | 1,795.6 | 362.0 | 248.5 | 3,853.0 | 307.0 |
| ***Annual*** | ***8,760*** | ***1,621.4*** | ***298.7*** | ***1,852.6*** | ***368.4*** | ***260.2*** | | |

Total gas use was 876 therms for the year. Just over 250 therms was attributable to water heating and 625 for space heating, based on pump run time measurements for DHW and space heating respectively (DHW gas use was 0.95 therms per hour of DHW pump run time).

### Table A7. Comparing Metered Gas Use to Estimated Gas Use for DHW and Space Heating

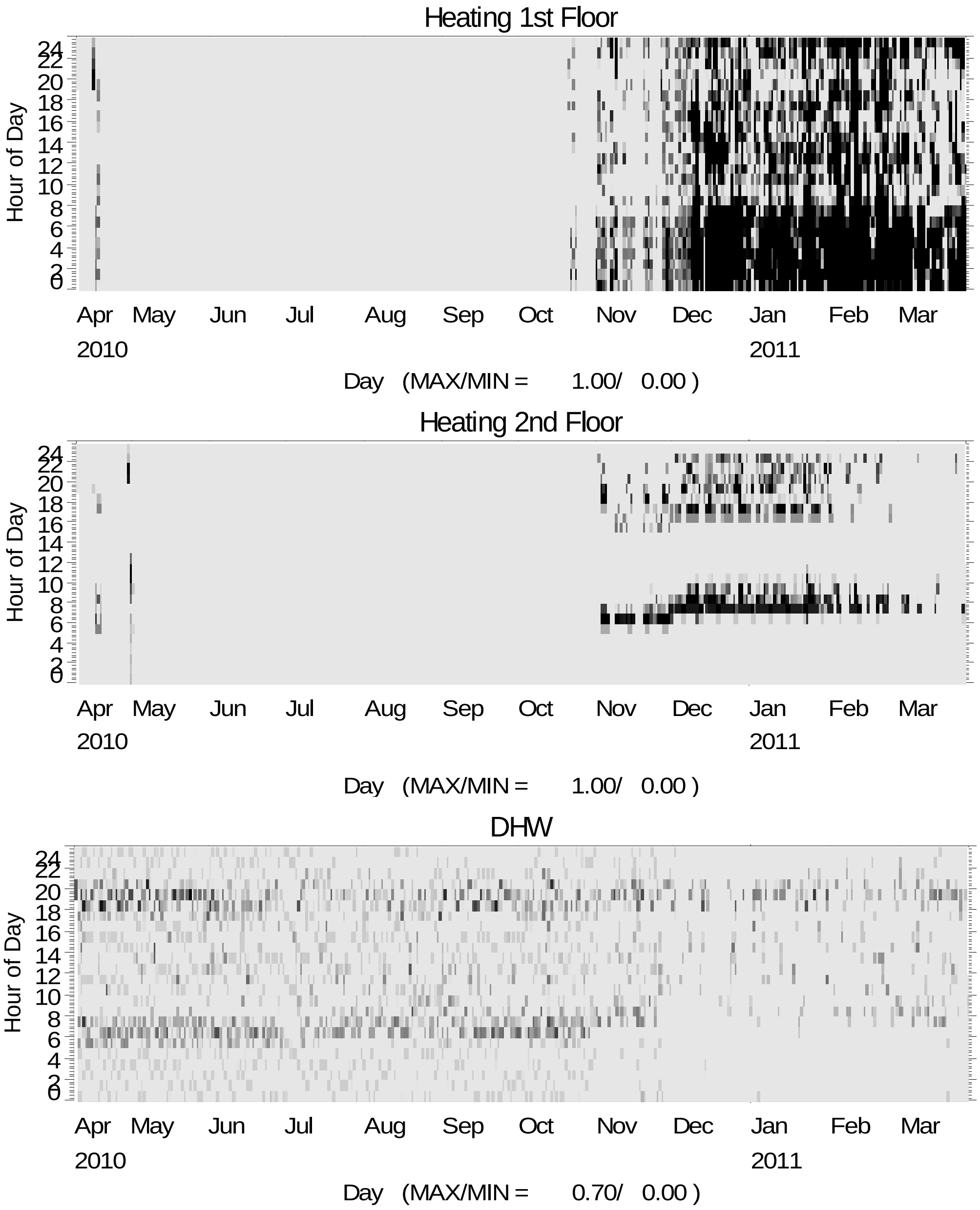
| End Date | No of Days of Metered Data | No of Days of Logged Data | Meter Gas Use (therms) | Estimated DHW Gas Use (therms) | Estimated Space Htg Gas Use (therms) |
|---|---|---|---|---|---|
| 5/18/2010 | 48 | 39.7 | 60 | 56 | 4 |
| 7/17/2010 | 60 | 60 | 50 | 50 | 0 |
| 9/20/2010 | 65 | 65 | 50 | 50 | 0 |
| 11/18/2010 | 59 | 59 | 91 | 49 | 42 |
| 3/22/2011 | 124 | 124 | 603 | 40 | 563 |
| Total | 356 | 347.7 | 854 | 244 | 610 |
| ***Annual*** | ***365*** |  | ***876*** | ***251*** | ***625*** |

A simple analysis of the total power bill with temperature implies that cooling energy use (condensing unit and fan) was about 2300 kWh for the season.

### Table A8. Comparing Metered Electric Use to Estimated Use for Boiler and AHU

| End Date | No of Days of Metered Data | No of Days of Logged Data | Metered Elecric Use (kWh) | Metered Electric Use (kWh/day) | Boiler Electric Use (kWh) | AHU Fan Electric Use (kWh) |
|---|---|---|---|---|---|---|
| 5/18/2010 | 48 | 39.7 | 899 | 18.7 | 57.7 | 4.9 |
| 7/17/2010 | 60 | 60.0 | 1,974 | 32.9 | 55.1 | 101.9 |
| 9/20/2010 | 65 | 65.0 | 3,031 | 46.6 | 58.6 | 119.6 |
| 11/18/2010 | 59 | 59.0 | 2,091 | 35.4 | 121.9 | 32.1 |
| 3/22/2011 | 124 | 124.0 | 3,678 | 29.7 | 1,226.2 | 34.4 |
| Total | 356 | 347.7 | 11,673 | 32.8 | 1,519.5 | 292.9 |
| ***Annual*** | ***365*** |  | 11,968 |  | 1,557.9 | 300.3 |
|  |  |  |  |  | 13% | 3% |

The shade plots below (Figure A2) reveal that the pump serving the second floor space heating ran considerably less than the pump serving the first floor. Some change in DHW use in later November is evident; less overnight usage and a near-cessation of morning DHW. The family added a new baby to the household at this time, which may have resulted in a change in DHW usage patterns.


Heating 1st Floor

Heating 2nd Floor

DHW

**Figure A2. Shade Plots showing Boiler Pump Operation**

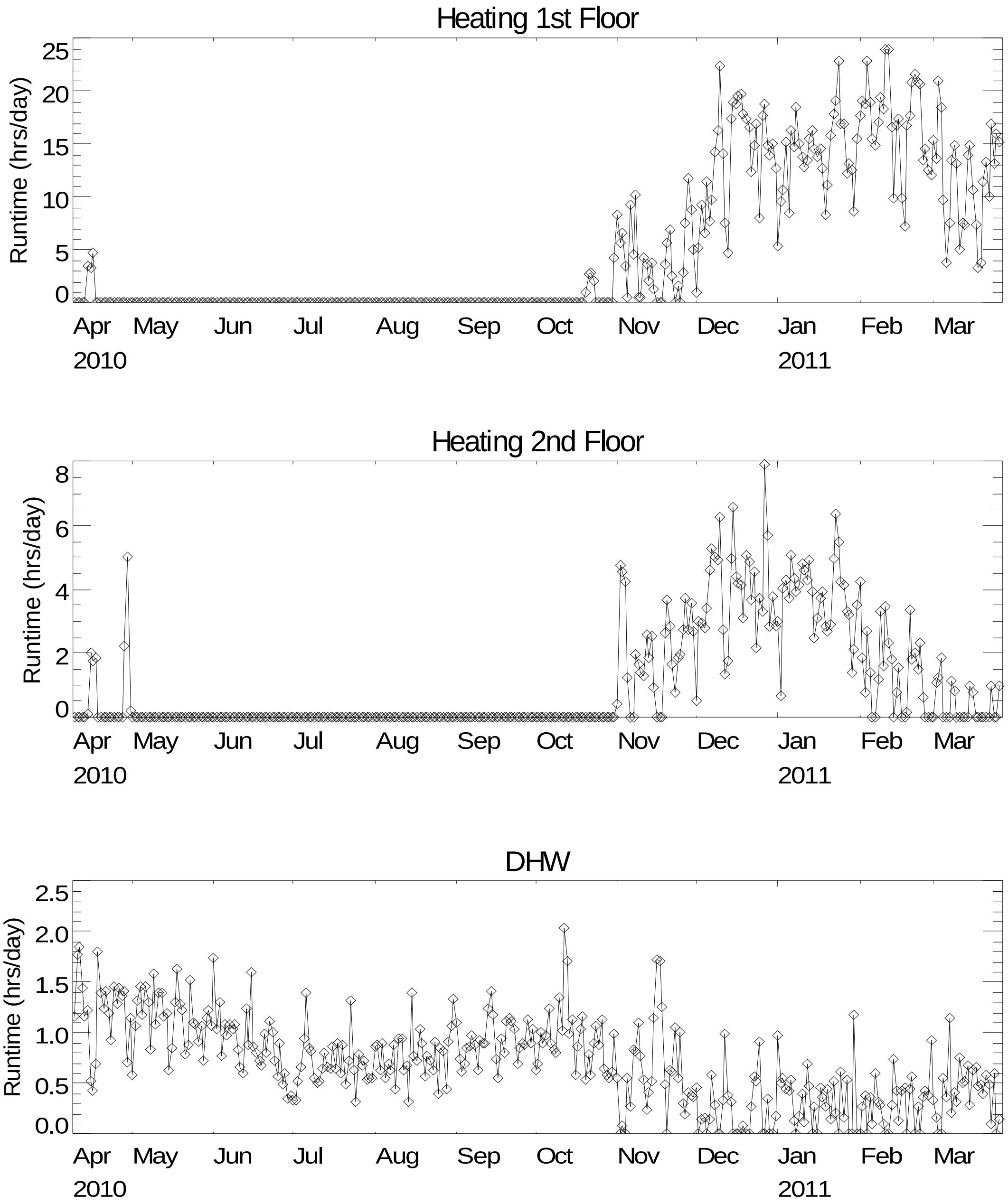


**Figure A3. Plots showing Daily Boiler Pump Operation**

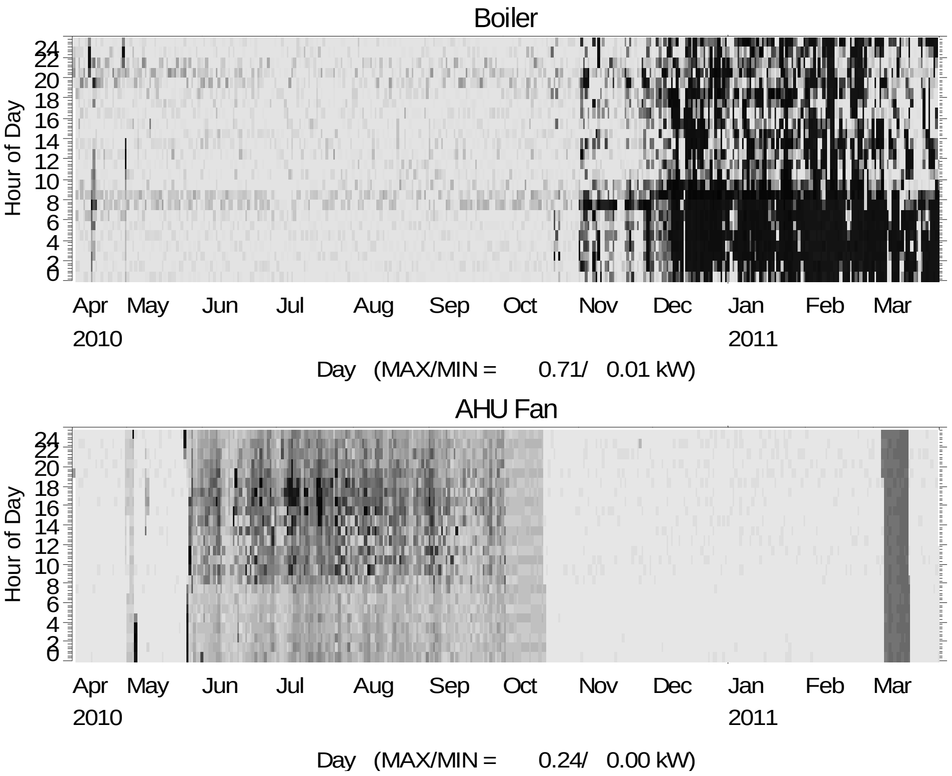


**Figure A4. Shade Plots showing Boiler and AHU Power Use**

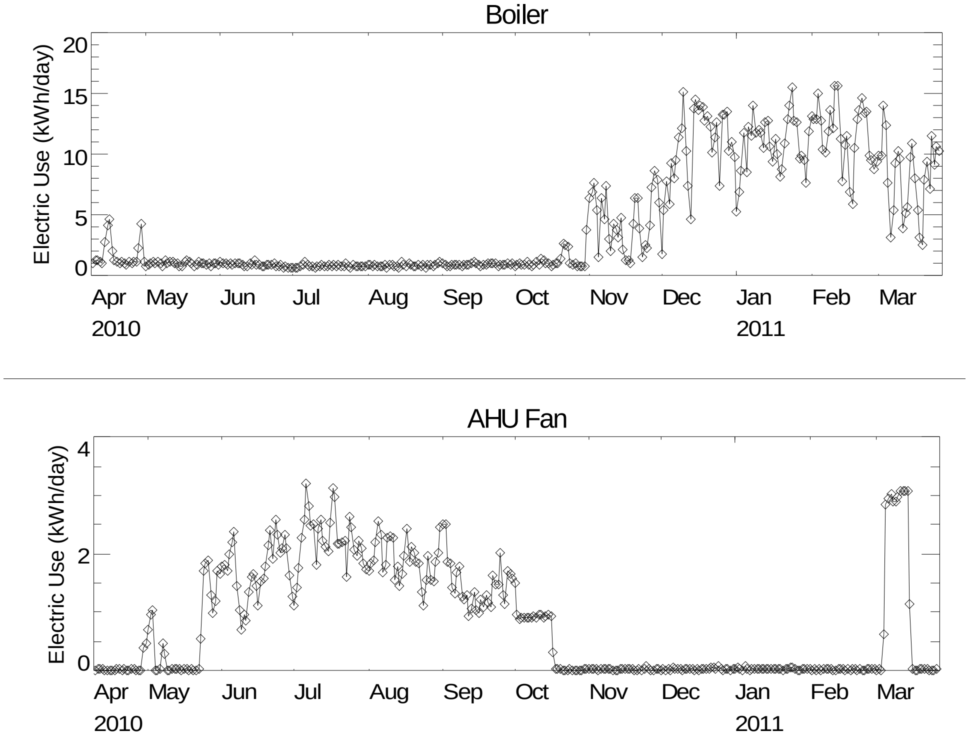


**Figure A5. Plots showing Boiler and AHU Daily Energy Use**

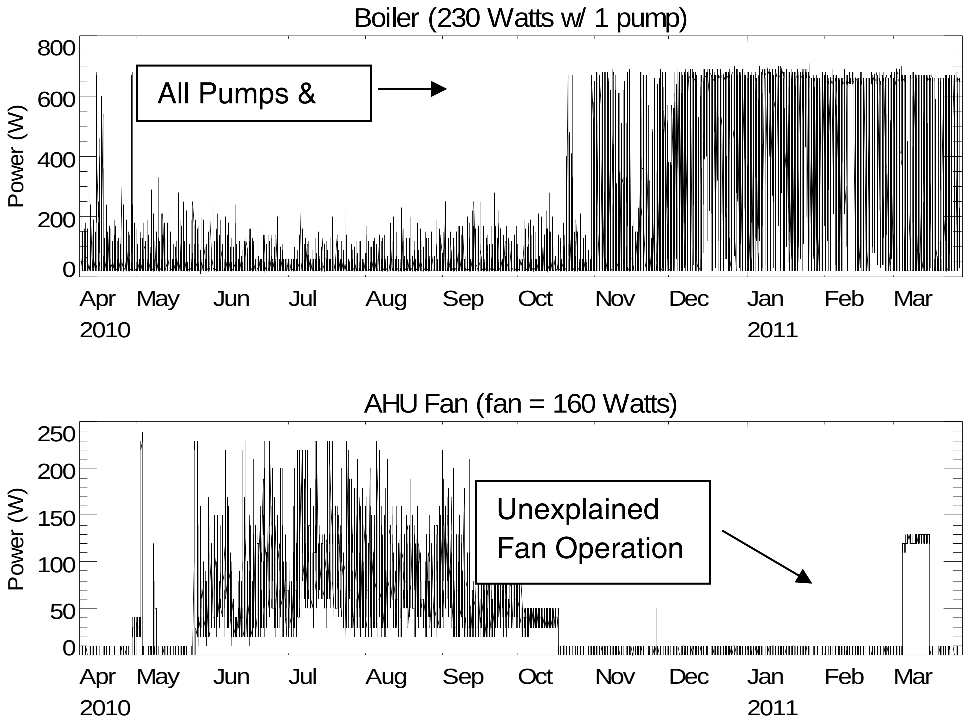


**Figure A6. Plots showing Boiler and AHU Power**

The plot below shows that the homeowner set the thermostat controls so that the fan ran continuously during the cooling season. The plot of relative humidity below confirms that constant fan operation resulted in unexpectedly high relative humidity levels in the space. This phenomenon has been thoroughly documented2 (reference) and is due to condensation on the cooling fins never getting a chance to drain out of the air handler, but rather being carried back off on the air stream to the living space. A recommendation will be provided to the homeowner to not run the air handler in constant fan mode.

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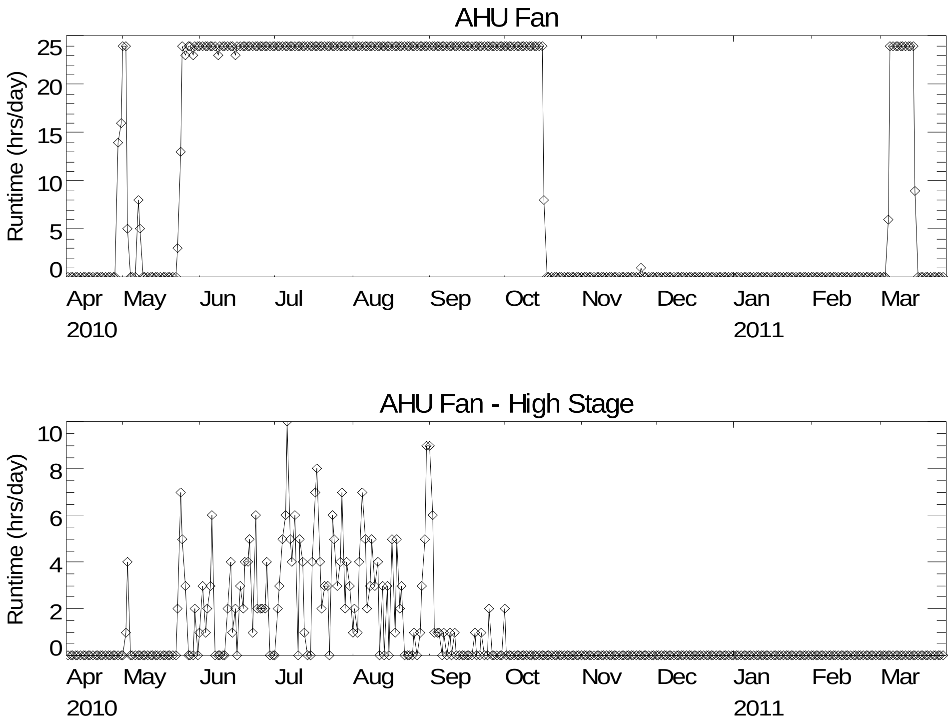
[2] Understanding the Dehumidification Performance of Air-Conditioning Equipment at Part-Load Conditions http://www.cdhenergy.com/presentations/CIBSE-ASHRAE%20Scotland%202003%20Part-Load%20Dehumidification.pdf


AHU Fan

AHU Fan - High Stage

**Figure A7. Plots showing Daily AHU Fan Operation**

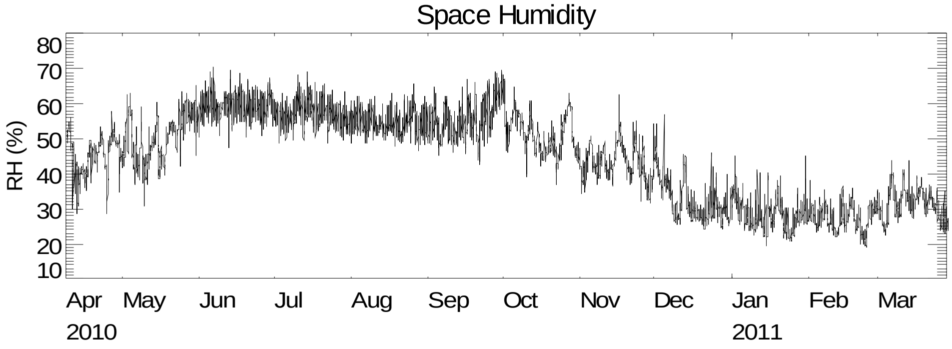

Space Humidity

**Figure A8. Plots showing Space Humidity Levels**

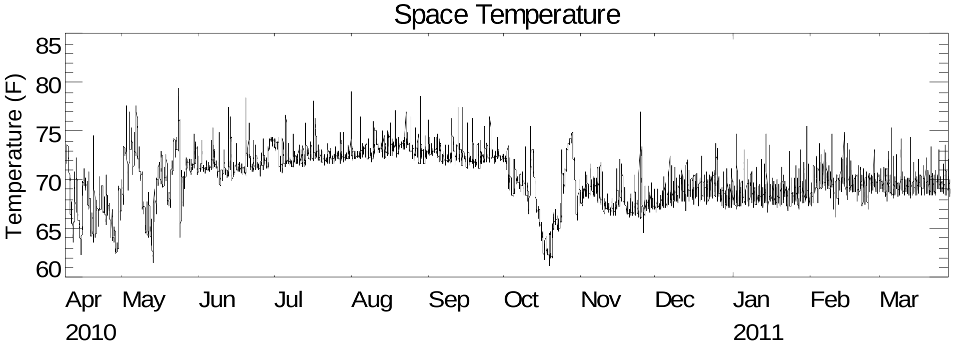

Space Temperature

**Figure A9. Plot showing Space Temperatures**

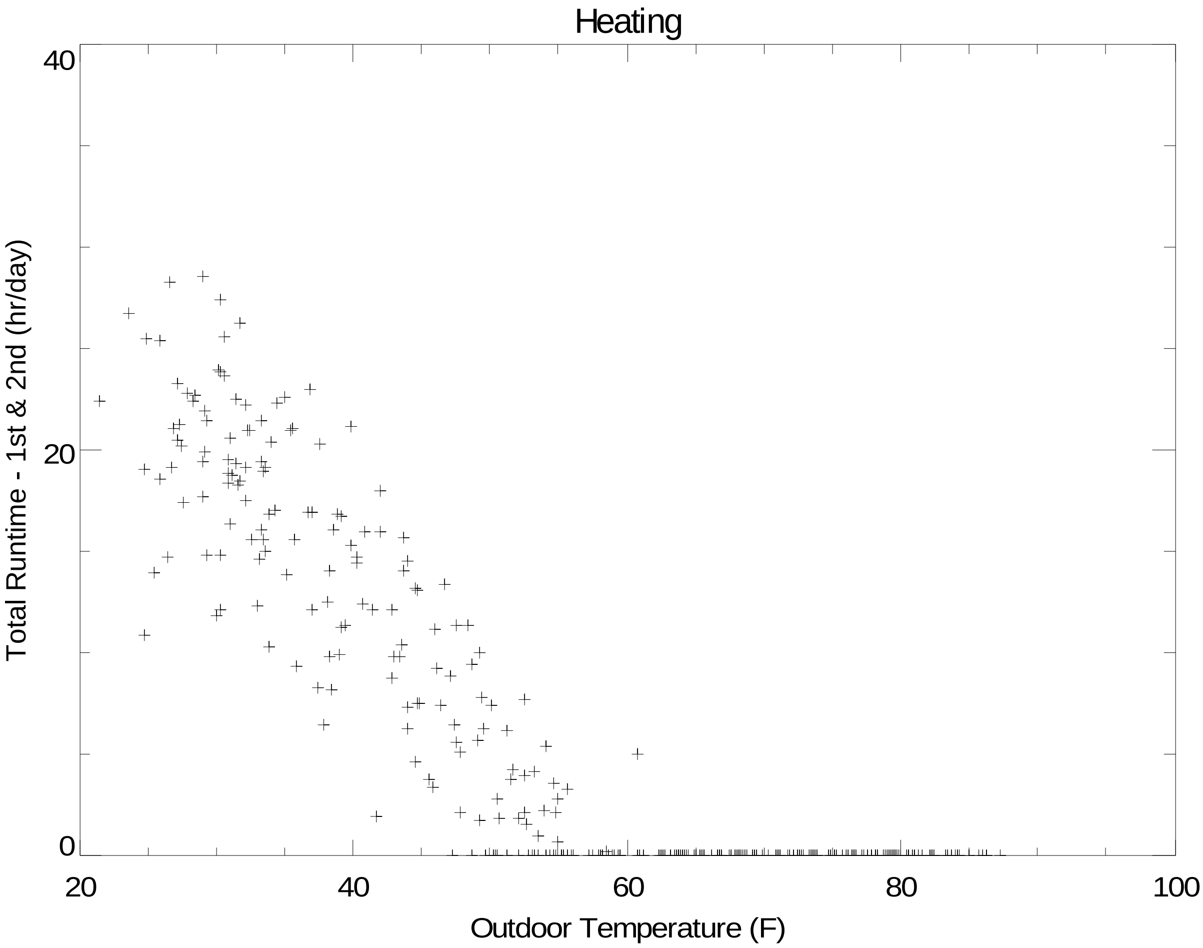
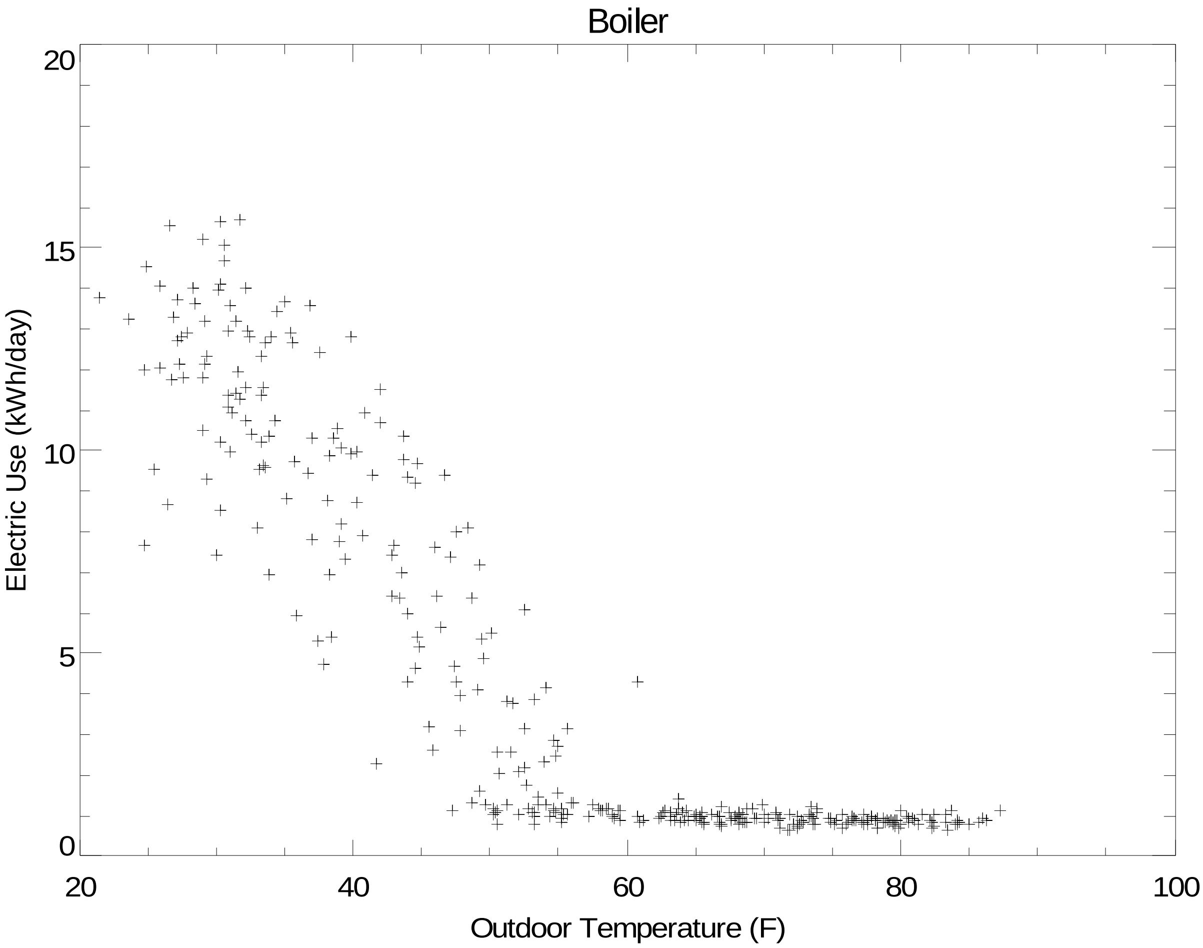


Figure A10. Plot showing Daily Runtime of Both Spacing Heating Pumps vs. Daily Outdoor Temperature



**FigureA11. Plot showing Daily Boiler System Power vs. Daily Outdoor Temperature**

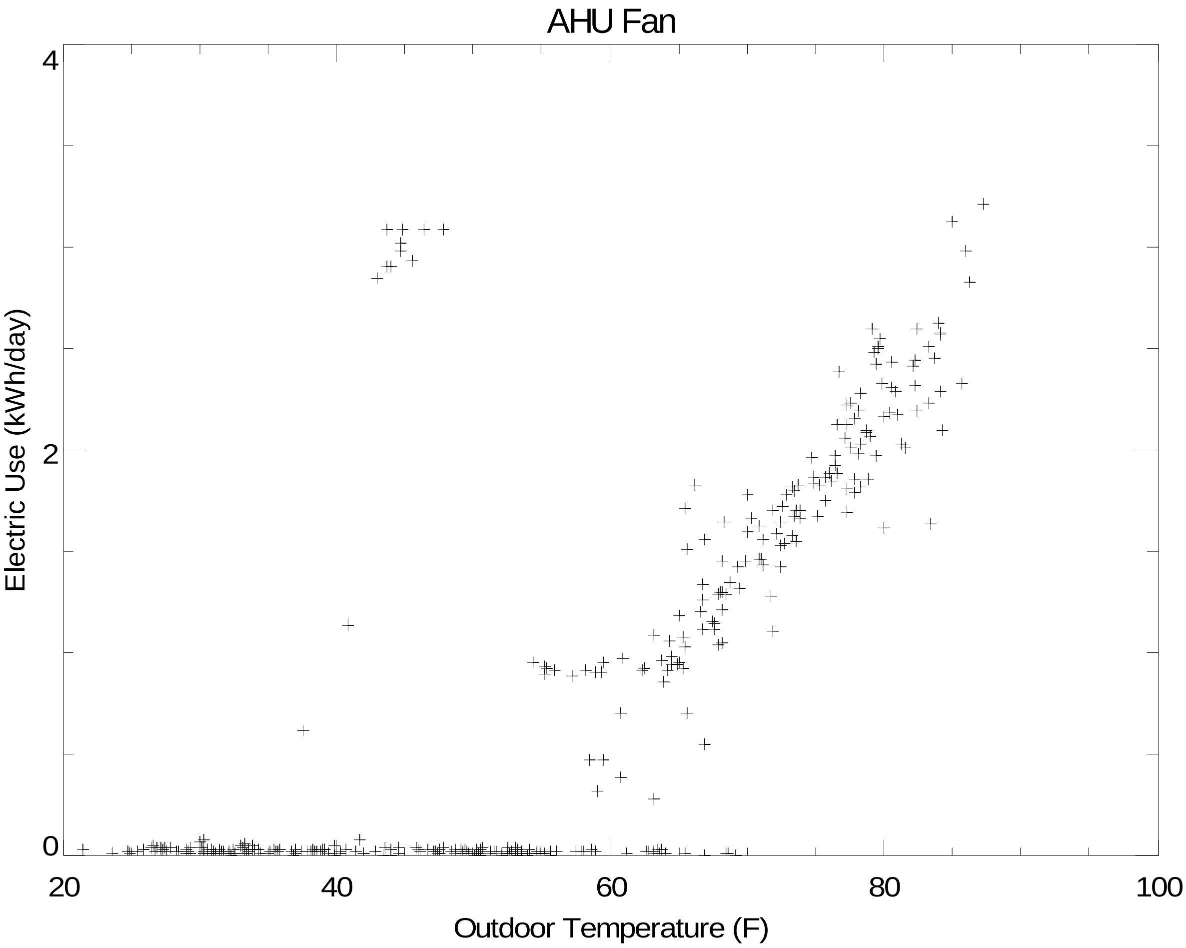


**Figure A12.  Plot showing Daily AHU Fan Power vs. Daily Outdoor Temperature**

# Occupant Survey

An occupant survey was conducted. Results are shown below with the responses by the homeowner in blue italics. It is interesting to note that the homeowner's perception of their energy bill is significantly lower than actual utility bills collected during the monitoring period.

**NYSERDA Challenge: Deerfield Homeowner Survey Responses**
**Interviewee: Mr. Herbst**
**Home address: 2 Miranda Court, Ridge, NY**
**Interviewer: David Podorson, The Levy Partnership, Inc.**
**Date: 8/25/11**

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

   *One*

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]

   *Old home was 900 sq ft, this is 2800 sq ft, and pay much less for utilities in this home! Only about $140/mo now.*

3. Which aspect of your home have you been most pleased with?

   - Low utility bills
   - Good indoor air quality
   - Very durable

   *Everything's been great: utility savings, construction, comfort. Gas bill has been the biggest savings. Only caveat is that they run out of hot water sometimes – the tank could be bigger.*

*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]

   *Great, no drafts at all*

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]

   *Great, home keeps all the cool in, turns off after he leaves in the morning, and is still cool when he gets home in the evening.*

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

*Works fine, but tank could be bigger.*

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]

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]

*Great, live right next to road, and don't hear any road noise.*

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]

*Great, 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]

*Didn't believe all the hype/talk about energy efficiency when purchased the house. Winter came, and had a few estimated gas readings. Then he learned to read it himself, and saw how much greater the estimates were from the actual usage. Had hardly any gas bills to pay for the remaining of the year.*

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]

*They said a lot, but he didn't believe it would perform so well.*

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

Everything is good, no preference, and bills are very low. DHW tank could be bigger though.

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

*In the beginning (within first month or two), the thermal expansion tank attached to the boiler had to be replaced. Also, they didn't know how to operate the boiler at first; they could have used some more instruction on that.*

*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

*Absolutely, exceeded all his expectations!*

# Appendix B

## NYSERDA High Performance Development Challenge Energy Monitoring Report – Domus Homes

The participating home is a single family detached home in Hampton Bays, NY. The house was completed and occupied in November 2011. It is occupied by one person full time.

Figure B1: The residence in Hampton Bays, NY; the unit is on the left

## Energy bills

The monthly energy consumption and costs from utility bills are shown in Table B1 and Table B2. Estimated bills have been omitted and the results combined to show only utility confirmed consumption.

**Table B1. Utility bills for natural gas**

| Month | Start | End | Days | Reading type | Natural Gas | | |
|---|---|---|---|---|---|---|---|
| | | | | | Therms | Cost | Therms/day |
| **1,2** | 11/3/2010 | 1/4/2011 | 62 | Actual | 134 | $229.86 | 2.16 |
| **3,4** | 1/4/2011 | 3/3/2011 | 58 | Actual | 163 | $275.03 | 2.81 |
| **5,6** | 3/4/2011 | 5/5/2011 | 62 | Actual | 89 | $175.76 | 1.44 |
| **7,8** | 5/5/2011 | 7/6/2011 | 62 | Actual | 14 | $52.16 | 0.23 |
| **9,10** | 7/6/2011 | 9/7/2011 | 63 | Actual | 7 | $41.88 | 0.11 |
| **11,12** | 9/7/2011 | 11/3/2011 | 57 | Actual | 35 | $82.04 | 0.61 |
| **1-12** | **11/3/2010** | **11/3/2011** | **364** | **Actual** | **442** | **$856.73** | **1.21** |

**Table B2. Utility bills for electricity**

| Month | Start | End | Days | Reading type | Electricity | | |
|---|---|---|---|---|---|---|---|
| | | | | | kWh | Cost | kWh/day |
| **1,2** | 11/3/2010 | 1/4/2011 | 62 | Actual | 711 | $151.25 | 11.47 |
| **3,4** | 1/4/2011 | 3/3/2011 | 58 | Actual | 632 | $130.34 | 10.90 |
| **5,6** | 3/3/2011 | 5/5/2011 | 63 | Actual | 539 | $119.80 | 8.56 |
| **7,8** | 5/5/2011 | 7/6/2011 | 62 | Actual | 575 | $125.51 | 9.27 |
| **9,10** | 7/7/2011 | 9/7/2011 | 62 | Actual | 783 | $167.40 | 12.63 |
| **11,12** | 9/7/2011 | 11/3/2011 | 57 | Actual | 521 | $114.78 | 9.14 |
| **1-12** | **11/3/2010** | **11/3/2011** | **365** | **Actual** | **3,761** | **$809.08** | **10.3** |

# Measured Performance Data

Battery powered data loggers were used to measure the parameters listed in Table B1 at hourly intervals. This report summarizes the data collected from fall 2010 to January 2012. The house had a two-stage, high efficiency Lennox 36B-045 furnace (94%) with an Energy Recovery Ventilator (ERV). Power consumption for the furnace fan and the condensing unit were measured. However, both these power transducers failed and did not provide any readings.

**Table B3. Monitored Points Measured at Domus**

| Logger | Description | Sensor | Collection period |
|---|---|---|---|
| **1-1** | Furnace Stage 1 Runtime (hrs)<br>(Orange wire – gas valve) | Veris CT | Nov 23,2010 – Nov 10, 2011 |
| **1-2** | Furnace Stage 2 Runtime (hrs)<br>(Brown wire – gas valve) | Veris CT | |
| **1-3** | Furnace Fan Power (kWh) | Ohio Semitronics SHW2100 (sensor FAILED) | |
| **2-1** | ERV Fan Runtime | Veris CT | Nov 22, 2010 – Jan 31, 2012 |
| **2-2** | Condensing Unit Power (kWh) | Ohio Semitronics SHW2100 (sensor FAILED) | |
| **HOBO** | Living Space Temperature and RH | HOBO T/RH (15-min data) | Aug 30, 2010 – Jan 31, 2012 |

One time power measurements were taken on the unit with a Fluke 39 Power Meter.

**Table B4. One-Time Power Readings**

| System | One-Time Power Reading |
|---|---|
| **Furnace Fan - Hi Speed Fan** | 370 Watts |
| **ERV Normal Mode**<br>**Boost Mode** | 144 Watts<br>176 Watts |

The table and graphs below summarize the monthly gas use and operating hours. The high stage and low stage gas furnace runtimes are nearly identical (see Figure B4). The high stage runtime is slightly lower than the low stage, implying that it comes on slightly after the low stage. This would be consistent with a single stage thermostat being used rather than a two-stage thermostat. A single-stage thermostat may have been used because it was the only choice for controlling the two-zone dampered distribution system. Use of a single stage thermostat would have little effect on energy consumption, but could theoretically impact comfort. The ERV ran nearly continuously across the monitoring period.

**Table B5. Summary of Gas Use, Temperatures and Runtimes**

| Period | No of Days | Average Outdoor Temp (F) | Gas Use (therms) | Stg 1 Heat (hrs) | Stg 2 Heat (hrs) | ERV Runtime (%) |
|---|---|---|---|---|---|---|
| **11/2/2010 - 1/4/2011** | 62 | 39.8 | 134 | 198.8 | 183.5 | 82% |
| **1/4/2011 - 3/3/2011** | 58 | 32.0 | 163 | 323.1 | 299.4 | 100% |
| **3/3/2011 - 5/5/2011** | 62 | 47.7 | 89 | 167.8 | 154.2 | 100% |
| **5/5/2011 - 7/6/2011** | 62 | 64.6 | 14 | 8.1 | 7.5 | 100% |
| **7/6/2011 - 9/7/2011** | 63 | 74.1 | 7 | 0 | 0 | 97% |
| **9/7/2011 - 11/3/2011** | 57 | 61.4 | 35 | 36.6 | 34.1 | 100% |
|  | 364 | - | 442 | 734 | 679 | 97% |

Figure B2 shows the high correlation of gas use with ambient temperature. The best fit line implies the balance point is 68°F and the peak gas use (at 0°F) is 22 MBtu/h. The non-heating gas use (DHW, cooking) use is 0.11 therms/day or 40 therms per year. The implied UA of the building, calculated from the slope of the line, is 287 Btu/h-°F. Figure B3 shows a similar linear trend with stage 1 gas valve runtime.

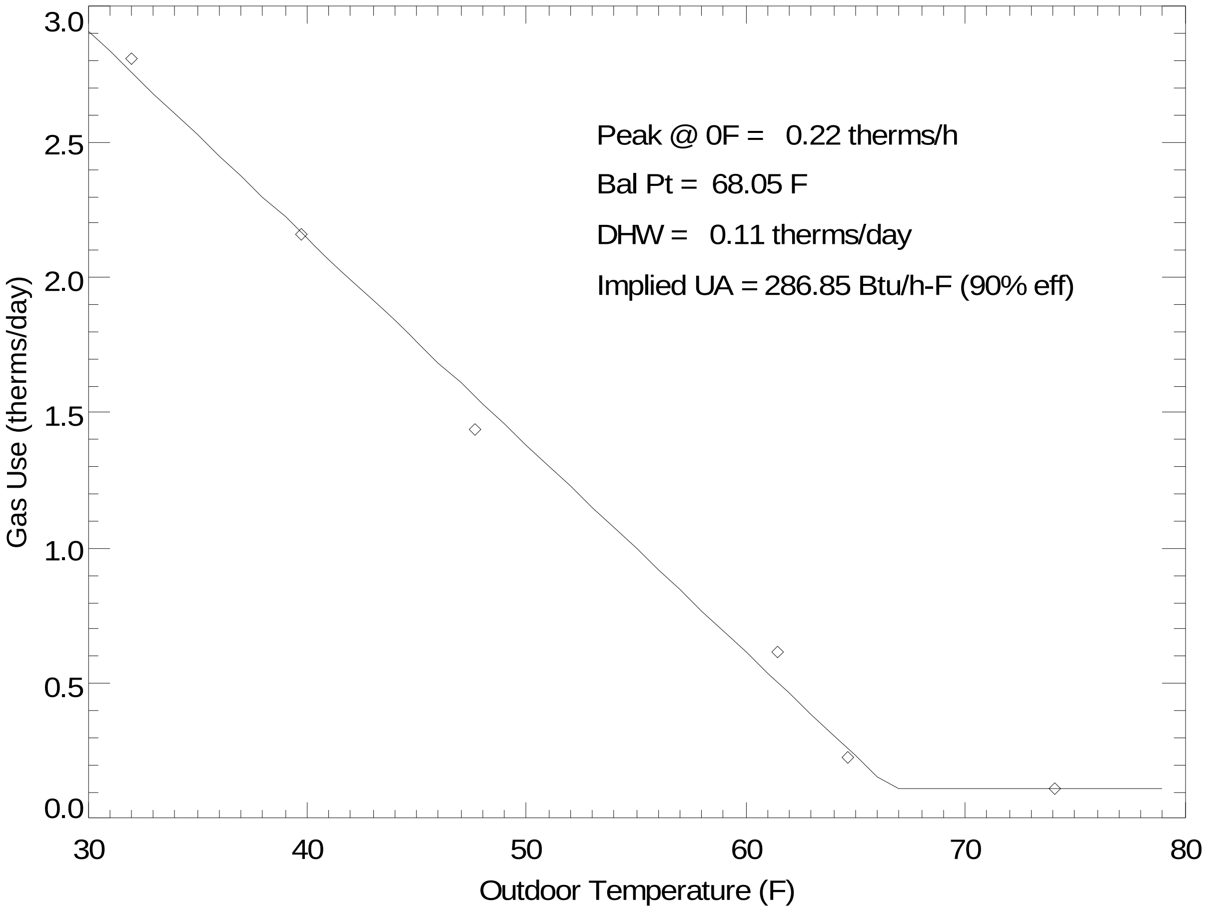


**Figure B2. Trend of Metered Gas Consumption with Ambient Temperature (from JFK)**

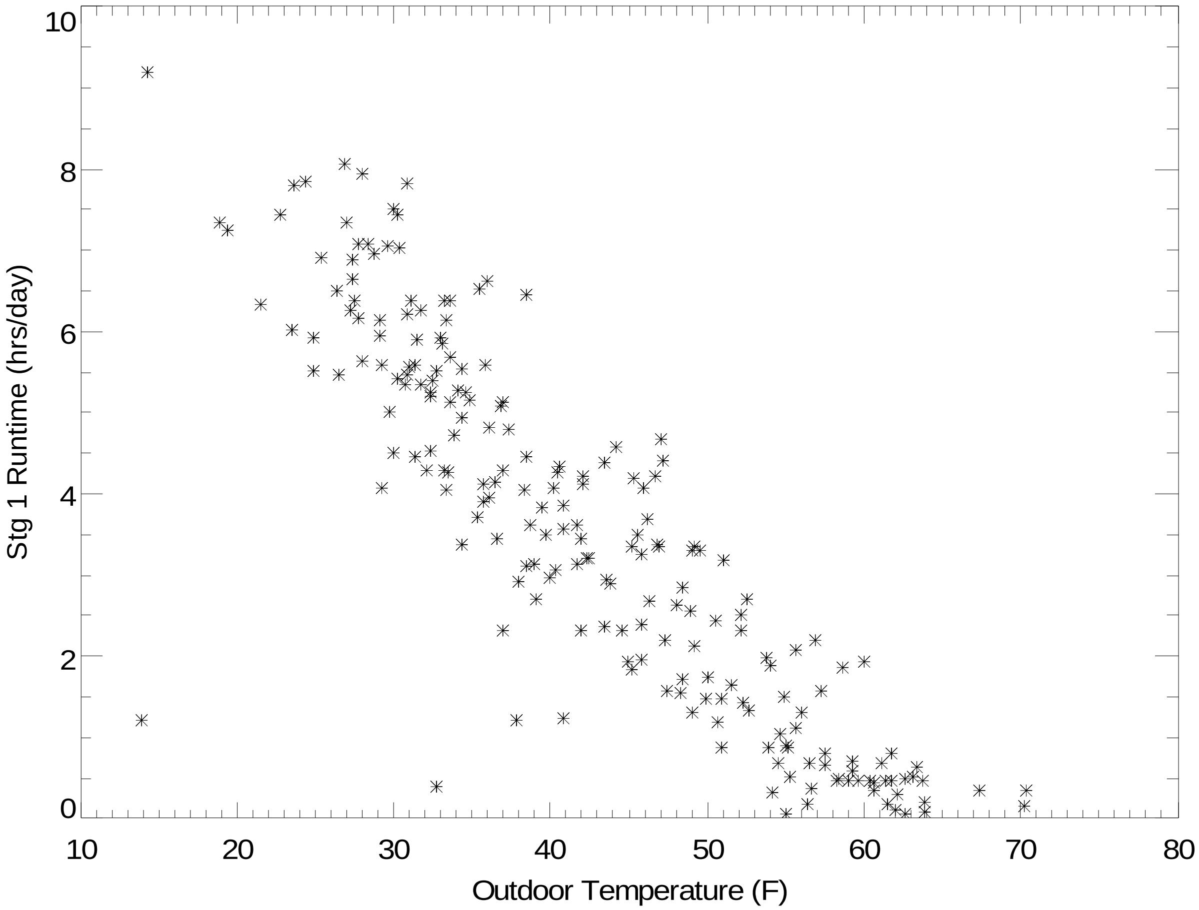


**Figure B3. Trend of Gas Furnace Runtime (Stage 1) with Ambient Temperature (from JFK)**

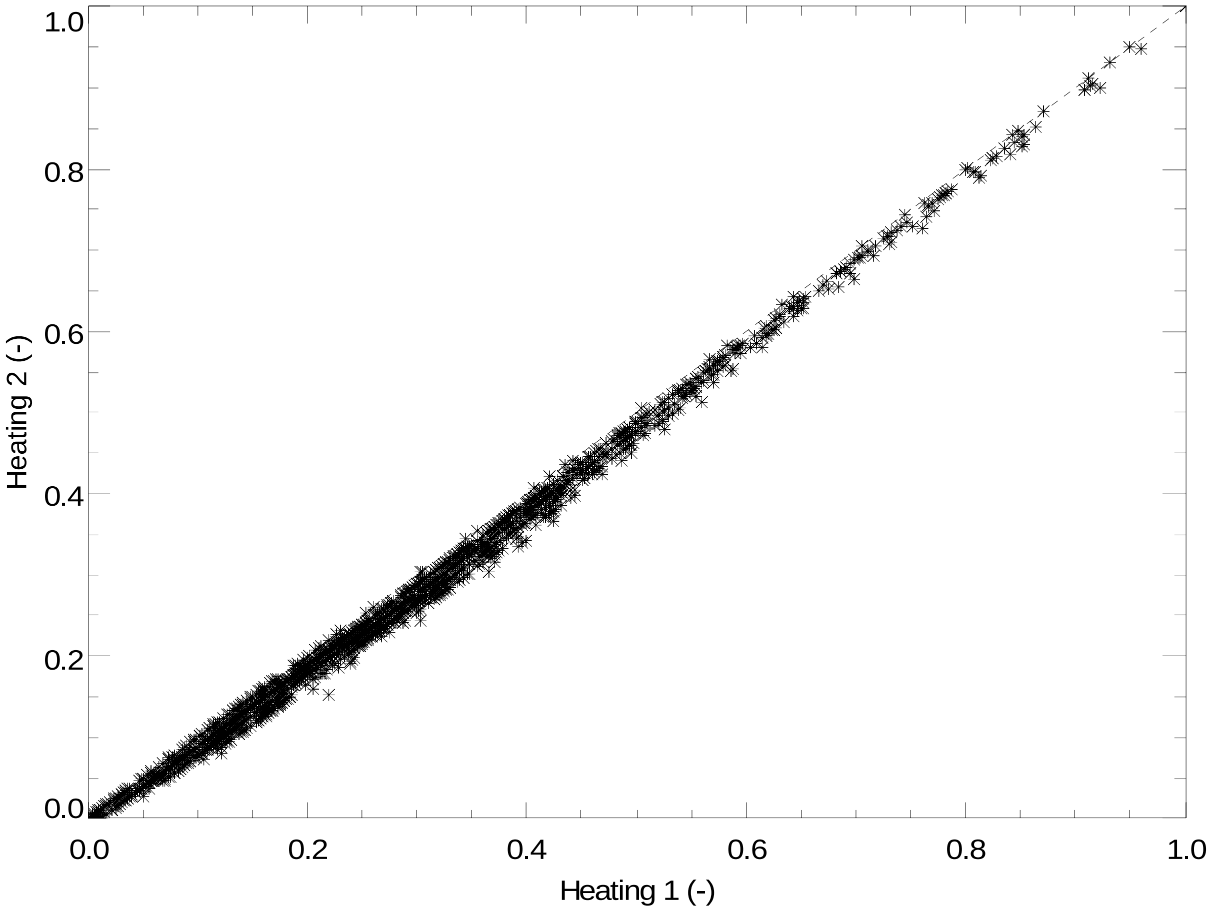


**Figure B4. Comparison of Stage 1 and Stage 2 Furnace Runtimes**

The space conditions in the home over the monitoring period are shown in Figure B5. The thermostat appears to be set to about 60-65°F in the winter. Temperatures float up to 80°F in the summer at times. The sensor was located on the first floor. Bedrooms are on the second floor. The home is divided into two space conditioning zones by floor. The resident reported that they regularly set back the thermostat for the unoccupied zone. The wide daily fluctuations in temperature seen in Figure B5 are consistent with such frequent setbacks.

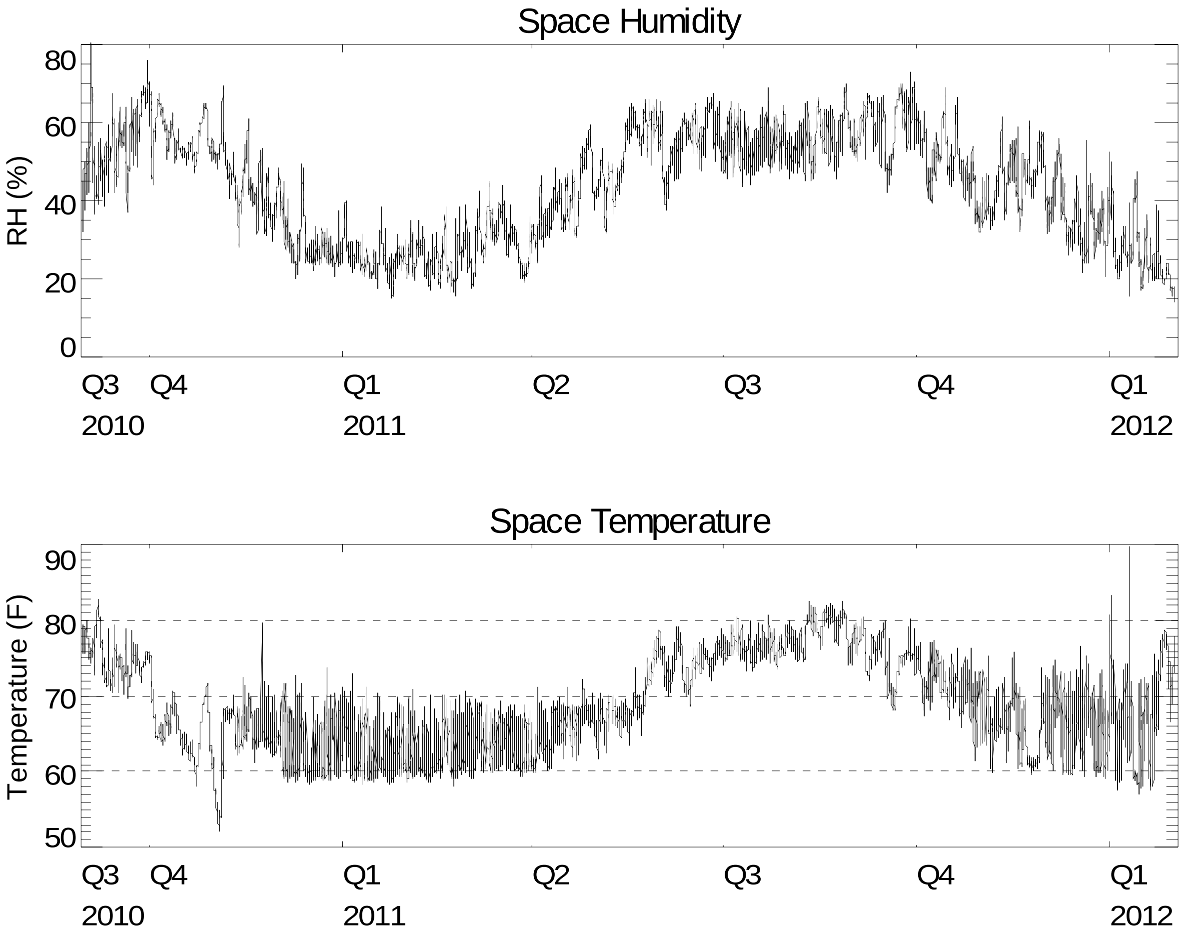


**Figure B5. Living Space Humidity and Temperatures for Monitoring Period**

Living space temperature and humidity are plotted on a psychrometric chart in Figure 6B. Again here, the temperature variation is consistent with the reported setbacks. Note that the relative humidity exceeded 60% for many hours of the year. The home is located near the water.

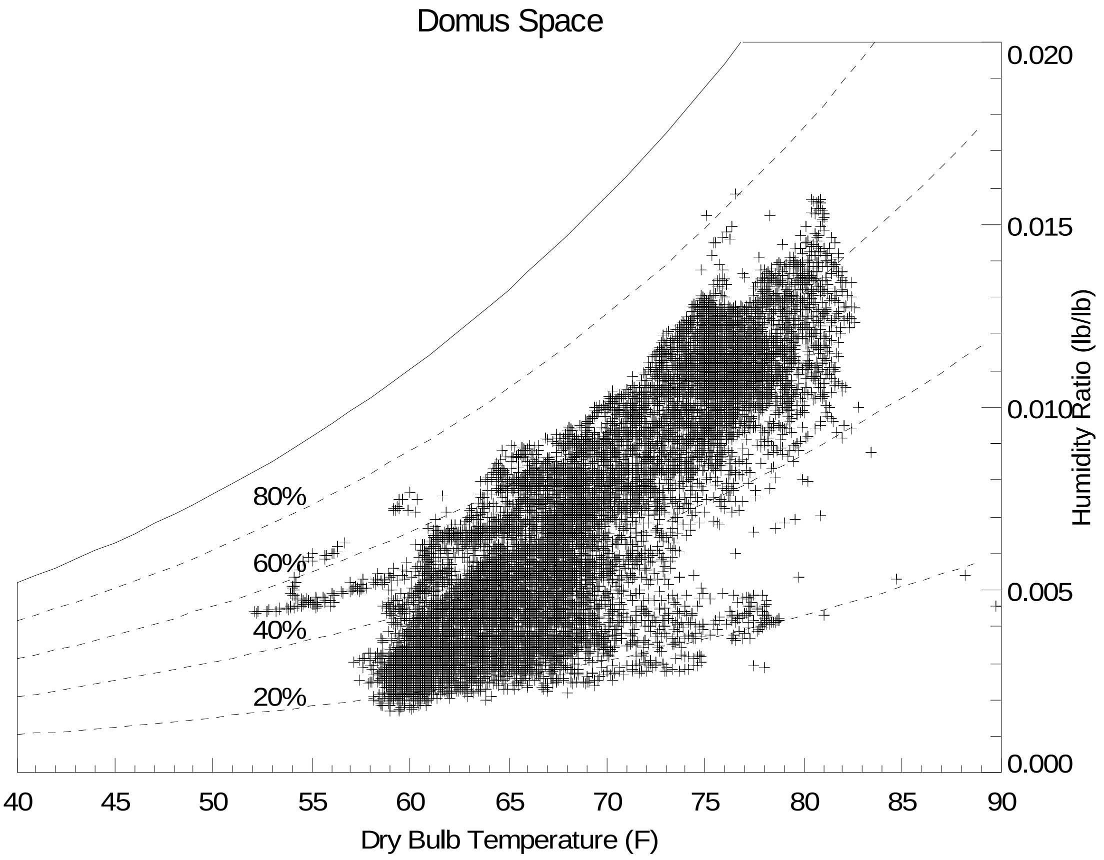


**Figure B6. Living Space Humidity and Temperatures on Psychrometric Chart**

# Cooling Energy Estimate

For electricity, baseload (non-cooling) energy consumption was determined by averaging the electricity during March-April 2011 and September-October 2011. Cooling energy use was determined by subtracting the electric baseload from the summer electricity consumption. Daily baseload energy consumption was calculated by dividing the total energy consumption during the baseload period by the duration of the baseload period (in days). Calculations are shown in Table B6 along with a comparison to the original REM/Rate projections.

**Table B6. Cooling and electricity baseload calculations**

| Row | | # days | # kWh |
|---|---|---|---|
| 1 | **Non-cooling period (mos 5,6,11,12) total use** | 120 | 1,060 |
| 2 | **Electric baseload per day** | 1 | 8.83 |
| 3 | **Cooling period (mos 7-10) total use** | 124 | 1,358 |
| 4 | **Electric baseload for cooling months** | 124 | 1,095 |
| 5 | **Cooling period cooling use (row 3-4)** | 124 | 263 |
| 6 | **REM/Rate estimated cooling energy expenditure** | | 724 |
| 7 | **Difference from estimated** | | -64% |

# Comparison of Modeled vs. Measured Energy Use

Actual measured consumption compared to REM/Rate's estimated energy expenditure is summarized in Table B7.

**Table B7. Actual versus predicted energy consumption**

| | REM/Rate | Utility bill analysis | Difference |
|---|---|---|---|
| | MBtu | MBtu | Bills compared to model |
| **Heating gas** | 36,300 | 40,196 | +11% |
| **Baseload gas** | 17,900 (10,500 DHW) | 4,004 | -78% |
| **Total gas** | 54,200 | 44,200 | -18% |
| **Cooling electric** | 2,500 | 947 | -62% |
| **Baseload electric** | 13,700 | 11,030 | -19% |
| **Total electric** | 16,200 | 11,977 | -26% |
| **Total** | 70,400 | 56,177 | -20% |

The bill analysis heating gas consumption was 11% higher compared to the model, despite there being 3% fewer heating degree days in the monitored winter compared to the 30 year average used by REM/Rate and despite the lower average winter set point used by the occupant as recorded by the space temperature logger. Baseload gas and total gas was substantially lower than the model, due at least in part to the lower actual occupancy (one verses the three people assumed by REM/Rate).

The bill analysis cooling energy use was more than 60% lower than the model, likely due to the judicious use of air conditioning and frequent thermostat setbacks as reported by the owner in the Occupant Survey (see below). Baseload electric was 19% lower, also affected by the lower occupancy. Overall, energy consumption was 20% lower than the REM/Rate model.

# Occupant Survey

An occupant survey was conducted. Results are shown below with the responses by the homeowner in blue italics. This is a particularly energy conscious homeowner. She reported that she regularly set back the thermostat by zone. This is borne out by the monitoring data above. Her favorite energy-related feature of the home is the high indoor air quality. She reported some technical problems with the domestic hot water.

**NYSERDA Challenge: Domus Homeowner Survey Responses**
**Interviewee: Pamela Monahan**
**Home address: 1 Canoe Place Landing, Hampton Bays, NY**
**Interviewer: Jordan Dentz, The Levy Partnership, Inc.**
**Date: 1/23/2012**

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

   *One single family home in South Hampton*

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?

   - Low utility bills
   - [✓ *Good indoor air quality*]
   - 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

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]

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

   *Defective unit, cycles off intermittently and have to reset manually. Only happens when taking baths, or sometimes in conjunction with the coffee maker.*

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

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]

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

   *Drafts come from windows.*

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

    *Would like the efficiency measures in writing for eventual re-sale.*

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

    *Ventilation, it feels clean.*

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

    *DHW and heat went out because of defective meter (set point was at 72° in winter)*

*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.

    - [✓ Agree]
    - Disagree
    - Not sure

15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

    - [✓ Agree]
    - Disagree
    - 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.

    - [✓ Agree]
    - Disagree
    - 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.

    - [✓ Agree]
    - Disagree
    - 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 in September 2010, full time.*

19. How many people on average occupied the house?

    *One*

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

    *Was vacant for about a month, from September-October 2010*

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

    *Heating was set at approximately 72° when home, 62° when out. And sometimes the vacant floor was set to 62°. Cooling was set between 69° - 72°.*

# Appendix C

## NYSERDA High Performance Design Challenge Monitoring Report – Lake Haven Homes

The participating home is a two-family detached home in Staten Island, NY. The house was completed in June 2010, but not occupied until July 2012. The owner's residence comprises the second and third floors as well as approximately 30% of the first floor. The basement is also included in the owner's portion of the home. The owner's residence is occupied by two people.

**Figure C1: 29 Haven Esplanade, Staten Island, NY**

## Energy bill analysis

Because the homeowner did not have access to the apartment utility accounts, the utility bill analysis is for the owner's residence only. The owner's residence was modeled separately. The monthly energy consumption and costs are shown in the utility bills in Table C1 and Table C2.

## Table C1. Utility bills for natural gas

| Month | Start | End | Days | Reading type | Natural Gas | |
|---|---|---|---|---|---|---|
| | | | | | Therms | $ |
| **October** | 9/25/2012 | 10/24/2012 | 29 | Actual | 13 | 32.37 |
| **November** | 10/24/2012 | 11/26/2012 | 33 | Actual | 49 | 76.46 |
| **December** | 11/26/2012 | 12/26/2012 | 30 | Actual | 56 | 89.48 |
| **January** | 12/26/2012 | 1/25/2013 | 30 | Actual | 82 | 119.29 |
| **February** | 1/25/2013 | 2/25/2013 | 31 | Actual | 91 | 120.96 |
| **March** | 2/25/2013 | 3/25/2013 | 28 | Actual | 62 | 91.41 |
| **April** | 3/25/2013 | 4/25/2013 | 31 | Actual | 29 | 58.37 |
| **May** | 4/25/2013 | 5/28/2013 | 33 | Actual | 14 | 39.22 |
| **June** | 5/28/2013 | 6/25/2013 | 28 | Actual | 8 | 28.35 |
| **July** | 6/25/2013 | 7/26/2013 | 31 | Actual | 7 | 28.35 |
| **August** | 7/26/2013 | 8/27/2013 | 32 | Actual | 8 | 29.36 |
| **September** | 8/27/2013 | 9/25/2013 | 29 | Actual | 6 | 25.34 |

## Table C2. Utility bills for electricity

| Month | Start | End | Days | Reading type | Electric | |
|---|---|---|---|---|---|---|
| | | | | | kWh | $ |
| **October** | 10/1/2012 | 10/30/2012 | 29 | Actual | 484 | 125.23 |
| **November** | 10/30/2012 | 12/3/2012 | 34 | Actual | 147 | 55.17 |
| **December** | 12/3/2012 | 1/2/2013 | 30 | Actual | 415 | 103.23 |
| **January** | 1/2/2013 | 2/1/2013 | 30 | Actual | 261 | 86.86 |
| **February** | 2/1/2013 | 3/5/2013 | 32 | Actual | 350 | 107.72 |
| **March** | 3/5/2013 | 4/3/2013 | 29 | Actual | 295 | 79.29 |
| **April** | 4/3/2013 | 5/2/2013 | 29 | Actual | 277 | 76.43 |
| **May** | 5/2/2013 | 6/3/2013 | 32 | Actual | 305 | 94.35 |
| **June** | 6/3/2013 | 7/2/2013 | 29 | Actual | 452 | 130.87 |
| **July** | 7/2/2013 | 8/1/2013 | 30 | Actual | 543 | 163.99 |
| **August** | 8/1/2013 | 8/30/2013 | 29 | Actual | 310 | 85.10 |
| **September** | 8/30/2013 | 10/1/2013 | 32 | Actual | 842 | 251.59 |

Heating season, cooling season, and baseload calculations are shown in Table C2 and Table C3. The monitoring period year was warmer in both summer (by 18.8%) and winter (by 4.5%) than the 30-year average. The heating and cooling energy derived from the utility bills were adjusted accordingly.

### Table C3. Heating calculations – Natural Gas (10/1/12 – 10/1/13)

| | HDD | Therms | MMBtu |
|---|---|---|---|
| **Energy use per day non-heating period (baseload)** | | 0.36 | 0.036 |
| **Base load energy use annual** | | 132 | 13.2 |
| **Total natural gas energy use annual** | | 425 | 42.5 |
| **Heating energy use annual** | | 293 | 29.3 |
| **Heating degree days during monitoring period** | 4564 | | |
| **Heating degree days 30-year average** | 4777 | | |
| **Adjustment based on heating degree days** | +4.5% | | |
| **Total heating energy expenditure normalized by 30-year average heating degree days** | | 306 | 30.6 |
| **REM/Rate estimated heating energy use (utilizes 30-year average weather data)** | | 377 | 37.7 |
| **Difference from estimated** | | -71 | -7.1 |

### Table C4. Cooling calculations (10/1/12 – 10/1/13)

| | CDD | kWh | MMBtu |
|---|---|---|---|
| **Energy use per day non-cooling period (baseload)** | | 9.86 | 0.034 |
| **Base load energy use annual** | | 3600 | 12.27 |
| **Total electrical energy use annual** | | 4681 | 15.96 |
| **Cooling energy use annual** | | 1081 | 3.69 |
| **Cooling degree days during monitoring period** | 1355 | | |
| **Cooling degree days 30-year average** | 1141 | | |
| **Adjustment based on cooling degree days** | -18.8% | | |
| **Total cooling energy use normalized by 30-year average heating degree days** | | 879 | 2.97 |
| **REM/Rate estimated cooling energy use (utilizes 30-year average weather data)** | | 1006 | 3.4 |
| **Difference from estimated** | | -127 | 0.43 |

Actual energy consumption compared to REM/Rate's estimated energy use is summarized in Table C4. While the home has four bedrooms, the number of bedrooms was reduced to one in the model to mimic the actual number of occupants (two) reported by the homeowner. REM/Rate estimates occupancy as number of bedrooms plus one. The number of occupants affects the internal heat gains, domestic hot water usage, lighting, appliance and plug load calculations. The REM/Rate predictions for heating, cooling and baseload energy consumption were higher than actual use by 23.2%, 14.5% and 37.8% respectively. This is consistent with the behavior reported in the occupant survey (see below) – in particular the high air conditioning set point and the judicious use of heating.

Table C5. Actual versus predicted energy consumption in MMBtu

| | Usage normalized for weather | REM/Rate | % Difference |
|---|---|---|---|
| **Heating** | 30.6 | 37.7 | +23.2% |
| **Cooling** | 2.97 | 3.4 | +14.5% |
| **Baseload** | 25.47 | 35.1 | +37.8% |
| **Total** | 59.04 | 76.2 | +29.1% |

**NYSERDA Challenge: Lake Haven Homeowner Survey Responses**
**Interviewee: Luciano Romanelli**
**Home address: 29 Haven Esplanade, Staten Island, NY**
**Interviewer: Jordan Dentz, The Levy Partnership, Inc.**
**Date: 8/5/2013**

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

   *None; previously lived in family home*

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?

   - Low utility bills
   - Good indoor air quality
   - Very durable
   - [✓ General comfort – no extremes of temperature]

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]

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

   *When the system works, it is a 2. When it does not, it is a 1.*

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

   *Takes 30-45 seconds for 2nd floor shower to get hot water.*

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

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]

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]

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]

*No expectations, similar to previous 3-bedroom apartment, so this home must be efficient because it is much larger.*

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

*I knew about the spray foam and high efficiency equipment.*

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

*Design of kitchen and open layout.*

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

*Within the first week of owning the home [summer 2012] the 2nd floor A/C stopped working –it turned out that the condensation pan was not draining. The 2nd floor A/C worked after this was corrected.*

*This summer [2013] the 1st floor A/C would not start. Replaced thermostat, unsure if it is working yet. 2nd floor A/C works better now.*

*Apt. hot water temperature too low – needed adjustment to faucet washer*

*Basement flooded once because sump was not working.*

*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.

- [✓ Agree]
- Disagree
- Not sure

15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

- Agree
- Disagree
- [✓ 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?

*Full time since July 2012. Apartment resident moved in August 2012.*

19. How many people on average occupied the house?

*Three total including the main residence and apartment*

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

*N/A*

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

*A/C was set at approximately 80° when home. Heating was used very little, mainly left it off.*

# Appendix D

## NYSERDA High Performance Development Challenge Energy Monitoring Report – Nuvision Homes

The participating home is a single family detached home in Mastic Beach, NY. The house was completed and occupied in October 2011. It is occupied by two adults and three small children full time.

The house has the following mechanical equipment:

- One two-ton Goodman SSZ16 hybrid electric heat pump (9.75 HSPF, 16 SEER) serving the bedroom zone.
- One three-ton Goodman SSZ16 hybrid electric heat pump (9.75 HSPF, 16 SEER) serving the common spaces (living, dining, kitchen, etc.).
- Each heat pump includes a 70 MBtu/h two-stage propane backup furnace (95 AFUE) that supplies heat when the outdoor temperature is too low for efficient functioning of the heat pumps.
- A heat recovery ventilator (HRV).
- A propane-fired tankless water heater (EF 0.82).

**Figure D1. The residence in Mastic Beach, NY**

## Energy bills

The monthly energy consumption and costs from utility bills are shown in Table D1 and Table D2. Estimated bills have been omitted and the results combined to show only confirmed utility consumption. Propane deliveries were sparse and the final volume was read from the tank gauge. The gallons shown in Table D1 are the amount consumed during the period indicated.

**Table D1. Propane deliveries**

| Start | End | Days | Gal | THERMS | THERMS/Day | $ |
|---|---|---|---|---|---|---|
| 5/13/2011 | 1/10/2012 | 242 | 120.0 | 109.6 | 0.5 | $343.46 |
| 1/10/2012 | 3/15/2012 | 65 | 100.9 | 92.2 | 1.4 | $306.88 |
| 3/15/2012 | 11/12/2012 | 242 | 165.0 | 150.7 | 0.6 | NA |
| **5/13/2011** | **11/12/2012** | **549** | **386.0** | **352.4** | **0.6** | **NA** |
| **Interpolated to annual consumption (-34%)**[3] | | **365** | **256.6** | **234.3** | **0.6** | **NA** |

**Table D2. Utility bills for electricity**

| Month | Start | End | Days | Reading type | KWH | $ | kWh/day |
|---|---|---|---|---|---|---|---|
| **1,2** | 10/14/2011 | 12/14/2011 | 61 | ACTUAL | 1,733 | $328.31 | 28.4 |
| **3,4** | 12/14/2011 | 2/15/2012 | 63 | ACTUAL | 2,606 | $483.74 | 41.4 |
| **5,6** | 2/15/2012 | 4/16/2012 | 61 | ACTUAL | 2,166 | $404.04 | 35.5 |
| **7,8** | 4/16/2012 | 6/14/2012 | 59 | ACTUAL | 1,455 | $275.75 | 24.7 |
| **9,10** | 6/14/2012 | 8/16/2012 | 63 | ACTUAL | 2,469 | $479.23 | 39.2 |
| **11,12** | 8/16/2012 | 10/15/2012 | 60 | ACTUAL | 1,733 | $333.99 | 28.9 |
| **1-12** | **10/14/2011** | **10/15/2012** | **367** | **ACTUAL** | **12,162** | **$2,305.06** | **33.1** |

# Measured Performance Data

Battery powered data loggers were used to measure the parameters listed in Table D3 at hourly intervals. This report summarizes the data collected from August 2011 to October 2012. Power consumption for each of the heat pump compressors and the air handler units were measured. One-time power measurements were taken on the units with a Fluke 39 Power Meter (Table D4).

**Table D3. Monitored Points Measured at Nuvision**

| Logger | Description | Sensor | Collection Period |
|---|---|---|---|
| **1-1** | Power on heat pump #1 (zone 1- common spaces) | Ohio Semitronics SHW2100 | Aug '11 – Aug'12 |
| **1-2** | Power on heat pump #2 (zone 2 - bedrooms) | Ohio Semitronics SHW2100 | Aug '11 – Aug'12 |
| **1-3** | Power on air handler unit | Ohio Semitronics SHW2100 | Aug '11 – Aug'12 |
| **2-1** | Runtime on zone 1 furnace, stage 1 | Veris CT | Aug '11 – May'12 |
| **2-2** | Runtime on zone1 furnace, stage 2 | Veris CT | Aug '11 – May'12 |
| **2-3** | Runtime on zone 2 furnace, either stage 1 or 2 | Veris CT | Aug '11 – May'12 |
| **2-4** | Runtime on HRV | Veris CT | Aug '11 – May'12 |

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[3] Propane interpolation assumes that no fuel was used for backup heating. This is a reasonable assumption given the low monitored furnace run-time.

### Table D4. One-Time Power Readings

| System | One-Time Power Reading |
|---|---|
| **Both Air Handler Units** | 1200 Watts |
| **Heat pump # 1 compressor** | 1800 Watts |
| **Heat pump # 2 compressor** | 1300 Watts |

The table and graphs below summarize the monthly electric use and operating hours of the heat pumps, air handler fan, furnace, and HRV. The total runtime on the backup furnace is 7.9 hours for the 3-ton unit (serving common spaces) and 4.6 hours for the 2-ton unit (serving bedrooms). Because the furnaces are oversized, it is assumed that all furnace activity occurred in the lower stage (stage 1) – see Figure D5 and Figure D6. Data collection began in late August 2011 and continued until early August 2012. The runtime data stopped in May 2012.

### Table D5. Summary of Electric Use, Propane Furnace Runtime, and ERV Runtime

| Month | Fraction of the month covered by the data | 3-ton heat pump (common spaces) energy (kWh) | 2-ton heat pump (bed rooms) energy (kWh) | Fan energy (kWh) | Furnace 1 (living room) runtime (hrs) | Furnace 2 (bed room) runtime (hrs) | HRV runtime (hrs) |
|---|---|---|---|---|---|---|---|
| **Oct-11** | 100% | 42.5 | 80.8 | 53.1 | 0 | 0 | 139.3 |
| **Nov-11** | 100% | 146.6 | 98.8 | 96.7 | 0 | 0 | 234.0 |
| **Dec-11** | 100% | 270.6 | 208.2 | 180.6 | 0 | 0 | 221.7 |
| **Jan-12** | 100% | 269.4 | 224.7 | 214.2 | 4.8 | 2.5 | 104.2 |
| **Feb-12** | 100% | 304.5 | 209.1 | 417.4 | 1.6 | 1.7 | 0 |
| **Mar-12** | 100% | 191.1 | 107.7 | 286.1 | 1.1 | 0.4 | 155.1 |
| **Apr-12** | 100% | 122.7 | 57.4 | 271.7 | 0.4 | 0.1 | 242.7 |
| **May-12** | 100% | 46.9 | 39.1 | 150.5 | 0 | 0 | 132.9 |
| **Jun-12** | 100% | 75.3 | 51.5 | 471.5 | - | - | - |
| **Jul-12** | 100% | 293.1 | 51.1 | 561.3 | - | - | - |
| **Aug-12** | 36% | 74.7 | 63 | 60.5 | - | - | - |
| **Sep-12** | 0% | - | - | - | - | - | - |
| **Oct-12** | 0% | - | - | - | - | - | - |
| **Total** | | **1837** | **1191** | **2764** | **7.9** | **4.7** | **1230** |
| **Heating (Oct - May)** | | **1394** | **1026** | **1670** | **7.9** | **4.7** | **NA** |
| **Actual Cooling (Jun '11 - Aug 11, '12)** | | **443** | **166** | **1093** | **0** | **0** | **NA** |
| **One Year Extrapolated Cooling and Ventilation** | | **502** | **188** | **1240** | **0** | **0** | **1999** |

## Heat pumps

The heat pumps used a total of 4,090 kWh (including the air handler fan) for the heating season. The seasonal cooling energy was extrapolated from the partial summer data by the ratio of CDDs that occurred after the monitoring stopped to when it had been active (an additional 13.4%). Seasonal cooling heat pump energy was 690 kWh and the fan power in the cooling season was 1,240 kWh, which included many summer hours with constant fan operation at a single speed (presumably to keep the space mixed). This constant fan operation would have degraded the moisture removal ability of the cooling coil by re-evaporating the condensate into the airflow, instead of allowing the condensate to drip off the coils as designed. This likely contributed to the musty smell observed by the homeowner.

Overall total energy use for the home was 12,162 kWh for the year. About half this energy use is attributed to the heat pumps and air handler fans, as shown in Table D6.

**Table D6. Breakdown of Electricity Use**

| Energy Use | Annual Energy Use (kWh) | Fraction of Total |
|---|---|---|
| **Other** | 6,141 | 50% |
| **Heat pumps and air handler fan** | 6,021 | 50% |
| **Total home** | 12,162 | 100% |

Figure D2 and Figure D3 show the pattern of operation for the two heat pumps in both the heating and cooling seasons. A setback (and setup) thermostat was used in both periods. Figure D4 shows that the fan power was high for both these air handlers. When one unit operated in the constant fan mode, power use was 600 Watts. In the cooling season (and with higher cooling flow rates) fan power was as high as 900 Watts per unit. In total, annual fan power was 1,670 kWh in the heating season and 1,093 kWh in the cooling season. The furnaces only operated during recovery from setback on cold winter days, as seen in Figure D5 and Figure D6.

## Hot water

Annual propane use for the home was about 250 gallons. The furnaces only ran for a total of 12.5 hrs over the year. Assuming the furnaces ran on the low stage, at half the maximum firing rate (35 MBtu/h), the propane use associated with space heating is only about 5 gallons for the year. The remaining propane use is about 0.7 gallons per day on average, which would be equivalent to roughly 60 gallons of hot water use with a water heater EF of 0.82. The amount of hot water is consistent with the family size (two adults and three children) and homeowner comments indicating significant hot water use (see homeowner survey below).

## Setpoints

The space temperature and relative humidity sensor was lost by the homeowner so indoor space conditions are unknown except for set points reported by the homeowner as 72° F during the heating season, 70° F during the cooling season and 50° F during unoccupied periods. Figure D7 and Figure D8 show a strong correlation between energy use and outdoor temperature, in both heating and cooling modes.

## Heat Recovery Ventilator

Operation of the HRV is intermittent, implying the homeowner operates the unit manually for a day or two at a time (Figure D6). This is also borne out by the owner’s comment that they have to run the HRV to eliminate musty odors – indicating that they are actively controlling its operation. The HRV ran for 1230 hours while the loggers were active (231 days), which extrapolates to 1999 hours for the full year. Estimated energy consumption of the HRV was 308 kWh based on the manufacturer rating (assuming medium speed) of 154 watts for 1999 hours of runtime.

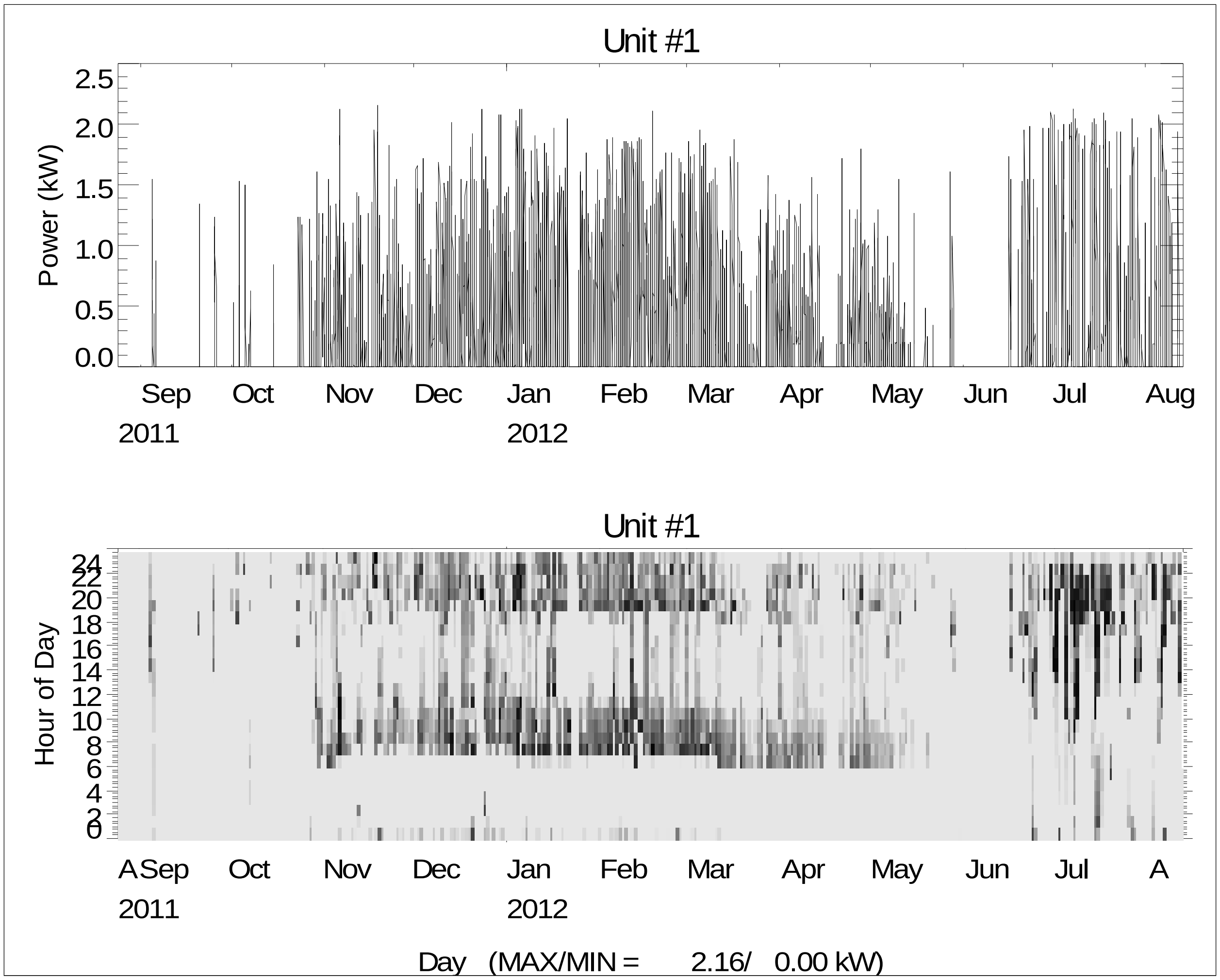

**Figure D2. Power Use for Heat Pump Unit #1 (Living Area)**

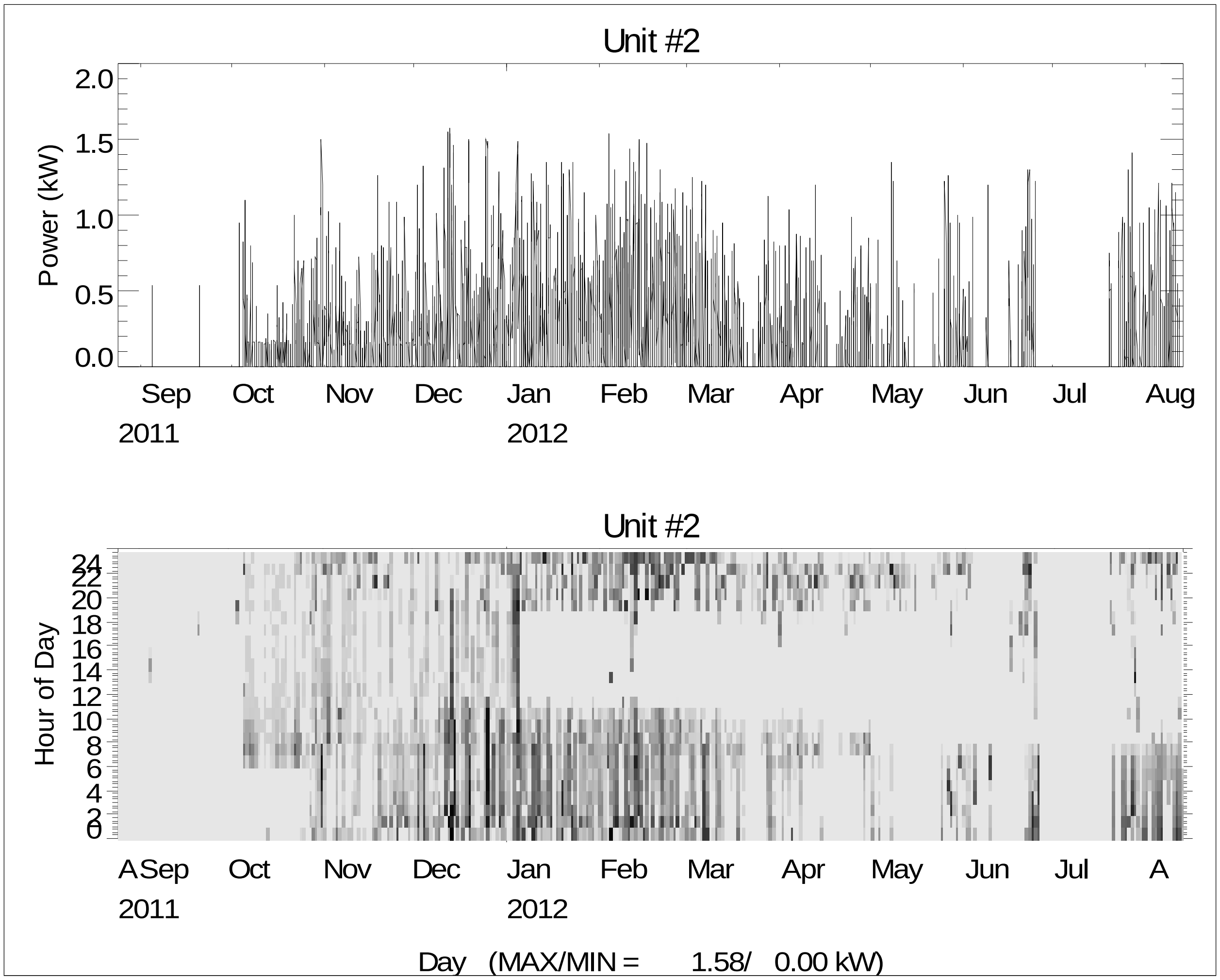

**Figure D3. Power Use for Heat Pump Unit #2 (Bedrooms)**

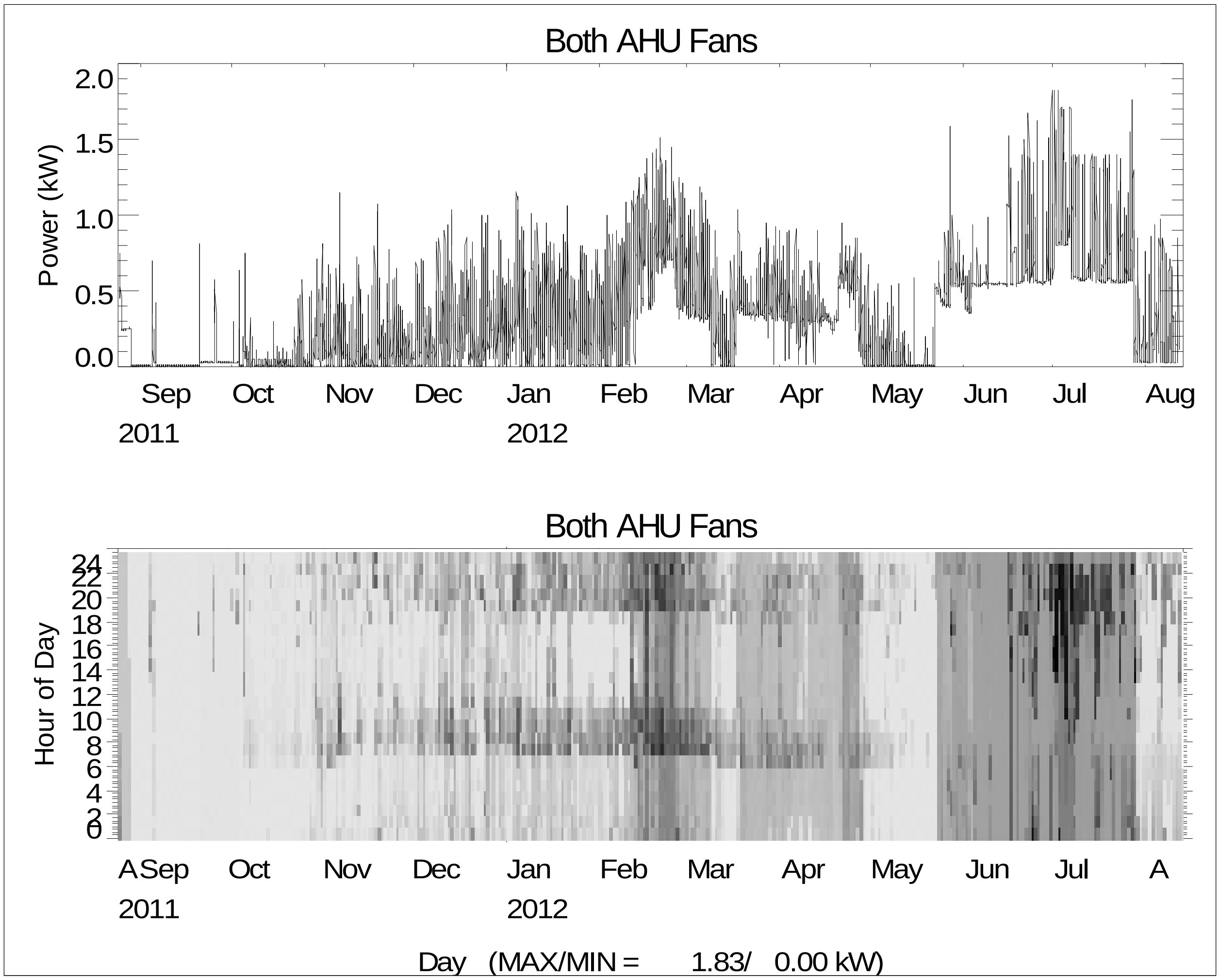

**Figure D4. Power Use for Both AHU Fans**

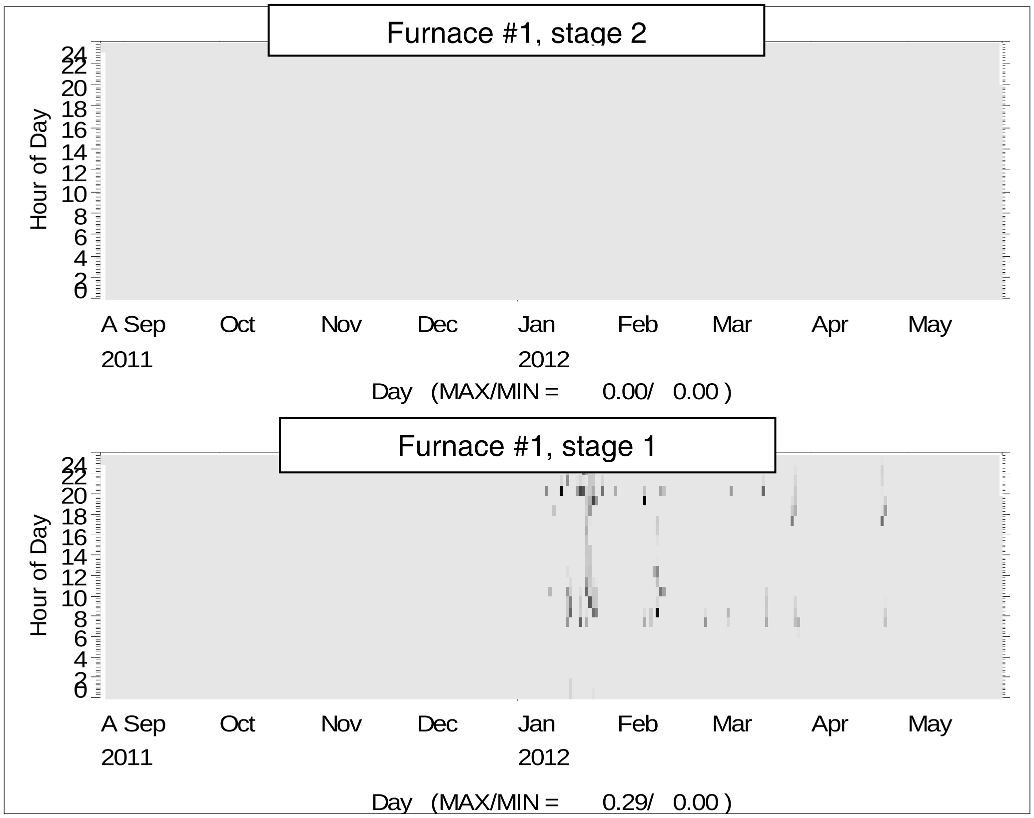

**Figure D5. Operating patterns for furnace #1 serving the living area**

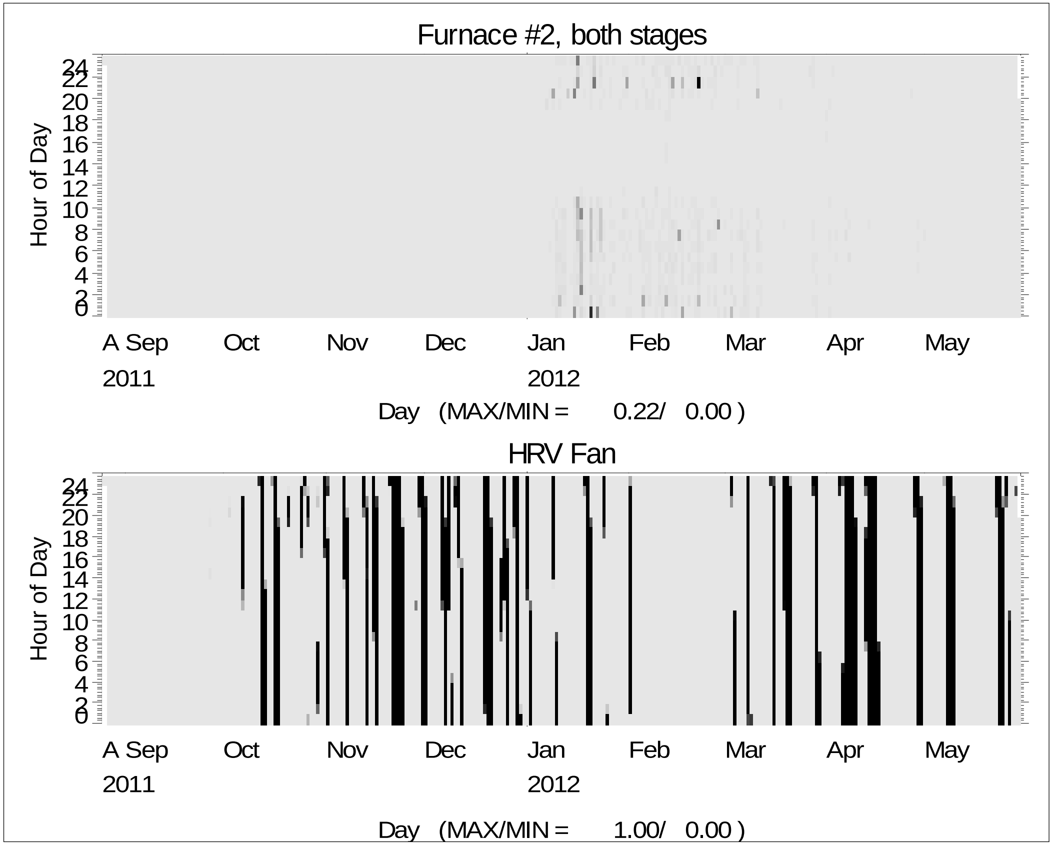

**Figure D6. Operating Patterns for Furnace #2 and the HRV fan**

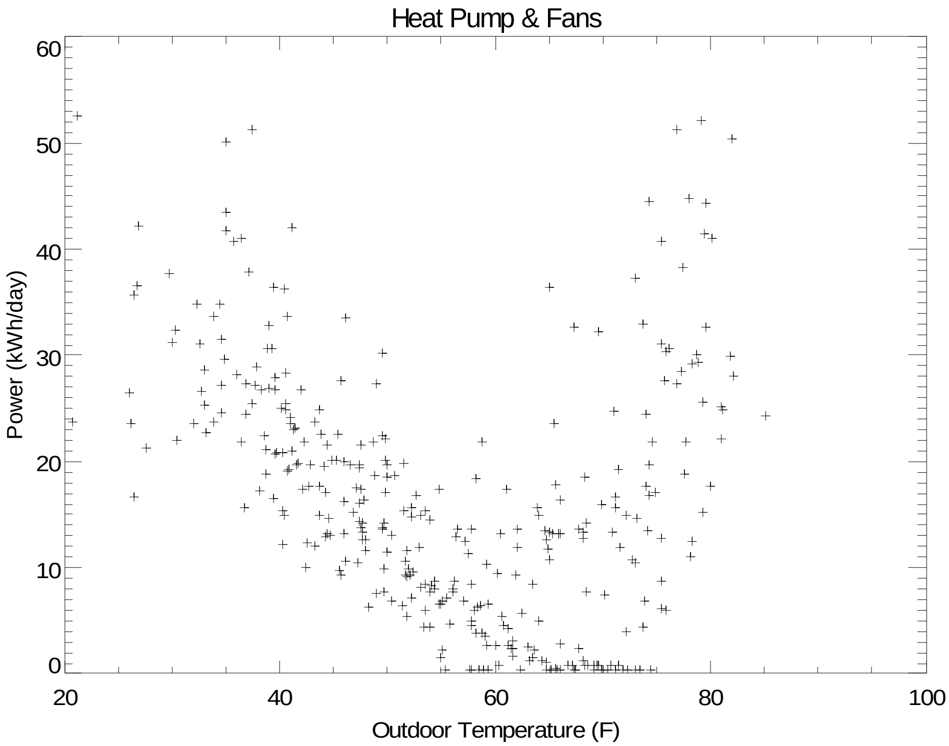

Figure D7. Heat pump and fan energy use compared to outdoor temperature

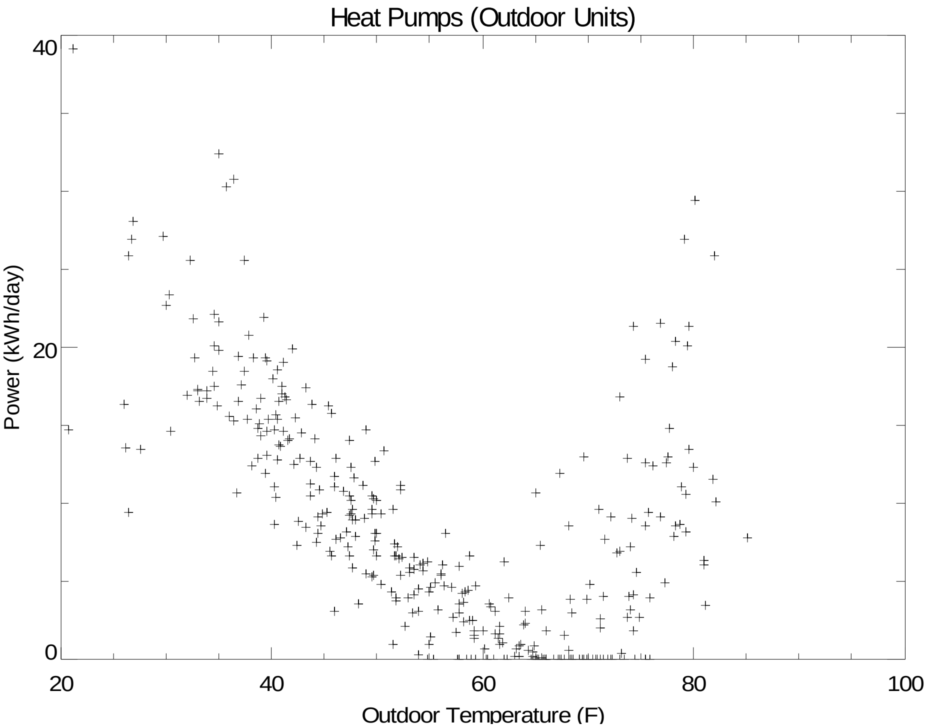

Figure D8. Heat pump energy use compared to outdoor temperature

# Comparison of Modeled vs. Actual Energy Use

REM/Rate's energy modeling uses 30-year average weather data from the nearest weather station in Riverhead, NY. Compared to the 30-year average, the actual weather over the monitoring period had 13.3% fewer HDDs and 12.2% additional CDDs. Normalized seasonal heating and cooling expenditures compared to the REM/Rate model are show in Table D7.

Overall, the total weather normalized energy consumption was very close to the REM/Rate prediction – only 5% less (Table D7). However, there were significant discrepancies among the categories: actual weather-normalized consumption was greater in every category except for propane backup heating and electric baseload (Figure D9 and Figure D10. Heating and cooling electric energy use were both significantly higher than the REM/Rate predicted usage, by an additional 78% and 186%, respectively (Table D7). However, much of this was due to unnecessary fan use when the homeowner had the air handlers set on constant fan operation. Fan use constituted 41% and 64% of the total heating and cooling energy use, respectively.

Also of interest is REM/Rate's prediction of propane use for backup heating, at more than twenty times actual use (Table D7). The mild winter had few cold (below 40°F) days when propane backup heat was required and a greater proportion of winter days when only the electric heat pumps were in use. This would not be captured in a HDD-based normalization and therefore resulted in an under-prediction of electricity and over-prediction of propane heating compared to the actual use in 2011-2012.

**Table D7. Weather normalized expenditure compared to REM/Rate's predicted expenditure**

| Fuel | Source | Weather Normalized Consumption | | REM/Rate Model | | Weather Normalized Expenditure Compared to REM/Rate Model |
|---|---|---|---|---|---|---|
| | | (kWh or Gal) | (MMBtu) | (kWh or Gal) | (MMBtu) | |
| Electricity (kWh) | Heating | 4,719 | 16.1 | 2,650 | 9.0 | +78% |
| | Cooling | 1,720 | 5.9 | 602 | 2.1 | +186% |
| | Ventilation | 308 | 1.1 | 1,012[4] | 3.5 | -70% |
| | Other | 5,833 | 19.9 | 7,475 | 25.5 | -22% |
| Propane (Gal) | DHW & Appliances | 252 | 23.0 | 195 | 17.8 | +29% |
| | Heating | 5.6 | 0.5 | 133 | 12.1 | -96% |
| Total | | | 66.4 | | 70.0 | -5% |

---

[4] This is based on REM/Rate inputs of a fan power of 154 W operating 18 hours per day.

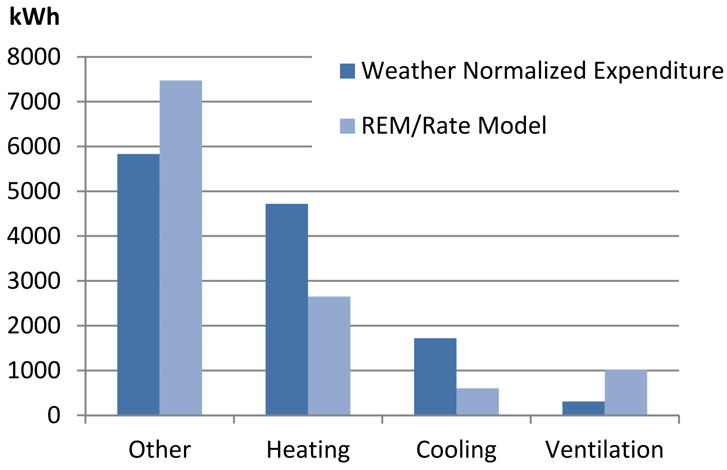

Figure D9. Disaggregated electricity consumption

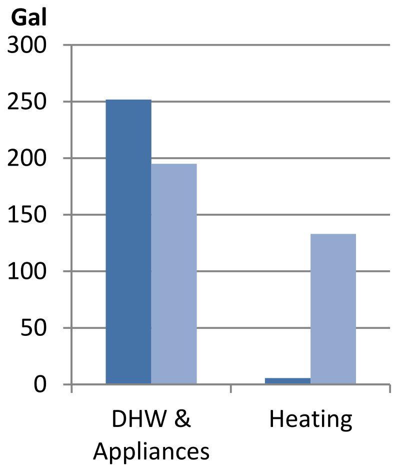

Figure D10. Disaggregated propane consumption

Disaggregated, weather normalized source energy use shown in MMBtu is shown in **Figure** and **Figure** .

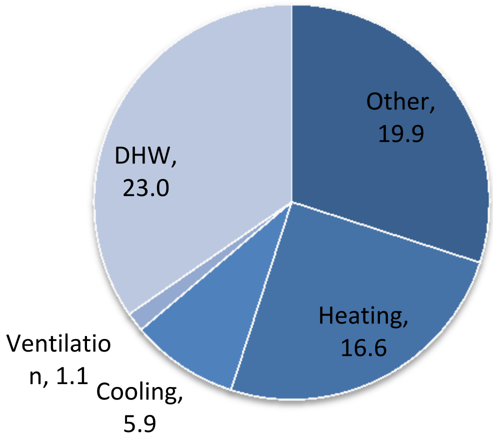

Figure D11. Weather normalized expenditure in MMBtu

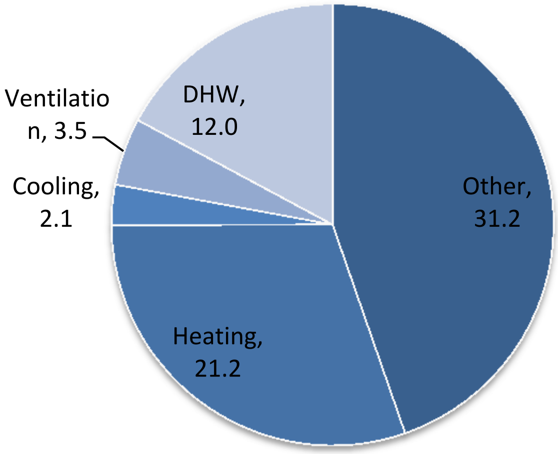

Figure D12. REM/rate predicted expenditure in MMBtu

# Occupant Survey

An occupant survey was conducted. Results are shown below with the responses by the homeowner in blue italics. Note that the “musty” odor reported by the occupant when the HRV is off may be due to wet conditions in the basement as there were issues with water in the basement during construction.

**NYSERDA Challenge: Nuvision Homeowner Survey Responses**
**Interviewee: Mr. Meier**
**Home address: 35A Peeker Ave, Mastic Beach, NY**
**Interviewer: David Podorson, The Levy Partnership, Inc.**
**Date: 10/15/12**

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

   *None*

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

   *N/A*

3. Which aspect of your home have you been most pleased with?

   - [✓ *Low utility bills*]
   - Good indoor air quality
   - Very durable

   *Air quality is not very good; air is musty, must run HRV 24/7.*

*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]

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]

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 is my favorite part of the house - gets hot instantly and never runs out.*

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 very happy with the CFL's, they take too long to warm up, I've been switching to LED's but they're very expensive.*

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

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]

*Great, no drafts at all.*

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.

*The hot water system.*

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

*The heat pump condenser valve broke down, and had to be replaced. It was under warranty but it would take six weeks for me to get it from the company, so I just bought it at the local store for about $100 because I wanted my air conditioning. I would have had to pay for the refrigerant charging anyhow.*

*Also, I am disappointed with the musty smell in the house, so I leave the HRV on 24/7. I don't think it is sized adequately for the house.*

*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] *As long as you eventually get it back*
o Disagree
o Not sure

15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

- [✓ Agree]
- Disagree
- 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.

- Agree
- [✓ Disagree]
- 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.

- [✓ Agree]
- Disagree
- 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 October 2011. We spent weekends here too, but were home basically only at night.*

19. How many people on average occupied the house?

*Two adults and three children.*

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

*50° F*

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

*72° F during the heating season, and 70° F during the cooling season.*

# Appendix E

## NYSERDA High Performance Development Challenge Energy Monitoring Report – Stephens Construction

### Towey Residence

The Towey residence, a single family residence located in Hague, NY, uses electricity for heating and cooling via a ground source heat pump. Domestic hot water is provided by a propane-fueled tankless water heater. Utility bills were collected for one year after occupancy. A summary is provided in Table E1 and Table E2.

**Table E1. Electricity bills from April 2010 - April 2011**

| Month | Start | End | Days | Elec | |
|---|---|---|---|---|---|
| | | | | KWH | $ |
| **1 (Apr-May'10)** | 4/8/2010 | 5/10/2010 | 32 | 576 | $89.14 |
| **2 (May-Jun'10)** | 5/10/2010 | 6/7/2010 | 28 | 396 | $65.46 |
| **3 (Jun-Jul'10)** | 6/7/2010 | 7/9/2010 | 32 | 553 | $93.69 |
| **4 (Jul-Aug'10)** | 7/9/2010 | 8/10/2010 | 32 | 1081 | $166.42 |
| **5 (Aug-Sep'10)** | 8/10/2010 | 9/9/2010 | 30 | 619 | $97.80 |
| **6 (Sep-Oct'10)** | 9/9/2010 | 10/8/2010 | 29 | 616 | $98.07 |
| **7 (Oct-Nov'10)** | 10/8/2010 | 11/5/2010 | 28 | 595 | $94.31 |
| **8 (Nov-Dec'10)** | 11/5/2010 | 12/6/2010 | 31 | 983 | $143.23 |
| **9 (Dec'10-Jan'11)** | 12/6/2010 | 1/6/2011 | 31 | 1371 | $206.33 |
| **10 (Jan-Feb'11)** | 1/6/2011 | 2/7/2011 | 32 | 1264 | $199.38 |
| **11 (Feb-Mar'11)** | 2/7/2011 | 3/8/2011 | 29 | 1136 | $171.53 |
| **12 (Mar-Apr'11)** | 3/8/2011 | 4/7/2011 | 30 | 780 | $114.97 |

**Table E2. Propane refills from October 2009 - May 2011**

| Month | Fill date | Note | Days | Refills | |
|---|---|---|---|---|---|
| | | | | Gallons | Therms |
| **1** | 10/6/2009 | Tank set | 0 | 60 | 55 |
| **1** | 10/15/2009 | Refill | 9 | 339.4 | 312 |
| **10** | 7/21/2010 | Refill | 279 | 232.2 | 213 |
| **12** | 9/8/2010 | Refill | 49 | 71 | 65 |
| **16** | 1/6/2011 | Refill | 120 | 282.2 | 259 |
| **21** | 6/28/2011 | Refill | 173 | 228 | 209 |

A summary of estimated heating and cooling expenditures is shown in Table E3. The base load was calculated by averaging the six months with little or no space conditioning loads. April and October would normally have heating loads in this climate, but because of low occupancy during those months, and due to the home's superior thermal envelope, the load during those periods was minimal.

**Table E3. Summary of energy expenditures**

| | Days | kWh | $ |
|---|---|---|---|
| **Total** | 364 | 9,970 | $1,540 |
| **Base load base months (Apr, May, Jun, Aug, Sept, Oct)** | 179 | 3,355 | $538 |
| **Base load annualized** | 364 | 6,822 | $1,095 |
| **Base load per month** | 30.33 | 569 | $91 |
| **Heating months (Nov - Apr)** | 153 | 5,534 | $835 |
| **Heating energy consumption – total for year** | | 2,691 | $379 |
| **Cooling months (Jul)** | 32 | 1,081 | $166 |
| **Cooling energy consumption – total for year** | | 512 | $75 |

A graph of the estimated heating and cooling expenditure, in kWh, is shown in Figure E1.

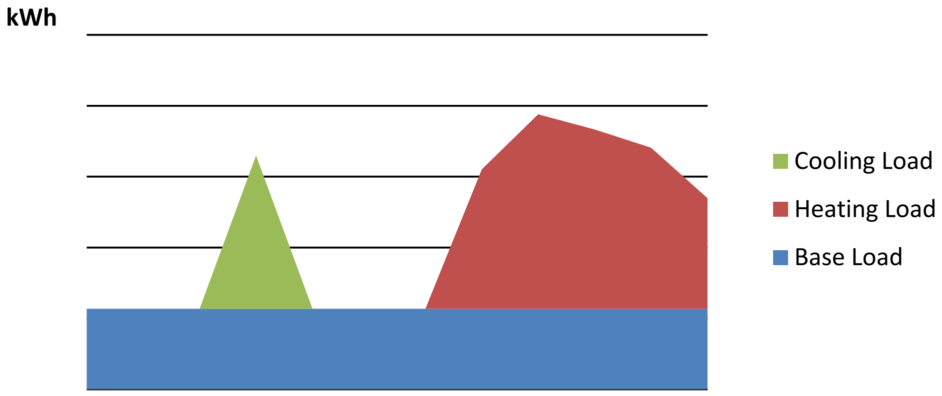

**Figure E1. Heating and cooling expenditure**

The actual energy consumption was much less than that predicted by REM/Rate in part due to low occupancy (Table E4). The home was occupied in the summer and sporadically for the rest of the year. The thermostat was set at 60°F during heating season when the home was unoccupied. Domestic hot water was provided by a propane appliance. Irregular propane tank refills, co-mingling of propane for multiple uses (heating the guest house and cooking in addition to DHW) made it difficult to isolate fuel consumption for DHW.

**Table E4. Predicted versus actual energy consumption**

| | Total Consumption | | | | Consumption per Degree Day (heating or cooling as appropriate) | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual | | REM/Rate | | Actual | | REM/Rate | |
| | kWh | MBtu | kWh | MBtu | kWh | MBtu | kWh | MBtu |
| **Heating (kWh)** | 2,691 | 9,183 | 15,064 | 51,400 | 0.4 | 1.2 | 2.0 | 6.9 |
| **Cooling (kWh)** | 512 | 1,749 | 4,103 | 14,000 | 0.7 | 2.3 | 5.4 | 18.4 |
| **Total** | 3,204 | 10,931 | 19,168 | 65,400 | | | | |

# Occupant Survey

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

**Stephens House Survey Questionnaire**
**9/6/11**
**Interviewee: John Towey**
**Interviewer: David Podorson (via phone)**

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

   *This is their first*

2. How many occupants reside in this house? What are their ages? Has this occupancy changed at all during the term that we are speaking of?

   *House was only occupied during the summer and on weekends and holidays. Occupancy varied from 2 to 8 people, but for most of the summer there were 6 people at the home.*

3. 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]

4. Which aspect of your home have you been most pleased with?

   - [✓ Low utility bills]
   - Good indoor air quality
   - Very durable

   *But they are happy with everything. Biggest caveat was that the upstairs was too hot in the winter, and not cool enough in summer; they would have liked to have a zoned system.*

*A few questions about comfort and energy efficiency:*

5. 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]

   *The first floor is very comfortable; the second floor is often too warm, especially if using the fireplace. They installed ceiling fans to help but haven't tested them fully yet.*

6. 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]

   *Their daughter stayed upstairs, and liked it much cooler than they do, so it was too warm for her. She would close the vents downstairs to get more cooling upstairs.*

7. 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]

*Very good, plenty of capacity, never had problems with concurrent/consecutive showers. There was sometimes a delay in receiving the hot water in the second (upstairs?) bathroom.*

8. 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

*He didn't choose a particular rating, just provided commentary: they had problems with electricians, and went through a few different ones. They had to get the wiring replaced in one of the walls. Tried to put in a dimmer switch to use with a CFL (and purchased a special CFL for that purpose), but it didn't work well. He would like to know alternatives.*

9. 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]

*Excellent, they had 15 guests over, and they could hardly hear them from the other room*

10. 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 rating was given, commentary: No drafts except for the duct in the hallway, which is uncomfortable in winter. He's not sure if it's set properly.*

11. 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]

*Biggest difference is in the winter*

12. 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

*Indicated a rating of about 1.5; he said they were not very well informed, and would have liked to know more.*

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

*Geothermal heating and cooling, because it saves the environment and saves on utility bills*

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

*There was a cheap sump pump which broke and the basement flooded. Also the electricity in one of the walls was shorting out, as previously mentioned. He mentioned that maybe the cables were pinched or stapled. They had to get it replaced.*

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

15. 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.

○ [✓ Agree]
○ Disagree
○ Not sure

16. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

○ [✓ Agree]
○ Disagree
○ Not sure

17. 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.

○ [✓ Agree]
○ Disagree
○ Not sure

18. 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.

○ [✓ Agree]
○ Disagree
○ Not sure

*Definitely!*

*Some questions about occupancy*

19. When did you occupy the house from April 2010 to April 2011 – what months; full time or only weekends/vacations?

*The house was occupied during the summer with six people on average, and occupied on weekends and holidays with anywhere from 2-8 people.*

20. How many people on average occupied the house?

*Six people during the summer.*

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

*60°F*

22. What thermostat settings did you typically use when the house was occupied?

*70° in winter*

*72° in summer, but only used the A/C intermittently; they would battle with their daughter about the temperature (she liked it cooler)*

# Appendix F

## NYSERDA High Performance Development Challenge Energy Monitoring Report – United Way (Long Island)

The participating home is a two-family detached home in Long Beach, NY. The house is a gut rehab of a dilapidated single family home. It is operated by Catholic Charities of New York as a residence for two families. Construction is complete and both apartments have been occupied for more than one year. Both apartments share a single gas meter, a single electric meter, and common heating and DHW equipment. Each apartment is a separate space conditioning zones. Utilities are paid by Catholic Charities of New York.

Note that a photovoltaic (PV) system was installed separate from the NYSERDA Challenge program.

**Figure F1: The residence in Long Beach, NY**

## Energy bills

The monthly energy consumption and costs from utility bills are shown in Table F1 and Table F2. Estimated bills have been omitted and the results combined to show only utility confirmed consumption for the entire house. Note that the electric bill is net of on-site PV production and therefore some months show negative usage.

**Table F1. Utility bills for natural gas**

| Month | Start | End | Days | Reading type | Natural Gas | | |
|---|---|---|---|---|---|---|---|
| | | | | | Therms | Cost | Therms/day |
| **1-4** | 3/14/2012 | 7/16/2012 | 124 | Actual | 329 | $443 | 2.6 |
| **5,6** | 7/16/2012 | 9/18/2012 | 64 | Actual | 82 | $153 | 1.3 |
| **7,10** | 9/18/2012 | 1/17/2013 | 131 | Actual | 558 | $704 | 4.3 |
| **11,12** | 1/17/2013 | 3/14/2013 | 56 | Actual | 514 | $553 | 9.2 |
| **13,14** | 3/14/2013 | 5/17/2013 | 64 | Actual | 539 | $625 | 8.4 |
| **15,16** | 5/17/2013 | 7/19/2013 | 63 | Actual | 189 | $317 | 3.0 |
| **1-16** | 3/14/2012 | 7/19/2013 | **502** | Actual | **2,211** | $2,796 | 4.7 |

### Table F2. Utility bills for electricity

| Month | Start | End | Days | Reading type | Electricity | | |
|---|---|---|---|---|---|---|---|
| | | | | | kWh | Cost | kWh/day |
| **1** | 4/17/2012 | 5/15/2012 | 28 | Actual | -599 | $10.97 | -21.4 |
| **2** | 5/15/2012 | 6/20/2012 | 36 | Actual | -786 | $14.10 | -21.8 |
| **3** | 6/20/2012 | 7/16/2012 | 26 | Actual | -265 | $10.19 | -10.2 |
| **4** | 7/16/2012 | 8/20/2012 | 35 | Actual | 140 | $13.71 | 4.0 |
| **5** | 8/20/2012 | 9/18/2012 | 29 | Actual | -9 | $11.36 | -0.3 |
| **6** | 9/18/2012 | 10/18/2012 | 30 | Actual | -116 | $11.75 | -3.9 |
| **7,8** | 10/18/2012 | 12/14/2012 | 57 | Actual | 366 | $22.32 | 6.4 |
| **9** | 12/14/2012 | 1/17/2013 | 34 | Actual | 429 | $13.33 | 12.6 |
| **10** | 1/17/2013 | 2/16/2013 | 30 | Actual | 62 | $11.75 | 2.1 |
| **11** | 2/16/2013 | 3/14/2013 | 26 | Actual | -47 | $10.19 | -1.8 |
| **12** | 3/14/2013 | 4/15/2013 | 32 | Actual | -367 | $12.54 | -11.5 |
| **13** | 4/15/2013 | 5/17/2013 | 32 | Actual | -581 | $12.54 | -18.2 |
| **14** | 5/17/2013 | 6/13/2013 | 27 | Actual | -413 | $10.58 | -15.3 |
| **1-14** | 4/17/2012 | 6/13/2013 | **422** | Actual | **-2186** | $165.33 | |

Table F3 shows monthly solar PV production for a typical year estimated using the National Renewable Energy Laboratory (NREL) PVWatt web tool (version 2). Table F4 presents the estimated electricity consumption of the house generated by combining the utility electricity bills and the solar PV estimated production. It should be noted in Table F4 that solar PV production was higher than energy consumption over the course of the monitoring period.

### Table F3. Total solar PV production estimated with the NREL PVWatt version 2.0 webtool

| Month | Solar Radiation ($kWh/m^2/day$) | AC Energy (kWh) | AC Energy (kWh/day) | Energy Value ($) |
|---|---|---|---|---|
| Jan | 2.64 | 559 | 18.0 | 91.68 |
| Feb | 3.29 | 628 | 22.4 | 102.99 |
| Mar | 4.14 | 848 | 27.4 | 139.07 |
| Apr | 4.34 | 839 | 28.0 | 137.60 |
| May | 4.61 | 901 | 29.1 | 147.76 |
| Jun | 4.73 | 869 | 29.0 | 142.52 |
| Jul | 4.55 | 847 | 27.3 | 138.91 |
| Aug | 4.59 | 863 | 27.8 | 141.53 |
| Sep | 4.17 | 769 | 25.6 | 126.12 |
| Oct | 3.75 | 742 | 23.9 | 121.69 |
| Nov | 2.71 | 527 | 17.6 | 86.43 |
| Dec | 2.40 | 497 | 16.0 | 81.51 |
| **Year** | **3.83** | **8,888** | | **1,457.63** |

### Table F4. Total electricity consumption in the house combining electricity bills and estimated solar PV production

| Start | End | Total Days | Meter Reading | Estimated Solar PV Production | Estimated total electricity consumption |
|---|---|---|---|---|---|
| 4/17/2012 | 5/15/2012 | 28 | -599 | 798 | 199 |
| 5/15/2012 | 6/20/2012 | 36 | -786 | 1045 | 259 |
| 6/20/2012 | 7/16/2012 | 26 | -265 | 732 | 467 |
| 7/16/2012 | 8/20/2012 | 35 | 140 | 965 | 1105 |
| 8/20/2012 | 9/18/2012 | 29 | -9 | 775 | 766 |
| 9/18/2012 | 10/18/2012 | 30 | -116 | 744 | 628 |
| 10/18/2012 | 12/14/2012 | 57 | 366 | 1093 | 1459 |
| 12/14/2012 | 1/17/2013 | 34 | 429 | 579 | 1008 |
| 1/17/2013 | 2/16/2013 | 30 | 62 | 607 | 669 |
| 2/16/2013 | 3/14/2013 | 26 | -47 | 647 | 600 |
| 3/14/2013 | 4/15/2013 | 32 | -367 | 885 | 518 |
| 4/15/2013 | 5/17/2013 | 32 | -581 | 912 | 331 |
| 5/17/2013 | 6/13/2013 | 27 | -413 | 783 | 370 |
| **4/17/2012** | **6/13/2013** | **422** | **-2186** | **10,566** | **8,380** |

# Measured Performance Data

On August 23, 2011 data loggers were installed and one-time power measurements were made on the completed house. Table F5 shows the loggers installed. Data loggers were programmed to collect the following hourly data. Table F6 shows one-time load measurements from the main electrical panel.

### Table F5. Monitored points measured at United Way

| Logger | Channel | Item Measured | Collection period |
|---|---|---|---|
| Data logger D270F | 1 | Zone 1 Damper (powered when closed) | August, 2011 to August, 2013 |
| | 2 | Zone 2 Damper (powered when closed) | |
| | 3 | Space Heat Valve | |
| | 4 | Boiler Pump | |
| Data logger D2156 | 1 | HVAC Compressor Runtime | |
| HOBO Zone 1 (1st floor) (side of kitchen cabinet) | 1 | Living Space Temperature | |
| | 2 | Living Space RH | |
| HOBO Zone 2 (2nd floor) (side of kitchen cabinet) | 1 | Living Space Temperature | |
| | 2 | Living Space RH | |

**Table F6. One-time power readings**

| Equipment | Watts |
|---|---|
| Air handler fan | 190 |
| Heat recovery ventilator | 123 |
| Air conditioner compressor for zone 1 | 1,020 |
| Air conditioner compressor for zone 2 | 1,080 |

# Indoor Space Conditions

The space conditions in the both the apartments over the monitoring period are shown in Figure F3 and Figure F2 The house was completed in summer 2011 and heating systems were in operation since August 2011, however the apartments were not occupied until mid-April 2012 (first floor) and July 2012 (second floor) – indicated by black arrows on the graphs. Both data loggers show similar temperature and humidity patterns: indoor temperatures dropping from summer 2011 until January 2012 when the heat is turned on; excessively high temperatures (~90°F on the first floor and ~100°F on the second floor) from January 2012 until occupancy of the first floor; a short period of more reasonable temperatures in the 70s; followed by more warm temperatures and then the cooling season with temperatures in the 70s. A dip in temperature occurs starting in early November 2012 after Hurricane Sandy interrupted power to the house. Temperatures in the winter of 2012 were again excessively warm – often in the 90s on the first floor and the mid-80s on the second floor through the end of heating season in May 2013. Interestingly, temperatures are somewhat cooler in the summer (70s and 80s) despite the fact that there was no air conditioning until early August because the compressors had not been damaged by flooding during Sandy and not replaced until then. Once the air conditioner was replaced, temperatures dropped to the 70s on both floors.

The high heating season indoor temperature data are consistent with the high gas consumption (three times the modeled heating usage) and resident reports of excessive heat (Table F9). It was determined that heating season temperatures were high due to problems with the heating system controller. The controllers were replaced in the winter of 2013-14.

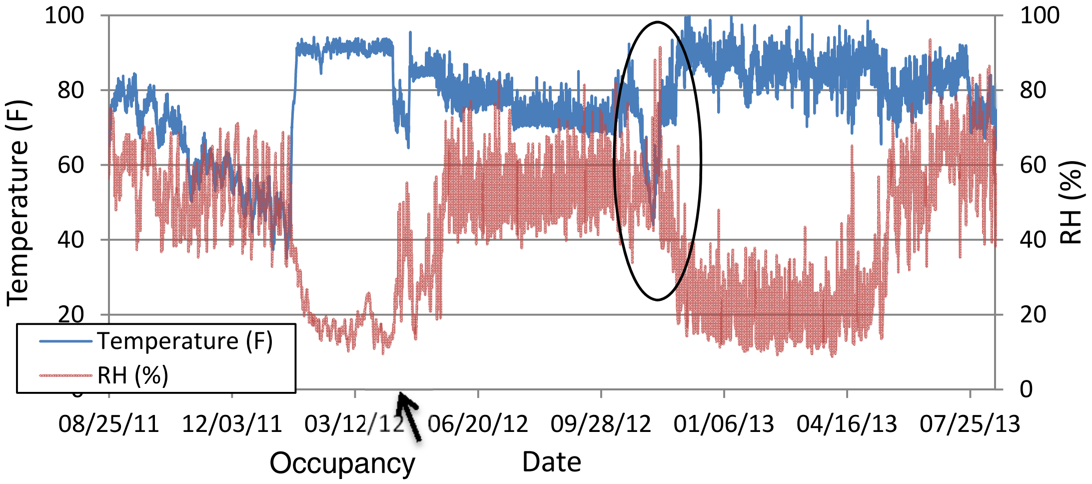

**Figure F2. Living space humidity and temperatures for monitoring period (first floor) – black arrow indicates start of occupancy**

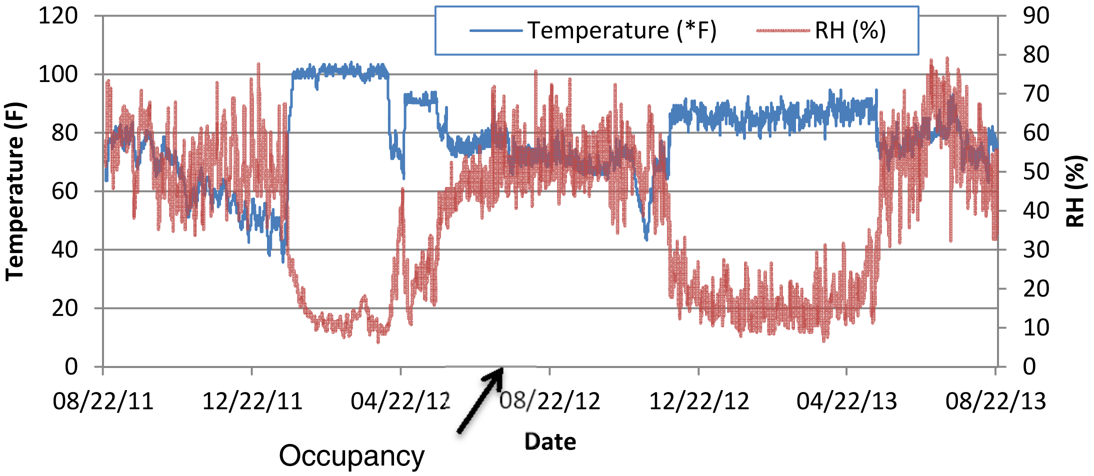

**Figure F3. Living space humidity and temperatures for monitoring period (second floor) – black arrow indicates start of occupancy**

# Heating

Table F7 summarizes monthly gas use and average outdoor temperature. These data were used to plot the graph in Figure F4 showing the correlation of gas use with ambient temperature. The best fit line implies the balance point is approximately 62°F. The peak gas use in the coldest months (average temperature 34.3°F) is 9.2 therms/day. The non-heating gas use (DHW, cooking) use is approximately 1.3 therms/day.

**Table F7. Gas use and outdoor temperatures**

| Month | Start | End | Days | Average Outdoor T | Natural Gas (Therms) | Therms/ day |
|---|---|---|---|---|---|---|
| **1,2** | 7/16/2012 | 9/18/2012 | 64 | 73.5 | 82 | 1.3 |
| **3,4** | 9/18/2012 | 11/14/2012 | 67 | 56.1 | 164 | 2.4 |
| **5,6** | 11/14/2012 | 1/17/2013 | 64 | 41.1 | 394 | 6.2 |
| **7,8** | 1/17/2013 | 3/14/2013 | 56 | 34.3 | 514 | 9.2 |
| **9,10** | 3/14/2013 | 5/17/2013 | 64 | 48.0 | 539 | 8.4 |
| **11,12** | 5/17/2013 | 7/19/2013 | 63 | 69.3 | 189 | 3.0 |
| **1-12** | 7/16/2012 | 7/19/2013 | **378** |  | **1882** | 5.0 |

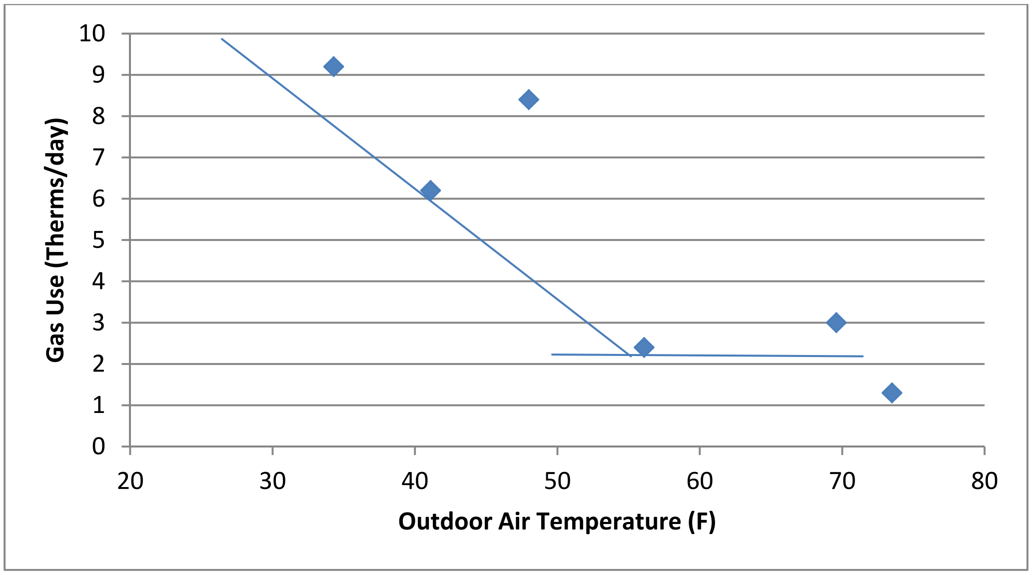

**Figure F4. Trend of metered gas consumption with ambient temperature (from Farmingdale Public Airport NY)**

Figure F5 shows space heat valve and boiler pump (between the boiler and the indirect DHW storage tank) runtime for the 2011-2012 winter. Space heat first turns on January 19, 2012 consistent with the rise in indoor temperature seen in Figure F2 and Figure F3.

It can be seen in Figure F5 boiler pump and space heat valve operate nearly continuously from January 19, 2012 through March 2012. The second floor damper is active throughout this period despite the second floor being unoccupied. The first floor damper becomes active shortly after occupancy on that floor.

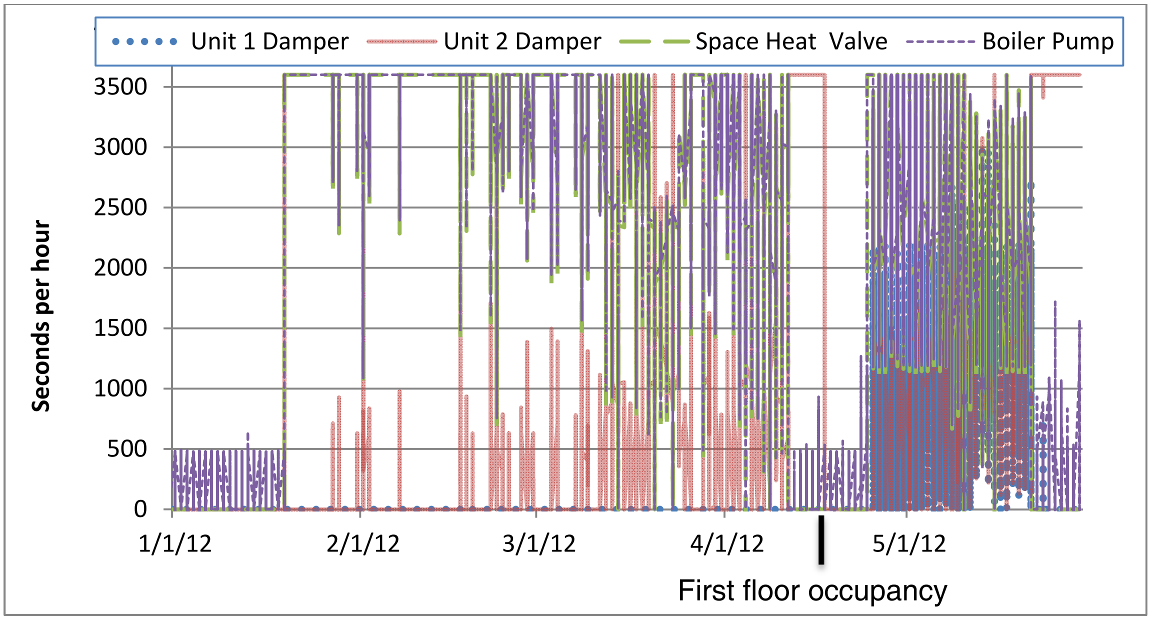

**Figure F5. Space heat valve, boiler pump and damper runtime for winter 2011-2012**

# Cooling

Figure F6 shows air conditioner compressor current status for the summer of 2012. Black arrows indicate occupancy start dates. Compressor current is lower in the beginning of 2012 cooling season (May to June) when only the first floor unit was occupied. The second floor unit was occupied in June 2012. Cooling ends in October 2012. There is no cooling data for the summer of 2013 because the air conditioner compressor was out of service due to flooding damage.

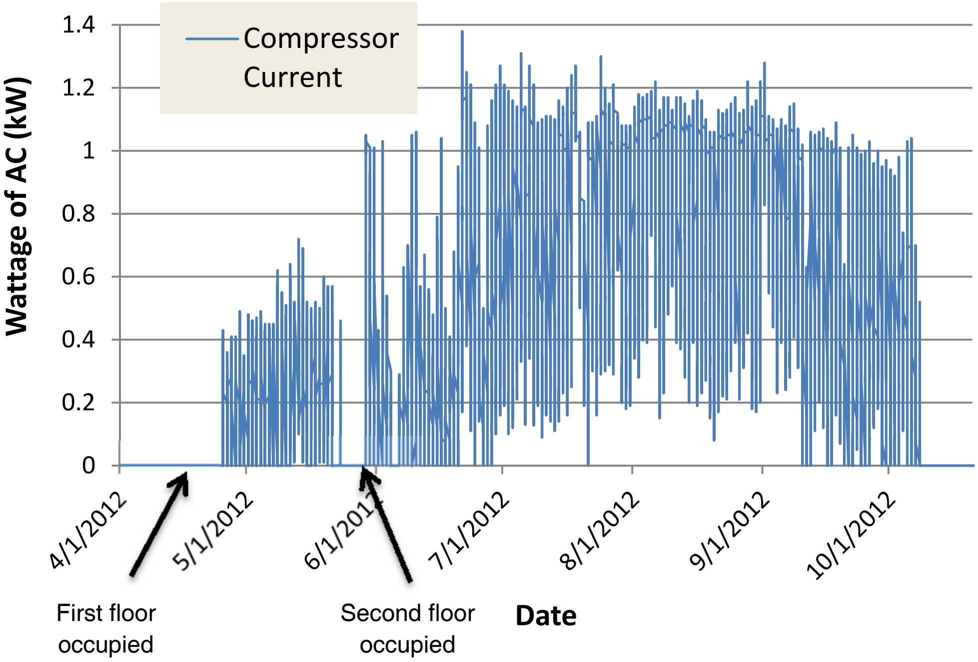

**Figure F6. HVAC compressor current during 2012 summer season**

Baseload (non-cooling) electricity consumption was determined during April 17 to May 15, 2012. Cooling energy use was determined by subtracting the electric baseload from the summer electricity consumption. Daily baseload energy consumption was calculated by dividing the total energy consumption during the baseload period by the duration of the baseload period (in days). Calculations are shown in Table F8.

**Table F8. Cooling and electricity baseload calculations**

| | Days | kWh |
|---|---|---|
| **Non-cooling period (April 17 to May 15, 2012) total use** | 28 | 199 |
| **Electric baseload per day** | 1 | 7.1 |
| **Cooling period total use** | 90 | 2,338 |
| **Electric baseload for cooling months** | 90 | 646 |
| **Cooling period cooling use (June 20 to Sept. 18, 2012)** | 90 | 1,692 |

## Comparison of Modeled vs. Measured Energy Use

Actual measured consumption compared to REM/Rate's estimated energy expenditure is summarized in Table F9.

**Table F9. Actual versus predicted energy consumption**

| | REM/Rate (MMBtu) | Utility bill analysis (2012-2013) (MMBtu) | Difference Bills compared to model |
|---|---|---|---|
| **Heating gas** | 41.5 | 130.2 | 214% |
| **Baseload gas (DHW)** | 19.9 | 46.8 | 135% |
| **Total gas** | 61.4 | 177.0 | 188% |
| **Cooling electric** | 4.8 | 5.8 | 21% |
| **Baseload electric** | 37.0 | 8.9 | -76% |
| **Total electric** | 41.8 | 14.7 | -65% |
| **Total Photovoltaics** | -33.6 | -30.3 | -10% |
| **Total** | 69.5 | 161.4 | 132% |

The comparison between the model and the data analysis show that heating gas consumption was nearly three times that of the model and DHW gas was more than double that of the model. The bill analysis cooling energy use was 21% higher than the model and the baseload electric was 76% lower than the model. Overall, energy consumption was 185% higher than the REM/Rate model.

# Occupant Surveys

An occupant survey was conducted with one resident of each apartment. Results are shown below with the responses by the residents in blue italics. There are two units in this house. Residents reported that the outdoor cooling equipment was recently replaced. Note that the home is owned by a charitable organization that provides housing for low-income families in need. The families pay a reduced rent and are not responsible for utility expenses.

**NYSERDA Challenge: United Way Residents Survey Responses**
**Home address: 56 East Fulton Rd, Unit#1, Long Beach, NY**
**Interviewer: Kapil Varshney, The Levy Partnership, Inc.**
**Date: 8/16/2013**

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

   *2*

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?

   *Overall house is performing well.*

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]

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]

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]

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]

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]

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

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.

*Windows, heating/cooling systems. Overall satisfied with everything.*

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

*No*

*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.

- [✓ Agree]
- Disagree
- Not sure

15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

- [✓ Agree]
- Disagree
- 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.

- [✓ Agree]
- Disagree
- 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.

- [✓ Agree]
- Disagree
- 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?

*Full time.*

19. How many people on average occupied the house?

*4*

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

*Resident inform that they did not leave the house during the winter.*

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

*70 F*

**Home address: 56 East Fulton Rd, Unit#2, Long Beach, NY**
**Interviewer: Kapil Varshney, The Levy Partnership, Inc.**
**Date: 8/16/2013**

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

   *4 (lived in, not necessarily owned)*

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?

   *Did not answer specifically but mentioned that overall house is performing well.*

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

   *Resident mentioned that for she was not informed where the thermostat was for her apartment and during the winter, she experienced excessively high temperatures. She added that she used a fan sometimes in an attempt to mitigate the excess heat.*

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]

   *Resident mentioned that at her previous home she had no control over cooling, whereas here, she does, and therefore is very comfortable with the cooling system.*

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]

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]

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]

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]

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

*N/A. The resident does not pay utility bills for this house – they are paid by the owner, Catholic Charities.*

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

*The resident said that she was not informed about the thermostat of the heating system at all. The indoor temperature in the winter was too high.*

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

*Heating/cooling, lighting and hot water.*

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

*Other than the thermostat problem stated above, no.*

*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.

- Agree
- Disagree
- [✓ Not sure]

15. Increased energy efficiency also carries other benefits like a quiet house and good indoor air quality.

- Agree
- Disagree
- [✓ 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.

- Agree
- Disagree
- [✓ 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.

○ Agree
○ Disagree
○ [✓ 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?

*August 2012 – Current*

19. How many people on average occupied the house?

*2*

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

*Did not know how to adjust the temperature.*

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

*The resident did not know where the thermostat was.*