FINAL REPORT

RESIDENTIAL PERFORMANCE CHALLENGE

Agreement #10504

OCTOBER 2014

Revised

Submitted to:

NYSERDA
17 Columbia Circle
Albany, NY 12203

Submitted by:

HOMEPIC Team

CDH Energy Corp.
PO Box 641
Cazenovia, NY 13035
315-655.1063

and

Syracuse Center of Excellence in Energy and Environmental Systems

Northeast Green Building Consulting

Camroden Associates

Building Performance Contractors Association of New York

Contents

Introduction

The purpose of the Home Performance Challenge Project was to work with builders to develop cost-effective, high-performance designs that exceed the typical requirements of the New York Energy Star Program. The intent was to identify practical easily-implemented improvements to a builder's home design and then fully document the added costs as well as measure and analyze the impact of the energy performance improvements. The measure impacts were compared to the expected impacts predicted by the RemRate software tool – the standard package widely used by the Home Energy Rating community in NYS to determine a Home Energy Rating Score (HERS).

Our "HomePIC" team worked with the builders to "re-design" or make recommendations for 6 houses. The team included:

- CDH Energy Corp. (Hugh Henderson, Jeremy Wade)
- Camroden Associates, Inc. (Terry Brennan)
- Northeast Green Building Consulting, (Kevin Stack)
- Building Performance Contractors Association of New York (Jim Hammel, Ed Voytovich)

The Levy Partnership (Jordan Dentz) took the lead on the project for the Hudson Passive House in Claverack, NY.

"Re-Design" Process

The approach is this project was to work with the builders to improve or "re-design" a given house to meet the needs of the builder and owner. This process started by identifying a builder with specific project and a basic plan set. Our team met with the builder, proposing concepts and design improvements that might be appropriate for the project. Base on that meeting, our team developed detailed drawings and specifications and then worked with the builder's architect to integrate these details into the plan set. For at least two of the projects the "re-designed" plan sets were used to build additional versions of the home beyond the specific houses described in this report. Out team also worked with the builders to document the incremental costs of these improvements relative to original or base design. For most projects, the "redesign" project budget paid some or all of these incremental costs in return for the builder's time and effort to breakdown costs and provide access for post-construction measurements and monitoring. The construction process and details were documented by our project website (www.cdhenergy.com/HomePIC).

Description of Homes and Improvements

Table 1 summarizes basic information about each home and the briefly describes the key features or improvements that were implemented in each case. The focus was primarily on envelope improvements. The remainder of this section provides further details on each house.

Table 1. Summary of Houses and Features

House (finish date)	Size & Type	Envelope Features	Mechanical Features
1 - Woodland Ave, Syracuse (2010)	1,586 sq ft new, single family	2" exterior foam, ICF foundation, OCSF and CCSF in shed roofs and garage, Window U = 0.29, 2.12 ACH50 (w/ basement)	Two-stage 95% furnace, power-vented DHW (EF=0.65), AHU fresh air intake (or skuttle)
2 – Bunker Hill, Syracuse (2011)	2,265 sq ft new, townhouse	1" SIS panels with 6" BIBS, 2" XPS on basement wall, Window U = 0.28, 3.8 ACH50 (w/o basement)	Two-stage 92.5% furnace, power-vented DHW (EF=0.65), AHU fresh air intake (or skuttle), 13 SEER AC
3 – Madison St, Troy (2010)	1,840 sq ft "gut rehab", 2 apartments	2" CCSF on masonry walls, with blown cellulose, 2x4 staggered walls for stairways, 4" CCSF on basement walls with membrane over dirt floor, 3.3 ACH 50 (w/ basement)	Wall-hung 95% modulating boiler in each apartment, indirect WH tank, exhaust fans for ventilation
4 – Astible Path, Liverpool (2011)	1,984 sq ft new, duplex	2" exterior foam with 6" BIBS, Superior Wall basement w/ 2.5" foam, 2" slab insulation, closed cell spray foam with 2" board foam(on top of rafters) with BIBS in cathedral ceilings, Window U = 0.22, 1.8 ACH (w/ basement)	Combi system with 95% tankless WH and solar system, AHU with HW coil, AHU fresh air intake with Honeywell damper controller, 13 SEER AC
5 – Hudson Passive House, Claverack (occupied 2011)	1,660 sq ft new, single family	SIP with 12.25" EPS, 12" foam under slab insulation, 0.16 ACH50	Two Mitsubushi Hyper-heat heat pumps, Zender HRV, Tankless electric DHW
6 – Welytok, Chittenango (2014 est)	2,097 sq ft new, townhome	2" exterior foam with OCSF in 2x6 wall cavity, CCSF in other walls, dormers, ICF footers with 4" underslab foam, Window U = 0.22	High performance heat pump with ducted indoor unit (minimal ducting), exhaust fan for ventilation

Notes: ICF - insulated concrete forms. SIP - Structurally insulated panel. EPS - expanded polystyrene (open cell). XPS - extruded polystyrene (closed cell). SIS - structural insulated sheathing. CCSF - closed cell spray foam. OCSF - open cell spray foam. ACH50 - measured air change rate at 50 Pascal. BIBS - blown in bagged system. HRV - heat recovery ventilator. DHW - domestic hot water.

House 1 - Woodland Ave, Syracuse

This new house was completed in Spring 2010 by Home Headquarters (www.homehq.org). This 1,586 square foot two-story house includes an ICF foundation and 2 inches of exterior foam. Closed cell foam is used in the shed roofs. House area is 2,326 square foot with the partially finished basement. The details of the baseline, proposed and actual design are given in Table 2.

The design for this energy efficient house – known as the "Energy Efficient Sherwood" – was originally developed for a location on Newell Street in 2008. The design was ultimately built at 113 Woodland Ave. The design has since been built by Home Headquarters at other locations in the City of Syracuse.

Figure 1. Completed Home at 113 Woodland Ave

Table 2. Summary of Improvements to Woodland Ave

	Base Design	Proposed Design (2008)	Actual Design (2010)
Walls	2x6 walls w/ Fiberglass Batts 16 in oc R19	2x4 wall cellulose, w/ 2 in exterior XPS foam board (DOW Wallmate)	2x6 wall 24 in OC Spacing w/ BIBS, w/ 2 in exterior XPS foam board (DOW Wallmate) R32
Attic	Fiberglass batts R38	R41 blown cellulose (11.5 in) Foam top plates, spray to proper vent	**Blown Fiberglass (18 in) R45**
Basement Walls	Masonry wall with 5½ inch Fiberglass Blanket (6 ft down wall)	2 in exterior XPS foam board (DOW Perimate)	**Nudura Insulated Concrete Form (ICF) R22**
Windows	U=0.35, SHGC=0.52 (double hung) U=0.33, SHGC=0.50 (inoperable)	U=0.35, SHGC=0.52 (double hung) U=0.33, SHGC=0.50 (inoperable)	**U=0.29, SHGC=0.26 (double hung)**
Rim/Band Joists	5½ inches of Fiberglass R21	6 in Closed Cell Spray Foam	**4 in XPS foam board/froth pack sealed w/ 2 in exterior XPS Foam Board R30**
Garage Ceiling	Fiberglass batts R30	Fiberglass batts R30	**Open cell foam** **w/ 1 in Polystyrene R35**
Shed Area Roofs	Fiberglass batts R38	3 in Closed Cell Spray Foam R21	3 in Closed Cell Spray Foam R21
Garage Walls	None	2 in exterior XPS foam board (DOW Wallmate) R10	2 in exterior XPS foam board (DOW Wallmate) R10
Garage-to-house Wall	2x6 walls w/ Fiberglass Batts 16 in oc R19	2x4 wall cellulose, w/ 1 in DOW Thermax taped	**2x6 wall w/ Blown Fiberglass w/ 2 in exterior XPS foam board (DOW Wallmate) R29**
Air Tightness	5 ACH50 (with basement)	1-2 ACH50 (with basement)	2.12 ACH50 (with basement)
Ventilation	Bathroom & kitchen exhaust fans 100 cfm, 15 hours/day, 20 Watts	Air Cycler 65 cfm continuous distributed to each bedroom	**Fresh air scuttle** **65 cfm continuous**
Heating	92% efficiency Gas Furnace	94% efficiency boiler	95% efficiency 2-stage Gas Furnace
Water Heating	0.65 EF, 40 gallon, Gas Water Heater	Indirect Tank on Boiler	**0.65 EF, 40 gallon, Gas Water Heater**

Notes: colored entries are changes compared to proposed design

House 2 – Bunker Hill, Syracuse

Home Headquarters (HHQ) purchased this partially completed 4-unit townhome and then completed construction as part of this project. The HomePIC team helped to develop an energy efficient design for all four of the units. The four "redesigned" units were started in 2009 and completed in stages throughout 2010 and 2011. The HomePIC project paid for the improvements to the end unit in while the other 3 units were supported with additional funding from the Syracuse COE.

SIS panels were used for exterior sheathing instead of traditional OSB or Zip Panels. The SIS panels from Dow nominally have 1 inch of foam which provides R-5 (compared to R-0.8 for OSB) while still providing adequate structural support and racking strength. The SIS foam panels are taped to provide a water seal as well as an air barrier. SIS panels were applied to insulated wall areas as well on the attic gable ends and the exterior garage walls. The details of the base, proposed and actual design are given in Table 3.

Figure 2. Photo of Bunker Hill Townhome

Table 3. Summary of Improvements to Bunker Hill

	Base Design	Proposed Design	Actual Construction
Walls	Wafer Board Siding w/ OSB Sheathing; 2x6 Frame wall with Fiberglass Batt (R19)	Wafer Board Siding SIS Panel (1 inch foam, R5) ; 2x6 frame wall w/ BIBS (R23 cavity+ R5 Continuous)	Wafer Board Siding SIS Panel (1 inch foam, R5) ; 2x6 frame wall w/ BIBS (R23 cavity+ R5 Continuous)
Open Attic	Scissor Truss with 2x4 Bottom Cord 11.5 inch Fiberglass Batt (R38)	Scissor Truss with 2x4 Bottom Cord 16 inch Cellulose (R60)	Scissor Truss with 2x4 Bottom Cord **11 inch Cellulose (R42)**
Cathedral/Vaulted Ceiling	2x6 Parallel Cord Truss with Fiberglass Batt (R38)	2x6 Parallel Cord Truss with 11 inch Cellulose (R42)	2x6 Parallel Cord Truss with 11 inch Cellulose (R42)
Basement Walls	CMU Block with Fiberglass Batt 5 ft down from ceiling (R11)	CMU Block with 2 inch rigid foam (Thermax) on inside (R10)	CMU Block with 2 inch rigid foam (Thermax **& XPS**) on inside (R10)
Garage-to-Exterior Wall	Wafer Board Siding w/ OSB Paneling Sheathing on 2x4 frame wall	Wafer Board Siding SIS Panel (1 inch foam, R5) on 2x4 frame wall	Wafer Board Siding SIS Panel (1 inch foam, R5) on 2x4 frame wall
Garage-to-Interior Wall	Fiberglass Batt, OSB Panel, 2x6 Framing (R19)	BIBS System, SIS Panel, 2x6 framing (R23+ R5 Continuous)	BIBS System, ZIP Panel, 2x6 framing (R23) **+ 2 inches XPS foam board (R10)**
2nd Floor-to-Attic Wall	Fiberglass Batt, OSB Panel, 2x6 Framing (R19)	BIBS System, SIS Panel, 2x6 framing (R23+ R5 Continuous)	BIBS System, SIS Panel, 2x6 framing (R23+ R5 Continuous)
Windows	U=0.31, SHGC=0.35 (double hung)	U=0.31, SHGC=0.35 (double hung)	**U=0.28, SHGC=0.32 (casement)**
Rim/Band Joists	5.5 inches of Fiberglass (R21)	4 inches Rigid Foam w/ 1 inch exterior SIS foam (R25)	4 inches Rigid Foam w/ 1 inch exterior SIS foam (R25)
Air Tightness & Thermal Bypass	5 ACH50 (with basement)	2 ACH50 (with basement) Various air sealing and thermal bypass improvements	**3.8 ACH50 (w/o basement) Various air sealing and thermal bypass improvements**
Heating	90% Efficient Gas Furnace	95% Efficient Gas Furnace	**92.5% Efficient Gas Furnace**
Ventilation	Exhaust Only Ventilation	HRV	**Inside Unit: HRV** **Outside Unit: Exhaust Only Ventilation (58 cfm)**

Notes: colored entries are changes compared to proposed design

House 3 - Madison St, Troy

The right-hand side of this existing duplex building (111 Madison Street) was gutted to the studs and rebuilt in the Spring 2010 by The Madison Project Partnership. The left-hand side of the building (109 Madison St.) had been previously gutted and renovated in 2008. The 2008 house was well insulated and constructed to Energy Star Standards. Our goal for 111 Madison was to improve on that orignal design.

The two sides of the buildings are separately deeded. Each has property been made into upstairs and downstairs apartments, each with their own gas and electrical utility meters. The Madison Project currently plans to rent the appartments but may consider selling the property in the future.

The project used closed cell spray foam the inside of the masonary surfaces as well as on the basement walls. Offset 2x4 walls were using in the unheated stairways. The details of the base and actual designs are given in Table 4.

Figure 3. Photo of Two Buildings at Madison St (after renovation was complete)

Table 4. Summary of Improvements for 111 Madison St

	Base Design (109 Madison)	**Improved Design (111 Madison)**
Walls (Front and Back Exterior)	Masonry w/ air gap and 2" Poly Iso Foam Board, 2x4 Frame w/ 6.5" netted cellulose (R-38)	Masonry w/ 2" closed cell spray foam, 2x4 w/ 6.5" to 8" netted cellulose (R-36)
Wall (Exterior Stairwell, Front)	Masonry and furring strips w/ Pieced in 1" Foam Board (R-7)	Masonry and furring strips w/ 1-1/2" closed cell spray foam (R-9)
Wall (Interior Stairwell, Front)	2x4 Frame, 4.5" Dense Deck Cellulose (R-25.5)	2x4 Frame, 1st Floor: 4.5" Dense Deck Cellulose with 1" Rigid Foam (R-25.5) 2nd Floor: 3.5" Fiberglass Batts with 1"Rigid Foam (R20)
Wall (Interior, Rear Stairwell)	2x8 Frame w/ Fiberglass batts and 1" Rigid Foam (R-24)	1st Floor, 8" wall with staggered 2x4 stud frame w/ 8" cellulose (R-30) 2nd Floor, 10" (R-37) cellulose upstairs
Wall (Kitchen and Bath)	Masonry and 2x4 Frame w/ 4.5" Cellulose and 2" Rigid Foam (R-24)	Masonry w/ 2" closed cell spray foam, 2x4 w/ 4.5" netted cellulose (R-24)
Wall (Exterior, Rear Stairwell)	Masonry and Stucco	Masonry and furring strips w/ 1-1/2" Closed cell spray foam (R-9)with sheet rock on top
2nd Floor Bonus Room Walls	2x4 Frame w/ Fiberglass Batts R13	2x4 frame w/ 3.5" Fiberglass w/ 1" rigid foam (R-20)
Bonus Room Floor	10" Fiberglass (R-35)	10" Fiberglass (R-35)
Attic	2x10 frame with 16" cellulose (R-60)	2x10 frame with 16" loose cellulose (R-60)
Basement Walls	Masonry w/ 4" closed cell spray foam (R-24)	Masonry w/ 4" closed cell spray foam (R-24)
Basement Floor	4" Stone with Poly	EPDM on dirt
Windows	U=0.32 (double hung)	U=0.32 (double hung)
Rim/Band Joists	3" Closed cell spray foam (R-18)	3" Closed cell spray foam (R-18)
Attic Hatch	4" Rigid Insulation	4" Rigid Insulation
Heating/DHW	(2) 95% Efficiency Goodman Gas Furnace with (2) Takagi T-K3 instantaneous water heaters	(2) 95% efficiency Prestige triangle tube fully condensing water boiler w/ Smart 30 indirect fired DHW heater
Air Tightness & Thermal Bypass	3.75 ACH50 (with basement)	3.29 ACH50 (with basement) Various air sealing
Ventilation	Exhaust Only Ventilation, manual control	Exhaust Only Ventilation, manual control

House 4 - Astible Path, Liverpool

This 2-unit model townhome was built by Miller Homes in September 2011. The house was part of the 2011 Syracuse Parade of Homes. This model has 2-story units with a loft option. The left side of the duplex was the finished model while the right side was left unfinished to highlight the construction and insulation details. The unfinished side was also open during Parade of Homes to educate the public about the energy efficiency improvements available in these units. As part of the re-design process we worked with the builder's architect to revise the plans for the 2-story unit with loft (1,984 sq ft) that was built at this site. In addition, the architect implemented the efficiency improvements into the plans for the 1-story unit (1,582 sq ft) and the 2-story without loft (1,841 sq ft).

The major energy efficiency improvements incorporated into these homes included the Superior Wall precast foundation system with 2.5" of insulation in the basement as well as the exterior walls with 2" of exterior foam and 2x6" with 24" OC framing. The wall cavities were filled with BIBS blown fiberglass. The cathedral ceiling used blown fiberglass, closed cell spray foam, and 2" exterior rigid foam on the rafters but under the roof deck. Blown cellulose was used in the attic. The details of the base, proposed and actual design are given in Table 5.

Figure 4. Two-Unit Model at Inverness Gardens (Astilbe Path)

Table 5. Summary of Baseline, Proposed and Actual Design Details at Astible Path House

	Base Design	Proposed Design	As Built Details
Walls	Vinyl Siding, 1-1/2" exterior foam, 2x6" framing w/ Fiberglass batts R29	Vinyl Siding, 2"Exterior Foam, 2x6" framing w/ dense packed cellulose R30	Vinyl Siding, 2" Exterior Foam, 2x6" framing, BIBS blown in fiberglass R33
2nd Floor Knee Walls	2x4" framing w/ fiberglass batts R13	2" Exterior Foam, 2x6" framing w/ dense packed cellulose R30	2" Exterior Foam and Closed Cell foam 2nd floor to attic walls
Garage (Exterior)	Vinyl Siding, 2x6" framing	Vinyl Siding, 2x6" framing	Vinyl Siding, 2x6" framing
Attic	2x12 rafters frame with Fiberglass batts R38	2x12 rafters frame with 16" cellulose R49	2x12 rafters frame with blown cellulose R60
Cathedral Ceiling	R38 Fiberglass Batts	Blown Fiberglass with 2" Exterior Foam above roof deck R58	BIBS, Closed Cell foam, and Exterior Foam beneath roof deck R67
Basement Walls	10" CMU w/ 5' Hanging Blown in Fiberglass R10	10" CMU, 2.5" white Thermax R15	Superior Walls Xi Foundation System with 2.5" Dow® Extruded Polystyrene Insulation R15
Basement Floor	Uninsulated poured concrete floor	2" Rigid Foam under poured concrete floor R10	2" Rigid Foam under poured concrete floor R10
Windows	U=0.33 Low E Argon double hung	Super Seal Windows U = 0.20	DH: Triple glazed, Low E, U = 0.22, SHGC = 0.23 Slider: Double glazed, Low E Argon filled, U = 0.30, SHGC = 0.20 Basement: Double glazed, Low E Argon/air filled, U=0.28, SHGC=0.35
Rim/Band Joists	6" Fiberglass batts w/ 1-1/2" Ext Foam R 29	3" Closed Cell foam in Band joists w/ 2" ext Foam R32	3" Closed Cell foam in Band joists w/ 2" ext Foam R32
Garage-to-house Wall	2x6 framing w/ Fiberglass batts R19	2"Exterior Foam, 2x6" framing w/ dense packed cellulose R33	2" Exterior Foam, 2x6" framing, BIBS system blown in fiberglass.
Air Tightness & Thermal Bypass	5 ACH50 (with basement)	2 ACH50 (with basement) Various air sealing and thermal bypass improvements	1.79 ACH50 with basement (actual)
Heating/ Cooling	90% Natural Gas Furnace 13 SEER AC Unit	94% Natural Gas Furnace 13 SEER AC Unit	95% Rheem tankless water heater and heating coil Combi System 13 SEER 2.5 ton AC unit
Ventilation	Exhaust Only Ventilation	HRV Fantech SH704 run 24 hours, 36 watts, 55 cfm	Fresh Air Ventilation with damper. Honeywell Whole House Ventilation Control. Exhaust fan in garage

House 5 – Hudson Passive House

This single family detached home was completed and occupied in October 2011.

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

The house has the following mechanical equipment:

- Mitsubishi MUZ-FE09A, ¾-ton heat pump serving the bedroom
- Mitsubishi MUZ-FE12A, 1-ton heat pump serving the main living area
- Zehnder heat recovery ventilator (HRV)
- Steibel Eltron tankless electric water heater

Figure 5. The Hudson Passive Project in Claverack, NY

House 6 – Welytok, Chittenango

New-Paradigm Developers is building nine (9) townhomes on the southern shore of Oneida Lake in the town of Chittenango, NY. Our team helped to develop an energy efficient design for these nine (9) units. The first four (4) units are scheduled for completion in 2014. The HomePIC project is supporting the improvements to one of these four units.

These two-story units have a slab on grade foundation with 4" rigid foam under the poured concrete slab. The foundation footings use an Insulating Concrete Form wall system (ICF) that uses 2" of expanded polystyrene (EPS) on each side as forms for the footings and remain in place. The exterior walls were designed with 2" of exterior rigid foam where it was practical. In other locations, the exterior wall cavities are filled with 5½" closed cell spray foam.

The planned HVAC system is a minimally-ducted heat pump such as the Mitsubishi MUZ-FE series Hyper-heat units. The indoor unit will be mounted near the ceiling in the first floor laundry room with short ducts to common areas, the upstairs loft and the front bedroom. Electric baseboard is used in the other remote bedrooms. Each townhouse will also have a solar thermal system with electric resistance to provide water heating. The solar DHW tank will also be able to provide heat to the in-floor piping.

Figure 6. Weletok Townhomes Under Construction

Table 6. Summary of Baseline and Proposed Design at Welytok House

	Base Design	Improved Design
Walls	2x6 Frame and Fiberglass Batt. **R19**	2" Rigid Foam Insulation on exterior of OSB 2x6 frame, Open Cell Spray Foam in Wall Cavity. ~**R33**
Lake-Side Walls and Dormers	2x6 Frame and Fiberglass Batt. **R19**	Closed Cell Spray Foam in Wall Sections w/o Exterior Foam. ~**R30**
Attic	Scissor Truss with 2x4 Bottom Cord 11.5" Fiberglass Batt. **R38**	Scissor Truss with 2x4 Bottom Cord 16" Cellulose. ~**R50**
Cathedral/Vaulted Ceiling	2x4 Parallel Cord Truss with Fiberglass Batt. **R38**	2x4 Parallel Cord Truss with 7-8" Closed Cell Spray Foam. ~**R42**
Foundation Walls and Slab	Poured concrete. 2" foam board on footer	ICF Forms with 2.5" Foam on Each Side of Poured Concrete. 4" Rigid Foam Under Poured Concrete Slab
Garage Walls and Ceiling	Fiberglass Batt	Closed Cell Spray Foam in ceiling Open Cell Spray Foam on exterior walls
Windows	U=0.31, SHGC=0.35 (double hung)	U=0.22, SHGC=0.20 (double hung)
Rim/Band Joists	5.5 inches of Fiberglass. **R21**	Caulked and Spray Foamed.
Garage-to-Interior Wall	Fiberglass Batt, 2x6 Framing. **R19**	Blown Bagged Cellulose, 2x6 Framing. **R19**
Air Tightness	5 ACH50	2 ACH50 Various air sealing and thermal bypass improvements
DHW	Electric water heater	Solar Hot Water System
Heating and Cooling	92.5% Efficient Gas Furnace	Solar HW tank connected to Radiant In-floor Heating 2 or 2-½ ton Hyper heat pump with some electric baseboard heaters.
Ventilation	Exhaust Only Ventilation	Exhaust Only Ventilation

Cost of Improvements and Expected Savings

Table 7 summarizes the incremental costs of the improvements in each house along with the baseline and actual HERS scores. The energy savings predicted by RemRATE are also given. More details are given in the detailed construction reports for each house at the project web site (www.cdhenergy.com/HomePIC).

Generally the implemented improvements increased the HERS score by about 3 points at a cost of $2,300 to $4,400 per point (excluding Astible Path). Incremental costs per square foot were $3 to $7 except at the Passive House. Simple paybacks based on actual energy savings ranged from 14 to 46 years.

Table 7. Summary of Costs, HERS Scores, and Predicted Savings in Each House

House Project	House Size (sq. ft.)	Incremental Cost of Improvements	ACH 50	Base HERS Score	Actual HERS Score	Cost per HERS Pt point	Inc Cost ($/sq ft)	Energy Savings (MMBtu)	Cost Savings	Simple Payback	Notes
Woodland Ave	1,586	$ 11,440	2.12	85.8	88.8	$ 3,813	$ 7.21	24.4	$ 366	31	
Bunker Hill	2,265	$ 6,916	3.7	85	88	$ 2,305	$ 3.05	32.1	$ 482	14	
Madison St	1,840	$ 10,250	3.29	86.8	90.2	$ 3,015	$ 5.57	14.8	$ 222	46	
Astible Path	1,984	$ 10,322	1.8	84.6	89.6	$ 2,064	$ 5.20	28.5	$ 428	24	Score includes solar, but costs do not
Hudson Passive House	1,660	$ 22,563	0.16	84.4	89.6	$ 4,339	$ 13.59	38.6	$ 1,359	17	all electric house
Welytok	2,097	$ 9,400		86	89	$ 3,133	$ 4.48				

Notes: gas costs at $1.50 per therm. Electric costs at $0.12/kWh

House Performance Measurements

Table 8 summarizes the energy use for each house broken down by major end use. Total electric ranged from 2,081 kWh in the apartments at Madison Troy to 7,680 kWh per year in the all-electric Hudson House. The "other" electric uses in the homes, which include lights, appliances and plug loads – but excludes HVAC power – ranged from 2,081 to 6,530 kWh per year, or 1.8 to 4.1 kWh per sq ft per year. Furnace or air handling unit (AHU) fan power was measured to be as high as 1,097 kWh per year. The AHU supply fan used as much as 600 Watts at high speed for cooling; power was usually less when operating at lower speed for ventilation and mixing. Cooling energy use for the condensing unit was typically smaller than AHU fan power, ranging from 140 kWh to 476 kWh per year.

Most homes used natural gas for space and water heating. Total gas use in the houses was determined from the utility bills. The gas use associated with space and water heating was typically determined from monitored data such as equipment runtimes. Space heating gas use was only 223 therms per year at the Woodland Ave house in part because of the high internal gains (i.e., from "other" electric use). Surprisingly at this house natural gas use for domestic water heating (DHW) was much larger than furnace gas use. Conversely, Bunker Hill had smaller internal gains from electric (and DHW) so it used a bit more gas for space heating. On a per square foot basis, space heating loads ranged from 0.14 to 0.34 therms per sq ft per year. The apartments at Madison St in Troy had miss-matched heating loads: the downstairs apartment accounting for most of the heating energy use while the upstairs apartment set its thermostat so that it used almost no gas for space heating.

Table 8. Summary of Energy Use in Each House

		Annual Electric Use						Annual Gas Use			
			Estimated or Measured						Estimated or Measured		
House	Floor Area (sq ft)	Total Electric Use (kWh)	DWH (kWH)	Space Htg or AHU Fan (kWh)	AC/Cooling Electric Use (kWh)	"Other" Electric Use (kWh)	"Other" Electric (kWh/sq ft)	Total Gas Use (therms)	DHW Gas Use (therms)	Space Heating Gas Use (therms)	Space Heating (therms/ sq ft)
Woodland Ave, Syracuse	1,586	7,479		949	-	6,530	4.1	631	408	223	0.14
Bunker Hill, Syracuse	2,265	5,719		1,097	476	4,146	1.8	823	111	712	0.31
Madson St, Troy (downstairs)	920	2,484				2,484	2.7	392	84	312	0.34
Madson St, Troy (upstairs)	920	2,081				2,081	2.3	112	102	14	0.02
Astible Path, Liverpool	1,984	5,543		382	140	5,021	2.5	611	120	491	0.25
Hudson Passive House	1,660	7,680	3,302	106	289	3,983	2.4				

Table 9 lists various space heating statistics determined from the monitored data collected at each house or from co-heat tests conducted at some houses. Bunker Hill was one of the houses with higher space heating gas use at 0.31 therms per sq ft per year; in this case higher use was in part due to the high balance point for the house – which was primarily driven by the higher space temperature set points used by these older homeowners. The normalized space heating gas use in the downstairs apartment for Madison St in Troy also was high, though the total space heating use for two apartments combined was only 0.18 therms per sq ft per year.

The house UA-values, which were determined by various means as indicated in the table, were similar for the Woodland and Astible Path houses. The UA-value is slightly higher for Bunker Hill house. The Hudson Passive House had a much lower UA-value.

Table 9. Space Heating Statistics Determined from Measurement and Analysis

House	Space Heating (therms/ sq ft)	Overall UA-value (Btu/h-F)	Heating Balance Point (F)	Peak Heating Load (therms/h @ -20F)	Notes
Woodland Ave, Syracuse	0.14	255	53.2	0.20	UA from load line
Bunker Hill, Syracuse	0.31	396	70.5	0.38	UA from load line
Madson St, Troy (downstairs)	0.34		73	0.18	
Madson St, Troy (upstairs)	0.02				
Astible Path, Liverpool	0.25	315		0.26	UA from co-heat test
Hudson Passive House	-	177			UA from calculations

Table 10 compares the measured energy use to the values predicted (or assumed) by REMRate. Some of these numbers, such as total electric and DHW energy, are assumptions that depend on occupant behavior. The calculated heating and cooling loads are strongly affected by these assumptions. In some cases the assumed load was significantly off from the RemRATE prediction/assumption.

Table 10. Comparing REMRate Predictions to Actual Energy Use

	Total Electric (kWh)		Total Gas (therms)		DHW Gas (therms)		Space Htg Gas (therms)	
House	Actual	RemRate	Actual	RemRate	Actual	RemRate	Actual	RemRate
Woodland Ave, Syracuse	7,479	4,478	631	692	408	212	223	480
Bunker Hill, Syracuse	5,719	5,983	823	717	111	197	712	431
Madson St, Troy (downstairs)	2,484	6,710	400	411	84	109	312	302
Madson St, Troy (upstairs)	2,081		115		102		14	
Astible Path, Liverpool	5,543	6,606	611	470	120	40	491	466
Hudson Passive House	7,680	12,184						

Notes: DHW gas use predicted by REMRate is low because of the Solar Hot Water System at this site